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TEXT-BOOK OF ANATOMY

CUNNINGHAM'S TEXT-BOOK

OF

ANATOMY

EDITED BY

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FIFTH EDITION REVISED

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TO

Sir William Turner, K.C.B.

F.R.S., M.B., LL.D., D.C.L., D.Sc.

IN RECOGNITION OF

HIS EMINENCE AS AN ANATOMIST

AND HIS INFLUENCE AS A TEACHER

THIS VOLUME

IS DEDICATED

BY THOSE OF HIS FORMER PUPILS AND ASSISTANTS

WHO HAVE CONTRIBUTED

TO ITS PAGES

PREFACE TO THE FIFTH EDITION.

THE regretted death of Professor A. M. Paterson, the inability of Professor Arthur Thomson, of Oxford, to revise his article on Osteology, on account of the pressure of other work, and the transference of Professor A. Campbell Geddes of Montreal from the anatomical to the diplomatic world, have necessitated changes in the authorship of several sections of this edition of Cunningham's *Text-book of Anatomy*.

The readers who contrast the fifth edition with its predecessors will find that the section on Ductless Glands, originally written by the late Professor D. J. Cunningham, and afterwards revised and partly rewritten by Professor A. Campbell Geddes, has been entirely rewritten and its scope greatly enlarged, in association with the growing importance of the subject, by Professor J. T. Wilson of Cambridge; that two sections, originally written by the late Professor A. M. Paterson—Myology and the Peripheral Nervous System—have been revised and largely rewritten by different authors, Myology by Professor T. B. Johnston of Guy's Hospital, London, and the Spinal and Cerebral Nerves and the Sympathetic Nervous System by Professor S. E. Whitnall of the McGill University, Montreal; and that the greater part of the section on Osteology has been rewritten and the remainder revised by Dr. E. B. Jamieson of the University of Edinburgh.

The other sections have remained in the hands of the authors who revised them for the last edition, and two of them, the Alimentary System and the Vascular System, have been considerably recast, whilst all have been carefully revised and brought up to date.

Each of the contributors has attempted to keep his section within the bounds allowable in a text-book primarily intended for the use of students and practitioners of medicine and surgery.

Some of the figures present in the last edition which were considered unessential have been removed, and many new figures, both monochrome and coloured, have been introduced.

As in the preceding editions, where sections written by different authors necessarily overlap one another, it may be found that varying statements occur regarding phenomena concerning which our knowledge is still in an indefinite stage, and it must be understood that the authors of the various sections are alone responsible for the opinions expressed in their own sections.

As editor I wish to express my thanks to all the authors for their kind, considerate and willing help.

I am indebted to Dr. J. S. Fraser for the use of specimens from which two new figures of the labyrinth of the internal ear were prepared, and to Messrs.

J. & A. Churchill for permission to use and modify the diagram of the Sympathetic Nervous System originally made by the late Professor Flower.

Sir Harold Stiles wishes me to express his indebtedness to Dr. Logan Turner for assistance in revising the section of his article dealing with the nose and its accessory air sinuses, and to Dr. J. S. Fraser for help with the portion concerned with the ear. He also desires to thank Dr. Goldthwait of Boston and his pupil Dr. W. A. Cochrane for their contribution to the description of certain conditions of the vertebral column.

Professor Whitnall desires to acknowledge the help he has received from his Associate Professor in Histology and Embryology—Professor J. C. Simpson—in the revision of the developmental portion of the article on the Peripheral Nervous System and in the preparation of some of the new figures.

The drawings for the majority of the new figures were made, with perhaps even more than his usual skill of technique and interpretation, by Mr. J. T. Murray, but three of the new figures in the section on Myology were made by Mr. W. T. Shiells, the new line drawings in Professor Whitnall's article by Professor J. C. Simpson, and the new half-tone drawings in the same section by Mr. N. M. Fralm.

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CONTENTS.

PAGE
Glossary of Variations between International and Old Terminology . . xvii
Introduction 1

GENERAL EMBRYOLOGY.

Professor Arthur Robinson

PAGE
Animal Cells 7
  Reproduction of Cells 7
  Life History and Capabilities of Cells 9
Germ Cells 12
Gametes 13
  The Ovum 15
  Maturation of the Ovum . . . 17
  Spermatocytes 20
  Spermatozoa 21
Fertilisation 23
The Zygote 24
Segmentation 25
The Embryonic Area 26
The Extra-Embryonic Cœlom . . 26
Early Stages of the Development of the Nervous System 35
Formation of the Embryo . . . 42
The Embryo 43
  The Limbs 44
PAGE
The Development of the Alimentary Canal 46
  Differentiation of the Foregut . . 46
  Derivatives of the Midgut . . 52
  Derivatives of the Hindgut . . 52
  Derivatives of the Stomatodæum . 53
The Ear 55
Protection and Nutrition of the Embryo 58
The Membranes and Appendages . . 58
The Chorion 58
The Amnion—the Body Stalk and Umbilical Cord 59
The Yolk-Sac 60
The Placenta 61
The Primitive Vascular System . . 68
The Cœlom 74
The External Features of the Human Embryo and Fœtus at different periods of Development . . . 77

OSTEOLOGY.

Dr. E. B. Jamieson.

Bones and Cartilages 83
Articulations of Bones 83
Constituents of Bone 84
Structure of Bone 84
Classification of Bones 84
Characters of Living Bone . . . 85
Appearances of Dried Bone . . . 86
Cartilage 87
Development of Bone 88
Growth of Bones 89
The Skeleton 91
  Axial Skeleton 91
  Appendicular Skeleton 91
The Vertebral Column 94
A Typical Vertebra 94
  Cervical Vertebræ 96
  Thoracic Vertebræ 99
  Lumbar Vertebræ 101
  The Sacrum 102
  The Coccyx 104
The Vertebral Column as a whole . 106
Ossification of the Vertebræ . . . 109
Variations of Vertebræ 111
Serial Homologies of Vertebræ . . 112
The Sternum 113
The Ribs 116
The Costal Cartilages 119
The Thorax as a whole 119
Development of Ribs, Vertebræ and Sternum 123
The Skull 124
The Bones of the Skull 124
The Skull as a whole 129
  Norma Verticalis 129
  Norma Frontalis 130
  Norma Occipitalis 136
  Norma Lateralis 137
  Norma Basalis 142
The Cranial Cavity 153
  Roof of Cranial Cavity . . . 154
  Floor of Cranial Cavity . . . 155
    Anterior Fossa 155
    Middle Fossa 157
    Posterior Fossa 163
The Nasal Fossæ 168
  Paranasal Air Sinuses . . . 174

PAGE
- The Mandible 177
- Teeth 181
- The Hyoid Bone 182
- The Skull at Birth 183
- Growth and Age changes of the Skull 185
- Sex Differences in the Skull 186
- Development and Morphology of the Skull 186
- The Bones of the Skull 189
  - Frontal Bone 189
  - Parietal Bones 191
  - Occipital Bone 193
  - Temporal Bones 196
  - Sphenoid Bone 202
  - Ethmoid Bone 206
  - Inferior Nasal Conchæ 208
  - Lacrimal Bones 209
  - Vomer 209
  - Nasal Bones 211
- Bones of the Upper Limb 217
  - Scapula 218
  - Clavicle 223
  - Humerus 225
  - Ulna 230
  - Radius 234

PAGE
  - The Carpus 238
  - The Metacarpus 242
  - The Phalanges 245
  - Sesamoid Bones 247
- Bones of the Lower Limb 247
  - The Hip Bone 249
  - The Pelvis 255
  - The Femur 260
  - The Patella 266
  - The Tibia 267
  - The Fibula 271
  - The Tarsus 275
    - Calcaneus 277
    - Talus 278
    - Cuboid 280
    - Navicular 281
    - Cuneiforms 282
  - The Metatarsus 284
  - The Phalanges 286
- The Arches of the Foot 287
  - Sesamoid Bones of the Foot 290
- Development and Morphology of the Limbs 290
  - Measurements and Indices employed in Anthropology 294

THE ARTICULATIONS OR JOINTS.

Professor David Hepburn.

- Syndesmology 301
  - Synarthroses 301
  - Diarthroses or Movable Joints 302
  - Structures which enter into the Formation of Joints 303
  - The Different Kinds of Movement at Joints 305
  - The Development of Joints 306
  - Morphology of Ligaments 307
- Ligaments of the Vertebral Column and Skull 307
  - Articulation between the Atlas and Epistropheus 311
  - Articulation between the Atlas and the Cranium 312
- Mandibular Joint 314
- Cranial Ligaments not directly associated with Articulations 315
- The Joints of the Thorax 315
  - Joints of the Heads of the Ribs 315
  - Costo-transverse Joints 316
  - Articulations between the Ribs and their Cartilages 317
  - Sterno-costal Joints 317
  - Sternal Articulations 319
- Articulations of the Superior Extremity 319
- Articulations of the Clavicle 319
  - Sterno-clavicular Joint 319
  - Acromio-clavicular Joint 320
- Ligaments of the Scapula 322
- Shoulder-joint 322
- Elbow-joint 325
- The Radio-ulnar Joints 328
- The Radio-carpal Joint 330
- Carpal Joints 331
- Intermetacarpal Joints 334
- Carpo-metacarpal Joints 334
- Metacarpo-phalangeal Joints 335
- Interphalangeal Joints 336
- Articulations and Ligaments of the Pelvis 337
  - Lumbo-sacral Joints 337
  - Sacro-iliac Joint 337
- Symphysis Pubis 339
- Articulations of the Inferior Extremity 341
  - The Hip-joint 341
  - The Knee-joint 344
  - The Tibio-fibular Joints 351
  - The Joints of the Foot 353
  - The Ankle-joint 353
  - The Intertarsal Joints 356
  - The Tarso-metatarsal Joints 361
  - Intermetatarsal Joints 363
  - Metatarso-phalangeal Joints 363
  - Interphalangeal Joints 363

THE MUSCULAR SYSTEM.

Professor T. B. Johnston.

- Muscles 365
  - A Typical Skeletal Muscle 365
  - Attachments of Muscles 365
  - Forms of Muscles 366
  - Tone 367
  - Nerve Supply 367
- Fasciæ 367
- Description of the Muscles 368
- Appendicular Muscles 368
- Fasciæ and Superficial Muscles of the Back 368
- The Superficial Muscles of the Back 369
- The Fasciæ and Muscles of the Pectoral Region 372
- Fasciæ of the Pectoral Region 372
- Muscles of the Pectoral Region 373
- Fasciæ and Muscles of the Shoulder 376
- Muscles of the Shoulder 376
- Fasciæ and Muscles of the Arm 381
- Fasciæ and Muscles of the Forearm and Hand 385
- The Muscles of the Front and Medial Aspect of the Forearm 388
  - Superficial Muscles 388
  - Intermediate Layer 390
  - Deep Layer 391
- Short Muscles of the Hand 394
- Muscles of the Thumb 395

PAGE
Muscles of the Little Finger 396
The Interosseous Muscles of the Hand . 397
The Muscles on the Dorsal Surface of the Forearm 398
  Superficial Muscles 399
  Deep Muscles 401
The Lower Limb 404
Fasciæ and Muscles of the Thigh and Buttock 404
Fasciæ of the Thigh and Buttock . . 404
Muscles of the Thigh and Buttock . 407
The Muscles on the Anterior Aspect of the Thigh 407
The Muscles on the Medial Side of the Thigh 413
The Muscles of the Buttock . . . 416
The Muscles on the Posterior Aspect of the Thigh 420
The Fasciæ and Muscles of the Leg and Foot 423
Fasciæ of the Leg and Foot 423
The Muscles on the Front of the Leg and Dorsum of the Foot 425
The Muscles on the Lateral Side of the Leg 428
The Muscles on the Posterior Aspect of the Leg 429
The Muscles in the Sole of the Foot . 433
Axial Muscles 437
The Fasciæ and Muscles of the Back . 437
The Fasciæ of the Back 437
The Muscles of the Back 438
  First Group 439
PAGE
  Second Group 440
  Third Group 442
  Fourth Group 444
The Fasciæ and Muscles of the Head and Neck 446
Fasciæ of the Head and Neck . . . 446
The Muscles of the Head 448
Superficial Muscles 448
The Muscles of the Scalp 448
The Muscles of the Face 450
The Fasciæ and Muscles of the Orbit . 453
Muscles of Mastication 455
The Muscles of the Neck 459
The Muscles of the Hyoid Bone . . 459
The Muscles of the Tongue . . . 463
The Muscles of the Pharynx . . . 464
The Muscles of the Soft Palate . . 466
Deep Lateral and Prævertebral Muscles of the Neck 468
The Muscles of the Thorax 471
Muscles of Respiration 471
Fasciæ and Muscles of the Abdominal Wall 475
Fasciæ of the Abdominal Wall . . 475
The Muscles of the Abdominal Wall . 476
Fasciæ and Muscles of the Perineum and Pelvis 486
Fasciæ of the Perineum 486
The Muscles of the Perineum . . . 487
The Fasciæ of the Pelvis 491
Muscles of the Pelvis 493
The Development and Morphology of the Skeletal Muscles . . . 495

THE CENTRAL NERVOUS SYSTEM.

Professor G. Elliot Smith.

Elements of the Central Nervous System 499
Outline of Development of the Central Nervous System 500
Neurone Theory 505
Nerve Components 506
Nerve-cells 507
Nerve-fibres 509
Neuroglia 512
The Nature of the Brain 513
The Spinal Medulla 518
  Internal Structure of Spinal Medulla 524
  Characters presented by the Spinal Medulla in its Different Regions . 525
  Component Parts of the Gray Matter of the Spinal Medulla . . . 529
  Component Parts of the White Matter of the Spinal Medulla . . . 533
The Encephalon or Brain . . . 540
  General Appearance of the Brain . 540
General Connexions of the Several Parts of the Brain 542
  Medulla Oblongata 544
  Pons 549
  The Fourth Ventricle . . . 550
  Internal Structure of Medulla Oblongata and Pons 552
  Internal Structure of the Pons . 565
The Cerebellum 570
  The Structure and Connexions of the Cerebellum 576
The Mesencephalon 580
  Internal Structure of the Mesencephalon 583
The Deep Connexions of the Cerebral Nerves attached to the Medulla Oblongata, Pons, and Mesencephalon 590
Prosencephalon or Fore-brain . . . 606
  Development of Parts derived from Fore-brain 606
  Parts derived from the Diencephalon 607
  Thalamus 607
  Hypothalamic Region 611
  Pineal Body 612
  Trigonum Habenulæ 612
  Corpora Mamillaria 613
  Hypophysis 613
  Third Ventricle 614
  Cerebral Connexions of the Optic Tract 616
Parts derived from the Telencephalon . 618
  Cerebral Hemispheres 618
  The Connexions of the Olfactory Nerves 621
  The Cerebral Commissures and the Septum Pellucidum . . . 626
  The Corpus Callosum 627
  The Lateral Ventricle 630
  Basal Ganglia of the Cerebral Hemisphere 634
  Intimate Structure of Cerebral Hemisphere 640
  The Cerebral Cortex 641
  The Neopallium 642
  The White Matter of the Cerebral Hemispheres 644
  The Sulci and Gyri of the Cerebral Hemispheres 650
  The Acoustic Area and Fibre Tracts 653
  The Visual Area and Fibre Tracts . 656
  The Parietal Region of the Brain . 660
  The Frontal Region 663
  Weight of the Brain 664

PAGE
- Meninges of the Encephalon and Spinal Medulla 665
  - Dura Mater 665
  - Arachnoidea 668
  - Pia Mater 671

THE PERIPHERAL NERVOUS SYSTEM.

Professor S. E. Whitnall.

- Cerebral Nerves 676
  - Olfactory Nerve 677
  - Optic Nerve 678
  - Oculo-motor Nerve 679
  - Trochlear Nerve 681
  - Trigeminal Nerve 681
  - Ophthalmic Nerve 681
    - Ciliary Ganglion . . . 683
  - Maxillary Nerve 685
    - Spheno-Palatine Ganglion . . 687
  - Mandibular Nerve 688
    - Sub-maxillary Ganglion . . 691
    - Otic Ganglion 691
  - Facial Nerve 693
  - Acoustic Nerve 696
  - Glossopharyngeal Nerve . . . 697
  - Vagus Nerve 698
  - Accessory Nerve 703
  - Hypoglossal Nerve 704
- Component Fibres of Cerebral Nerves . 706
- Development and Morphology of Cerebral Nerves 707
- Spinal Nerves 711
  - Cervical Nerves 715
  - Thoracic Nerves 717
  - Lumbar Nerves 718
  - Sacral and Coccygeal Nerves . . 718
- Morphology of Posterior Rami . . 718
- Anterior Rami 719
- Cervical Nerves 721
- Cervical Plexus 722
  - Phrenic Nerve 726
  - Morphology of Cervical Plexus . 726
- Brachial Plexus 727
  - Nerve to Subclavius 731
  - Dorsal Scapular Nerve . . . 731
  - Long Thoracic Nerve 731
  - Supra-scapular Nerve 731
  - Anterior Thoracic Nerves . . 732
  - Musculo-cutaneous Nerve . . . 732
  - Median Nerve 734
  - Ulnar Nerve 736
  - Medial Anti-brachial Cutaneous Nerve 738
  - Medial Brachial Cutaneous Nerve . 738
  - Axillary Nerve 739
  - Radial Nerve 739
  - Subscapular Nerves 742
  - Thoraco-dorsal Nerve . . . 742
- Thoracic Nerves 742
- Lumbo-sacral Plexus 747
- Lumbar Plexus 749
  - Ilio-hypogastric Nerve . . . 750
  - Ilio-inguinal Nerve 751
  - Genito-femoral Nerve . . . 751
  - Lateral Cutaneous Nerve of Thigh . 751
  - Obturator Nerve 752
  - Femoral Nerve 753
- Sacral Plexus 756
  - Sciatic Nerve 757
  - Superior Gluteal Nerve . . . 758
  - Inferior Gluteal Nerve . . . 759
  - Common Peroneal Nerve . . . 759
  - Tibial Nerve 761
    - Medial Plantar Nerve . . . 763
    - Lateral Plantar Nerve . . . 764
- Pudendal Plexus 765
  - Posterior Cutaneous Nerve of Thigh 765
  - Perforating Cutaneous Nerve . . 767
  - Ano-coccygeal Nerve 768
  - Morphology of Pudendal Plexus . 770
- Development of Spinal Nerves . . 773
- Sympathetic Nervous System . . 774
  - Cephalic and Cervical Parts . . 780
  - Thoracic Part 784
  - Abdominal Part 785
  - Pelvic Part 786
  - Plexus of Sympathetic System . 787
    - Cardiac Plexus 787
    - Cœliac Plexus 789
    - Pelvic Plexuses 791
  - Development of Sympathetic Nervous System 792

ORGANS OF SENSE AND THE INTEGUMENT.

Professor Robert Howden.

- Olfactory Organ 793
  - Cartilages of Nose 794
- Nasal Cavity 795
- Organ of Sight 800
- Bulb of the Eye 800
- Sclera 802
- Cornea 803
- Vascular and Pigmented Tunic . . 805
- Retina 809
- Refracting Media of Eyeball . . . 813
- Eyelids 815
- Lacrimal Apparatus 818
- Development of the Eye 820
- Auditory Organ 822
- External Ear 822
  - Auricle 822
  - External Acoustic Meatus . . 824
- Tympanic Cavity 826
  - Tympanic Antrum and Mastoid Air-cells 830
  - Auditory Tube 831
  - Auditory Ossicles 832
- Internal Ear 837
- Osseous Labyrinth 837
- Membranous Labyrinth 840
  - Development of Labyrinth . . 847
- Organs of Taste 848
- The Integument or Skin . . . 849
- Appendages of the Skin 852
- Development of the Skin and its Appendages 855
- Endings of Nerves of General Sensation 856
- Special End Organs 856

THE VASCULAR SYSTEM.

Professor Arthur Robinson.

- Object and Component Parts of the Vascular System 861
- The Tunics of the Vascular System . 863
- The Heart 866
  - The Chambers of the Heart . . 869
  - Structure of the Heart . . . 874

PAGE

- The Pericardium 877
- ARTERIES 878
- The Pulmonary Artery 878
- The Aorta 880
  - The Thoracic Aorta 880
  - The Abdominal Aorta 882
  - Branches of the Ascending Aorta 884
    - The Coronary Arteries 884
- Branches of the Arch of the Aorta 885
- The Innominate Artery 886
- Arteries of the Head and Neck 887
- The Common Carotid Arteries 887
- The External Carotid Artery 889
  - Branches of the External Carotid Artery 891
- The Internal Carotid Artery 899
  - Branches of the Internal Carotid Artery 902
  - The Vertebral Artery 905
- The Arteries of the Upper Extremity 909
- The Subclavian Arteries 909
  - Branches of the Subclavian Arteries 911
- The Axillary Artery 915
  - Branches of the Axillary Artery 917
- The Brachial Artery 919
  - The Radial Artery 920
  - The Ulnar Artery 923
  - The Arterial Arches of the Wrist and Hand 925
- Branches of Descending Thoracic Aorta 927
  - Visceral Branches of the Descending Thoracic Aorta 927
  - Parietal Branches of the Descending Thoracic Aorta 927
- Branches of Abdominal Aorta 929
  - The Paired Visceral Branches of the Abdominal Aorta 929
  - The Unpaired or Single Visceral Branches of the Abdominal Aorta 931
  - Parietal Branches of the Abdominal Aorta 936
  - Common Iliac Arteries 939
- Hypogastric Artery 939
  - Branches of the Posterior Division 941
  - Branches of the Anterior Division 942
    - Visceral Branches 942
    - Parietal Branches 943
- The Arteries of the Lower Extremity 947
  - The External Iliac Artery 948
  - The Femoral Artery 950
  - Popliteal Artery 955
    - Posterior Tibial Artery 957
      - Plantar Arteries 958
    - Anterior Tibial Artery 960
- THE VEINS 963
- The Pulmonary Veins 963
- Systemic Veins 963
- Coronary Sinus and Veins of Heart 964
- Superior Vena Cava and its Tributaries 965
  - Azygos Veins 966
  - Innominate Veins 968
- Veins of the Head and Neck 970
  - The Veins of the Scalp 973
  - Veins of the Orbit, Nose, and Infratemporal Region 974
- Venous Sinuses and Veins of the Cranium, and its Contents 975
  - Diploic and Meningeal Veins 975
  - Veins of the Brain 976
  - Sinuses of the Dura Mater 978
- Vertebral Veins 982
  - Veins of the Spinal Medulla 983
- Veins of the Superior Extremity 983
  - Deep Veins of the Upper Extremity 983
  - Axillary Vein 983
  - The Superficial Veins of the Superior Extremity 985
- Inferior Vena Cava and its Tributaries 987
  - Common Iliac Veins 991
- Veins of the Lower Extremity 993
  - Deep Veins of the Lower Extremity 994
  - Superficial Veins of the Lower Extremity 996
- The Portal System 998
  - Mesenteric and Splenic Veins 1000
- THE LYMPH VASCULAR SYSTEM 1001
- The Terminal Lymph Vessels 1004
- Lymph Glands of the Head 1006
- Lymph Glands of the Neck 1008
- Lymph Vessels of the Head and Neck 1011
- Lymph Glands of the Superior Extremity 1014
- Lymph Vessels of the Superior Extremity 1017
- The Lymph Glands of the Thorax 1018
- The Lymph Vessels of the Thorax 1021
- Lymph Glands of the Inferior Extremity 1021
- Lymph Vessels of the Inferior Extremity 1022
- Lymph Glands of the Pelvis and Abdomen 1023
- Lymph Vessels of the Pelvic Viscera 1025
- Lymph Glands of the Abdomen 1027
- Lymph Vessels of the Abdomen 1030
- Abnormalities of Lymph Vessels 1032
- DEVELOPMENT OF THE BLOOD-VASCULAR SYSTEM 1032
- Development of the Heart 1033
  - The Division of the Atrio-ventricular Canal 1033
  - The Division of the Atrium 1034
  - The Division of the Truncus Arteriosus 1035
  - The Division of the Ventricle 1035
  - The Fate of the Sinus Venosus 1037
  - The Fate of the Ventral Aortæ, the Aortic Arches, and the Infused Parts of the Dorsal Aortæ 1037
  - The Branches of the External Carotid 1039
  - The Branches of the Dorsal Aortæ 1039
- Development of the Veins 1041
  - The Vitelline and Umbilical Veins 1042
  - The Ductus Venosus 1044
  - The Precardinal Veins 1044
  - The Post-cardinal Veins, the Subcardinal Veins, the Supracardinal Veins, and the Inferior Vena Cava 1047
- Development of the Lymph Vascular System 1050
- The Fœtal Circulation 1050
- MORPHOLOGY OF THE VASCULAR SYSTEM 1052
  - The Arteries 1052
  - The Veins 1056
- ABNORMALITIES AND VARIATIONS OF THE VASCULAR SYSTEM 1059

THE RESPIRATORY SYSTEM.

Professor Richard J. A. Berry.

PAGE
The Organs of Respiration and Voice . 1061
The Larynx 1061
Cartilages of the Larynx 1062
Articulations, Ligaments, and Membranes of the Larynx 1065
Cavity of the Larynx 1068
Muscles of the Larynx 1072
Trachea 1077
Bronchi 1081
Thoracic Cavity 1082
Pleuræ 1082
Mediastinum 1088
The Lungs 1089
  Root of the Lung 1094
  Structure of the Lungs 1096
Development of the Respiratory Apparatus 1098

THE DIGESTIVE SYSTEM.

Professor David Waterston.

Digestive System, General Arrangement of 1101
Mouth 1101
Palate 1106
Teeth 1109
  Structure of the Teeth 1110
  Permanent Teeth 1112
  Deciduous Teeth 1116
Tongue 1118
Glands 1125
  Salivary Glands 1127
The Pharynx 1134
  The Palatine Tonsils 1138
The Œsophagus 1143
  Structure of the Œsophagus . . 1146
The Abdominal Cavity 1148
  Subdivisions of the Abdominal Cavity 1151
The Peritoneum 1153
Stomach 1156
  Relations and Connexions of Stomach 1163
  Position of Stomach 1164
  Structure of the Stomach . . . 1166
Intestines 1170
  Structure of Intestines 1171
Duodenum 1175
Liver 1180
  Structure of Liver 1190
  Vessels of Liver 1191
Gall-Bladder and Bile Passages . . 1192
Pancreas 1194
Jejunum and Ileum 1198
Large Intestine 1201
Cæcum and Vermiform Process . . 1203
Colon 1209
Rectum 1213
Anal Canal 1218
Peritoneum 1223
Development of Digestive System . . 1231
Development of the Teeth 1233
Morphology of Teeth 1235
Development of the Pharynx . . . 1236
  of the Œsophagus, Stomach, and Intestines 1236
  of the Peritoneum 1240
  of the Liver and Pancreas . . . 1241

THE URINO-GENITAL SYSTEM.

Professor A. Francis Dixon.

The Urinary Organs 1245
The Kidneys 1245
The Ureters 1255
The Urinary Bladder 1258
The Urethra (Female) 1269
The Male Reproductive Organs . 1271
The Testis 1271
The Deferent Duct 1274
The Seminal Vesicles 1277
Descent of the Testis 1279
Spermatic Funiculus 1281
Scrotum 1281
Penis 1282
Prostate 1285
Bulbo-urethral Glands 1288
The Male Urethra 1289
The Female Reproductive Organs . 1293
Ovary 1294
Uterine Tubes 1297
Uterus 1298
Vagina 1304
Female External Genital Organs . . 1306
  Larger Vestibular Glands . . . 1309
Development of the Urino-genital Organs 1310
  The Wolffian Duct and Embryonic Secretory Organ 1311
  The Ureter and Permanent Kidney 1313
  The Urethra 1314
  Sexual Glands and Generative Ducts 1315
  External Genital Organs . . . 1317
The Mammary Glands 1318
Development of the Mammæ . . . 1320

THE DUCTLESS GLANDS.

Professor J. T. Wilson.

General 1321
The Chromaffin Group 1323
  The Paraganglia 1324
  The Carotid Gland 1325
  Glomus Coccygeum 1325
  Development of the Chromaffin System and the Glomus Coccygeum 1326
The Cortical Group 1326
  The Suprarenal Glands 1327
The Pharyngeal Group 1330
  The Thyreoid Gland 1331
  The Parathyreoids 1332
  The Thymus 1334
The Cerebro-Glandular Group . . . 1337
  The Hypophysis 1337
  The Pineal Body 1340
The Lymphoid Group 1342
The Spleen 1342

SURFACE AND SURGICAL ANATOMY.

Professor Sir Harold J. Stiles.

Head and Neck 1347
  Cranium 1348
  Face 1366
  Neck 1376
Thorax 1387
  The Lungs and Pleuræ 1390

	PAGE
The Heart and Great Vessels	1394
Abdomen	1398
The Anterior Abdominal Wall	1398
Abdominal Cavity	1401
The Abdominal Viscera	1405
Male Perineum	1418
Prostate	1420
Female Pelvis	1425
Back	1427
The Upper Extremity	1438
Shoulder	1438
Axilla	1440
Arm	1441
Elbow	1443
Forearm and Hand	1445
The Lower Extremity	1449
The Buttock	1449
The Back of the Thigh	1451
The Popliteal Fossa	1452
The Front of the Thigh	1453
The Knee	1454
The Leg	1456
The Foot and Ankle	1457

INDEX 1461

A GLOSSARY

OF THE

INTERNATIONAL (B.N.A.) ANATOMICAL TERMINOLOGY

GENERAL TERMS.

Terms indicating Situation and Direction.

Longitudinalis	Longitudinal	Referring to the long axis of the body.
Verticalis	Vertical	Referring to the position of the long axis of the body in the erect posture.
Anterior Posterior	Anterior Posterior	Referring to the front and back of the body or the limbs.
Ventral Dorsal	Ventral Dorsal	Referring to the anterior and posterior aspects, respectively, of the body, and to the flexor and extensor aspects of the limbs, respectively.
Cranial Caudal	Cranial Caudal	Referring to position nearer the head or the tail end of the long axis. Used only in reference to parts of the head, neck, or trunk. *Cephalic* is sometimes used instead of *cranial.*
Superior Inferior	Superior Inferior	Used in reference to the head, neck, and trunk. Equivalent to cranial and caudal respectively.
Proximalis Distalis	Proximal Distal	Used only in reference to the limbs. Proximal, nearer the attached end. Distal, nearer the free end.
Sagittalis	Sagittal	Used in reference to planes parallel with the sagittal suture of the skull, *i.e.* vertical antero-posterior planes.
Frontalis	Frontal	Used in reference to planes parallel with the coronal suture of the skull, *i.e.* vertical transverse planes.
Horizontalis	Horizontal	Used in reference to planes at right angles to vertical planes.
Medianus	Median	Referring to the median vertical antero-posterior plane of the body.
Medialis Lateralis	Medial Lateral	Referring to structures relatively nearer to or further away from the median plane.
Intermedius	Intermediate	Referring to structures situated between more medial and more lateral structures.
Superficialis Profundus	Superficial Deep	Referring to structures nearer to and further away from the surface.
Externus Internus	External Internal	Referring, with few exceptions, to the walls of cavities and hollow organs. **Not to be used as synonymous with medial and lateral.**
Ulnaris Radialis	Ulnar Radial	Used in reference to the medial and lateral borders, respectively, of the forearm and hand.
Tibial Fibular	Tibial Fibular	Used in reference to the medial and lateral borders, respectively of the leg and foot.

THE BONES.

B.N.A. TERMINOLOGY.	OLD TERMINOLOGY.
Vertebræ	**Vertebræ**
Fovea costalis superior	Incomplete facet for head of rib, upper
Fovea costalis inferior	Incomplete facet for head of rib, lower
Fovea costalis transversalis	Facet for tubercle of the rib
Radix arcus vertebræ	Pedicle
Atlas	**Atlas**
Fovea dentis	Facet for odontoid process
Epistropheus	**Axis**
Dens	Odontoid process
Sternum	**Sternum**
Corpus sterni	Gladiolus
Processus xiphoideus	Ensiform process
Incisura jugularis	Supra-sternal notch
Planum sternale	Anterior surface
Ossa Cranii.	**Bones of Skull.**
Os frontale	**Frontal**
Spina frontalis	Nasal spine
Processus zygomaticus	External angular process
Facies cerebralis	Internal surface
Facies frontalis	Frontal surface
Pars orbitalis	Orbital plate
Os parietale	**Parietal**
Lineæ temporales	Temporal ridges
Sulcus transversus	Groove for lateral sinus
Sulcus sagittalis	Groove for sup. longitudinal sinus
Os occipitale	**Occipital**
Canalis hypoglossi	Anterior condyloid foramen
Foramen occipitale magnum	Foramen magnum
Canalis condyloideus	Posterior condyloid foramen
Sulcus transversus	Groove for lateral sinus
Sulcus sagittalis	Groove for sup. long. sinus
Clivus	Median part of upper surface of basi-occipital
Linea nuchæ suprema	Highest curved line
Linea nuchæ superior	Superior curved line
Linea nuchæ inferior	Inferior curved line
Os sphenoidale	**Sphenoid**
Crista infratemporalis	Pterygoid ridge
Sulcus chiasmatis	Optic groove
Crista sphenoidalis	Ethmoidal crest
Spina angularis	Spinous process
Lamina medialis processus pterygoidei	Internal pterygoid plate
Lamina lateralis processus pterygoidei	External pterygoid plate
Canalis pterygoideus [Vidii]	Vidian canal
Fossa hypophyseos	Pituitary fossa

B.N.A. TERMINOLOGY.	OLD TERMINOLOGY.
Sulcus caroticus	Cavernous groove
Conchæ sphenoidales	Sphenoidal turbinal bones
Hamulus pterygoideus	Hamular process
Canalis pharyngeus	Pterygo-palatine canal
Tuberculum sellæ	Olivary eminence
Fissura orbitalis superior	Sphenoidal fissure
Os temporale	**Temporal Bone**
Canalis facialis [Fallopii]	Aqueduct of Fallopius
Hiatus canalis facialis	Hiatus Fallopii
Vagina processus styloidei	Vaginal process of tympanic plate
Incisura mastoidea	Digastric fossa
Impressio trigemini	Impression for Gasserian ganglion
Eminentia arcuata	Eminence for sup. semicircular canal
Sulcus sigmoideus	Sigmoid fossa
Fissura petrotympanica	Glaserian fissure
Fossa mandibularis	Glenoid cavity
Semicanalis tubæ auditivæ	Eustachian tube
Os ethmoidale	**Ethmoid**
Labyrinthus ethmoidalis	Lateral mass
Lamina papyracea	Os planum
Processus uncinatus	Unciform process
Os lacrimale	**Lachrymal Bone**
Hamulus lacrimalis	Hamular process
Crista lacrimalis posterior	Lachrymal crest
Os nasale	**Nasal Bone**
Sulcus ethmoidalis	Groove for nasal nerve
Maxilla	**Superior Maxillary Bone**
Facies anterior	Facial or external surface
Facies infratemporalis	Zygomatic surface
Sinus maxillaris	Antrum of Highmore
Processus frontalis	Nasal process
Processus zygomaticus	Malar process
Canales alveolares	Posterior dental canals
Canalis naso-lacrimalis	Lachrymal groove
Os incisivum	Premaxilla
Foramen incisivum	Anterior palatine foramen
Os palatinum	**Palate Bone**
Pars perpendicularis	Vertical plate
Crista conchalis	Inferior turbinate crest
Crista ethmoidalis	Superior turbinate crest
Pars horizontalis	Horizontal plate

B.N.A. Terminology.	Old Terminology.
Os zygomaticum	**Malar Bone**
Processus temporalis	Zygomatic process
Processus fronto-sphenoidalis	Frontal process
Foramen zygomatico-orbitale	Temporo-malar canal
Foramen zygomatico-faciale	Malar foramen
Mandibula	**Inferior Maxillary Bone**
Spina mentalis	Genial tubercle or spine
Linea obliqua	External oblique line
Linea mylohyoidea	Internal oblique line
Incisura mandibulæ	Sigmoid notch
Foramen mandibulare	Inferior dental foramen
Canalis mandibulæ	Inferior dental canal
Protuberantia mentalis	Mental process

The Skull as a Whole.

B.N.A. Terminology.	Old Terminology.
Ossa suturarum	Wormian bones
Foveolæ granulares (Pacchioni)	Pacchionian depressions
Fossa pterygo-palatina	Spheno-maxillary fossa
Canalis pterygo-palatinus	Posterior palatine canal
Foramen lacerum	Foramen lacerum medium
Choanæ	Posterior nares
Fissura orbitalis superior	Sphenoidal fissure
Fissura orbitalis inferior	Spheno-maxillary fissure

Upper Extremity.

B.N.A. Terminology.	Old Terminology.
Clavicula	**Clavicle**
Tuberositas coracoidea	Impression for conoid ligament
Tuberositas costalis	Impression for rhomboid ligament
Scapula	**Scapula**
Incisura scapularis	Supra-scapular notch
Angulus lateralis	Anterior or lateral angle
Angulus medialis	Superior angle
Humerus	**Humerus**
Sulcus intertubercularis	Bicipital groove
Crista tuberculi majoris	External lip
Crista tuberculi minoris	Internal lip
Facies anterior medialis	Internal surface
Facies anterior lateralis	External surface
Margo medialis	Internal border
Margo lateralis	External border
Sulcus nervi radialis	Musculo-spiral groove
Capitulum	Capitellum
Epicondylus medialis	Internal condyle
Epicondylus lateralis	External condyle
Ulna	**Ulna**
Incisura semilunaris	Greater sigmoid cavity
Incisura radialis	Lesser sigmoid cavity
Crista interossea	External or interosseous border
Facies dorsalis	Posterior surface
Facies volaris	Anterior surface
Facies medialis	Internal surface
Margo dorsalis	Posterior border
Margo volaris	Anterior border
Radius	**Radius**
Tuberositas radii	Bicipital tuberosity
Incisura ulnaris	Sigmoid cavity
Crista interossea	Internal or interosseous border
Facies dorsalis	Posterior surface
Facies volaris	Anterior surface
Facies lateralis	External surface
Margo dorsalis	Posterior border
Margo volaris	Anterior border
Carpus	**Carpus**
Os naviculare	**Scaphoid**
Os lunatum	**Semilunar**
Os triquetrum	**Cuneiform**
Os multangulum majus	**Trapezium**
Os multangulum minus	**Trapezoid**
Os capitatum	**Os magnum**
Os hamatum	**Unciform**

Lower Extremity.

B.N.A. Terminology.	Old Terminology.
Os coxæ	**Innominate Bone**
Linea glutæa anterior	Middle curved line
Linea glutæa posterior	Superior curved line
Spina ischiadica	Spine of the ischium
Incisura ischiadica major	Great sacro-sciatic notch
Incisura ischiadica minor	Lesser sacro-sciatic notch
Tuberculum pubicum	Spine of pubis
Ramus inferior ossis pubis	Descending ramus of pubis
Ramus superior ossis pubis	Ascending ramus of pubis
Ramus superior ossis ischii	Body of ischium
Ramus inferior ossis ischii	Ramus of ischium
Pecten ossis pubis	Pubic part of ilio-pectineal line
Facies symphyseos	Symphysis pubis
Pelvis	**Pelvis**
Pelvis major	False pelvis
Pelvis minor	True pelvis
Apertura pelvis minoris superior	Pelvic inlet
Linea terminalis	Margin of inlet of true pelvis
Apertura pelvis minoris inferior	Pelvic outlet
Femur	**Femur**
Fossa trochanterica	Digital fossa
Linea intertrochanterica	Spiral line
Crista intertrochanterica	Post. intertrochanteric line

B.N.A. Terminology.	Old Terminology.
Condylus medialis	Inner condyle
Condylus lateralis	Outer condyle
Epicondylus medialis	Inner tuberosity
Epicondylus lateralis	Outer tuberosity
Tibia	**Tibia**
Condylus medialis	Internal tuberosity
Condylus lateralis	External tuberosity
Eminentia intercondyloidea	Spine
Tuberositas tibiæ	Tubercle
Malleolus medialis	Internal malleolus
Fibula	**Fibula**
Apex capituli fibulæ	Styloid process
Malleolus lateralis	External malleolus

Bones of the Foot.

B.N.A. Terminology.	Old Terminology.
Talus	**Astragalus**
Calcaneus	**Os calcis**
Tuber calcanei	Tuberosity of os calcis
Processus medialis tuberis calcanei	Inner } tuberosities of os calcis
Processus lateralis tuberis calcanei	Outer
Os cuneiforme primum	**Inner cuneiform**
Os cuneiforme secundum	**Middle cuneiform**
Os cuneiforme tertium	**Outer cuneiform**

THE LIGAMENTS.

Ligaments of the Spine.

Lig. longitudinale anterius	Anterior common ligament
Lig. longitudinale posterius	Posterior common ligament
Lig. flava	Ligamenta subflava
Membrana tectoria	Posterior occipito-axial ligament
Articulatio atlanto-epistrophica	Joint between the atlas and the axis
Lig. alaria	Odontoid or check ligaments
Lig. apicis dentis	Suspensory ligament

The Ribs.

Lig. capituli costæ radiatum	Anterior costo-vertebral or stellate ligament
Lig. sterno-costale interarticulare	Interarticular chondro-sternal ligament
Lig. sterno-costalia radiata	Anterior and posterior chondro-sternal ligament
Lig. costoxiphoidea	Chondro-xiphoid ligaments

The Jaw.

Lig. temporo-mandibulare	External lateral ligament of the jaw
Lig. spheno-mandibulare	Internal lateral ligament of the jaw
Lig. stylo-mandibulare	Stylo-maxillary ligament

Upper Extremity.

Lig. costo-claviculare	Rhomboid ligament
Labrum glenoidale	Glenoid ligament
Articulatio radio-ulnaris proximalis	Superior radio-ulnar joint
Lig. collaterale ulnare	Internal lateral ligament of elbow-joint
Lig. collaterale radiale	External lateral ligament
Lig. annulare radii	Orbicular ligament
Chorda obliqua	Oblique ligament of ulna
Articulatio radio-ulnaris distalis	Inferior radio-ulnar joint
Discus articularis	Triangular fibro-cartilage
Recessus sacciformis	Membrana sacciformis
Lig. radio-carpeum volare	Anterior ligament of the radio-carpal joint
Lig. radio-carpeum dorsale	Posterior ligament of the radio-carpal joint
Lig. collaterale carpi ulnare	Internal lateral ligament of the wrist-joint
Lig. collaterale carpi radiale	External lateral ligament of the wrist-joint
Articulationes intercarpeæ	Carpal joints
Lig. accessoria volaria	Palmar ligaments of the metacarpo-phalangeal joints
Lig. capitulorum ossium metacarpalium transversa	Transverse metacarpal ligament
Lig. collateralia	Lateral phalangeal ligaments

The Lower Extremity.

Lig. arcuatum	Subpubic ligament
Lig. sacro-tuberosum	Great sacro-sciatic ligament
Processus falciformis	Falciform process
Lig. sacro-spinosum	Small sacro-sciatic ligament
Labrum glenoidale	Cotyloid ligament
Zona orbicularis	Zonular band
Ligamentum ilio-femorale	Y-shaped ligament
Lig. ischio-capsulare	Ischio-capsular band
Lig. pubo-capsulare	Pubo-femoral ligament
Lig. popliteum obliquum	Ligament of Winslow
Lig. collaterale fibulare	Long external lateral ligament
Lig. collaterale tibiale	Internal lateral ligament
Lig. popliteum arcuatum	Arcuate popliteal ligament
Meniscus lateralis	External semilunar cartilage

B.N.A. Terminology.	Old Terminology.
Meniscus medialis	Internal semilunar cartilage
Plica synovialis patellaris	Lig. mucosum
Plicæ alares	Ligamenta alaria
Articulatio tibio-fibularis	Superior tibio-fibular articulation
Lig. capituli fibulæ	Anterior and posterior superior tibio-fibular ligaments
Syndesmosis tibio-fibularis	Inferior tibio-fibular articulation
Lig. deltoideum	Internal lateral ligament of ankle
Lig. talo-fibulare anterius	Anterior fasciculus of external lateral ligament
Lig. talo-fibulare posterius	Posterior fasciculus of external lateral ligament
Lig. calcaneo-fibulare	Middle fasciculus of external lateral ligament
Lig. talo-calcaneum laterale	External calcaneo-astragaloid ligament
Lig. talo-calcaneum mediale	Internal calcaneo-astragaloid ligament
Lig. calcaneo-naviculare plantare	Inferior calcaneo-navicular ligament
Lig. talo-naviculare	Astragalo-scaphoid ligament
Pars calcaneo-navicularis Pars calcaneo-cuboidea } lig. bifurcatum	Superior calcaneo-scaphoid ligament Internal calcaneo-cuboid ligament

THE MUSCLES.

Muscles of the Back.

Superficial.

Levator scapulæ	Levator anguli scapulæ

Muscles of the Chest.

Serratus anterior	Serratus magnus

Muscles of Upper Extremity.

Biceps brachii	Biceps
Lacertus fibrosus	Bicipital fascia
Brachialis	Brachialis anticus
Triceps brachii	Triceps
Caput mediale	Inner head
Caput laterale	Outer head
Pronator teres	Pronator radii teres
Caput ulnare	Coronoid head
Brachio-radialis	Supinator longus
Supinator	Supinator brevis
Extensor carpi radialis longus	Extensor carpi radialis longior
Extensor carpi radialis brevis	Extensor carpi radialis brevior
Extensor indicis proprius	Extensor indicis
Extensor digiti quinti proprius	Extensor minimi digiti
Abductor pollicis longus	Extensor ossis metacarpi pollicis
Abductor pollicis brevis	Abductor pollicis
Extensor pollicis brevis	Extensor primi internodii pollicis
Extensor pollicis longus	Extensor secundi internodii pollicis
Lig. carpi transversum	Anterior annular ligament
Lig. carpi dorsale	Posterior annular ligament

Muscles of Lower Extremity.

Tensor fasciæ latæ	Tensor fasciæ femoris
Canalis adductorius (Hunteri)	Hunter's canal
Trigonum femorale (fossa Scarpæ major)	Scarpa's triangle
Canalis femoralis	Crural canal
Annulus femoralis	Crural ring
M. quadriceps femoris—	Quadriceps—
Rectus femoris	Rectus femoris
Vastus lateralis	Vastus externus
Vastus intermedius	Crureus
Vastus medialis	Vastus internus
M. articularis genu	Subcrureus
Tibialis anterior	Tibialis anticus
Tendo calcaneus	Tendo Achillis
Tibialis posterior	Tibialis posticus
Quadratus plantæ	Accessorius
Lig. transversum cruris	Upper anterior annular ligament
Lig. cruciatum cruris	Lower anterior annular ligament
Lig. laciniatum	Internal annular ligament
Retinaculum musculorum peronæorum superius Retinaculum musculorum peronæorum inferius	External annular ligament

Axial Muscles.

Muscles of the Back.

Serratus posterior superior	Serratus posticus superior
Serratus posterior inferior	Serratus posticus inferior
Splenius cervicis	Splenius colli
Sacro-spinalis	Erector spinæ
Ilio-costalis—	**Ilio-costalis**—
Lumborum	Sacro-lumbalis
Dorsi	Accessorius
Cervicis	Cervicalis ascendens
Longissimus—	**Longissimus**—
Dorsi	Dorsi
Cervicis	Transversalis cervicis
Capitis	Trachelo-mastoid

B.N.A. TERMINOLOGY.	OLD TERMINOLOGY.
Spinalis—	Spinalis—
Dorsi	Dorsi
Cervicis	Colli
Capitis	Capitis
Semispinalis—	Semispinalis—
Dorsi	Dorsi
Cervicis	Colli
Capitis	Complexus
Multifidus	Multifidus spinæ

Muscles of Head and Neck.

Epicranius	Occipito-frontalis
Galea aponeurotica	Epicranial aponeurosis
Procerus	Pyramidalis nasi
Pars transversa (nasalis)	Compressor naris
Pars alaris (nasalis)	Dilatores naris
Auricularis anterior	Attrahens aurem
Auricularis posterior	Retrahens aurem
Auricularis superior	Attollens aurem
Orbicularis oculi	Orbicularis palpebrarum
Pars lacrimalis	Tensor tarsi
Triangularis	Depressor anguli oris
Quadratus labii superioris—	
Caput zygomaticum	Zygomaticus minor
Caput infraorbitale	Levator labii superioris
Caput angulare	Levator labii superioris alæque nasi
Zygomaticus	Zygomaticus major
Caninus	Levator anguli oris
Quadratus labii inferioris	Depressor labii inferioris
Mentalis	Levator menti
Platysma	Platysma myoides
Sterno-thyreoid	Sterno-thyroid
Thyreo-hyoid	Thyro-hyoid

Muscles and Fascia of the Orbit.

Fascia bulbi	Capsule of Tenon
Septum orbitale	Palpebral ligaments
Rectus lateralis	Rectus externus
Rectus medialis	Rectus internus

Muscles of the Tongue.

Genio-glossus	Genio-hyo-glossus
Longitudinalis superior	Superior lingualis
Longitudinalis inferior	Inferior lingualis
Transversus linguæ	Transverse fibres
Verticalis linguæ	Vertical fibres

Muscles of the Pharynx.

Pharyngo-palatinus	Palato-pharyngeus
M. uvulæ	Azygos uvulæ
Levator veli palatini	Levator palati
Tensor veli palatini	Tensor palati
Glosso-palatinus	Palato-glossus

Deep Lateral Muscles of Neck.

B.N.A. TERMINOLOGY.	OLD TERMINOLOGY.
Scalenus anterior	Scalenus anticus
Scalenus posterior	Scalenus posticus
Longus capitis	Rectus capitis anticus major
Rectus capitis anterior	Rectus capitis anticus minor

Muscles of Thorax.

Transversus thoracis	Triangularis sterni
Diaphragma, pars lumbalis	Diaphragm, lumbar part—
Crus mediale	Crus and origin from internal arcuate ligaments
Crus intermedium	
Crus laterale	
Arcus lumbocostalis medialis (Halleri)	Ligamentum arcuatum internum
Arcus lumbocostalis lateralis (Halleri)	Ligamentum arcuatum externum

Muscles of the Abdomen.

Ligamentum inguinale (Pouparti)	Poupart's ligament
Ligamentum lacunare (Gimbernati)	Gimbernat's ligament
Fibræ intercrurales	Intercolumnar fibres
Ligamentum inguinale reflexum (Collesi)	Triangular fascia
Annulus inguinalis subcutaneus	External abdominal ring
Crus superius	Internal pillar
Crus inferius	External pillar
Falx (aponeurotica) inguinalis	Conjoined tendon
M. transversus abdominis	Transversalis muscle
Linea semicircularis (Douglasi)	Fold of Douglas
Annulus inguinalis abdominalis	Internal abdominal ring

Perineum and Pelvis.

Transversus perinei superficialis	Transversus perinei
M. sphincter urethræ membranaceæ	Compressor urethræ
Diaphragma urogenitale	Deep transverse muscle and compressor urethræ
Fascia diaphragmatis urogenitalis superior	Deep layer of triangular ligament
Fascia diaphragmatis urogenitalis inferior	Superficial layer of the triangular ligament
Arcus tendineus fasciæ pelvis	White line of pelvis
Ligamenta puboprostatica	Anterior and lateral true ligaments of bladder
Fascia diaphragmatis pelvis superior	Visceral layer of pelvic fascia
Fascia diaphragmatis pelvis inferior	Anal fascia

THE NERVOUS SYSTEM.

Spinal Medulla.

B.N.A. Terminology.	Old Terminology.	B.N.A. Terminology.	Old Terminology.
Fasciculus anterior proprius (Flechsig)	Anterior ground or basis bundle	Columnæ anteriores, etc.	Anterior grey horns, etc.
Fasciculus lateralis proprius	Lateral ground bundle	Fasciculus cerebrospinalis anterior	Direct pyramidal tract
Nucleus dorsalis	Clarke's column	Fasciculus cerebrospinalis lateralis (pyramidalis)	Crossed pyramidal tract
Pars thoracalis	Dorsal part of spinal medulla	Fasciculus cerebellospinalis	Direct cerebellar tract
Sulcus intermedius posterior	Paramedian furrow	Fasciculus antero-lateralis superficialis	Gowers' tract

The **Brain** or **Encephalon** is divided into parts as follows :—

RHOMBENCEPHALON = Myelencephalon (medulla oblongata) (after-brain) } Posterior primary vesicle.
Metencephalon (pons and cerebellum) (hind-brain) }

CEREBRUM
- **MESENCEPHALON** (mid-brain—peduncles, corpora quadrigemina, etc.—) Middle primary vesicle
- **PROSENCEPHALON** (fore-brain)
  - **Diencephalon** = (inter-brain)
    - Thalamencephalon
      - Thalamus (optic thalamus).
      - Metathalamus (geniculate bodies).
      - Epithalamus (pineal body, etc.).
    - Mamillary portion of hypothalamus.
    - Posterior part of 3rd ventricle.
  - **Telencephalon**
    - Optic portion of hypothalamus (hypophysis).
    - Optic nerves.
    - Anterior part of 3rd ventricle.
    - Pallium (cortex cerebri).
    - Lateral ventricles.

Brain.

Rhombencephalon

Eminentia medialis	Eminentia teres
Ala cinerea	Trigonum vagi
Area acustica	Trigonum acusticum
Nucleus nervi abducentis	Nucleus of 6th nerve
Nuclei n. acustici	Auditory nucleus
Fasciculus longitudinalis medialis	Posterior longitudinal bundle
Corpus trapezoideum	Corpus trapezoides
Incisura cerebelli anterior	Semilunar notch (of cerebellum)
Incisura cerebelli posterior	Marsupial notch
Sulcus horizontalis cerebelli	Great horizontal fissure
Lobulus centralis	Lobus centralis
Folium vermis	Folium cacuminis
Tuber vermis	Tuber valvulæ
Lobulus quadrangularis	Quadrate lobule
Brachium conjunctivum cerebelli	Superior cerebellar peduncle
Brachium pontis	Middle cerebellar peduncle
Restiform body	Inferior cerebellar peduncle
Lobulus semilunaris superior	Postero-superior lobule
Lobulus semilunaris inferior	Postero-inferior lobule

Cerebrum

Pedunculus cerebri	Crus cerebri
Colliculus superior	Anterior corpus quadrigeminum
Colliculus inferior	Posterior corpus quadrigeminum
Aquæductus cerebri	Iter e tertio ad quartum ventriculum, or aqued. of Sylvius
Foramen interventriculare	Foramen of Monro
Hypothalamus	Subthalamic region
Sulcus hypothalamicus	Sulcus of Monro
Massa intermedia	Middle commissure
Fasciculus thalamomamillaris	Bundle of Vicq d'Azyr
Pars opercularis	Pars basilaris
Thalamus	Optic thalamus
Pallium	Cortex cerebri
Gyri transitivi	Annectant gyri
Fissura cerebri lateralis	Fissure of Sylvius
Gyrus temporalis superior	First temporal gyrus
Gyrus temporalis medius	Second temporal gyrus
Gyrus temporalis inferior	Third temporal gyrus
Sulcus centralis (Rolandi)	Fissure of Rolando
Sulcus temporalis superior	Parallel sulcus

B.N.A. Terminology.	Old Terminology.
Sulcus temporalis medius	Second temporal sulcus
Sulcus circularis	Limiting sulcus of Reil
Sulcus temporalis inferior	Occipito-temporal sulcus
Gyrus fusiformis	Occipito-temporal convolution
Sulcus interparietalis	Intraparietal sulcus
Sulcus corporis callosi	Callosal sulcus
Sulcus cinguli	Calloso-marginal fissure
Fissura hippocampi	Dentate fissure
Gyrus cinguli	Callosal convolution
Stria terminalis	Tænia semicircularis
Trigonum collaterale	Trigonum ventriculi
Hippocampus	Hippocampus major
Digitationes hippocampi	Pes hippocampi
Fascia dentata hippocampi	Gyrus dentatus
Columna fornicis	Anterior pillar of fornix
Septum pellucidum	Septum lucidum
Cornu inferius	Descending horn of lateral ventricle
Commissura hippocampi	Lyra
Nucleus lentiformis	Lenticular nucleus
Pars frontalis capsulæ internæ	Anterior limb (of internal capsule)
Pars occipitalis capsulæ internæ	Posterior limb (of internal capsule)
Radiatio occipito-thalamica	Optic radiation
Radiatio corporis callosi	Radiation of corpus callosum
Pars frontalis	Forceps minor
Pars occipitalis	Forceps major

Membranes of Brain.

B.N.A. Terminology.	Old Terminology.
Cisterna cerebello-medullaris	Cisterna magna
Cisterna interpeduncularis	Cisterna basalis
Granulationes arachnoideales	Pacchionian bodies
Tela chorioidea ventriculi tertii	Velum interpositum
Tela chorioidea ventriculi quarti	Tela choroidea inferior

Cerebral Nerves.

B.N.A. Terminology.	Old Terminology.
N. oculomotorius	Third nerve
N. trochlearis	Fourth nerve
N. trigeminus	Fifth nerve
Ganglion semilunare (Gasseri)	Gasserian ganglion
N. naso-ciliaris	Nasal nerve
N. maxillaris	Superior maxillary nerve
N. meningeus (medius)	Recurrent meningeal nerve
N. zygomaticus	Temporo-malar nerve
Rami alveolares superiores posteriores	Posterior superior dental
Rami alveolares superiores medi	Middle superior dental
Rami alveolares superiores anteriores	Anterior superior dental
Ganglion spheno-palatinum	Meckel's ganglion
N. palatinus medius	External palatine nerve
N. mandibularis	Inferior maxillary nerve
Nervus spinosus	Recurrent nerve
N. alveolaris inferior	Inferior dental
N. abducens	Sixth nerve
N. facialis	Seventh nerve
N. intermedius	Pars intermedia of Wrisberg
N. acusticus	Eighth or auditory nerve
Ganglion superius	Jugular ganglion of 9th nerve
N. recurrens	Recurrent laryngeal nerve
Ganglion jugulare	Ganglion of root of vagus
Ganglion nodosum	Ganglion of trunk of vagus
Plexus œsophageus anterior	Plexus gulæ
Plexus œsophageus posterior	
Nervus accessorius	Spinal accessory
Ramus internus	Accessory portion of spinal accessory nerve
Ramus externus	Spinal portion

Spinal Nerves.

B.N.A. Terminology.	Old Terminology.
Rami posteriores	Posterior primary divisions
Rami anteriores	Anterior primary divisions
N. cutaneus colli	Transverse superficial cervical nerve
Nn. supraclaviculares anteriores	Suprasternal nerves
Nn. supraclaviculares medii	Supraclavicular nerves
Nn. supraclaviculares posteriores	Supra-acromial nerves
N. dorsalis scapulæ	Nerve to the rhomboids
Nn. intercosto-brachiales	Intercosto-humeral nerves
N. thoracalis longus	Nerve of Bell
N. thoraco-dorsalis	Long subscapular nerve
N. cutaneus brachii medialis	Lesser internal cutaneous nerve
N. cutaneus brachii lateralis	Cutaneous branch of circumflex nerve
Fasciculus lateralis	Outer cord (of plexus)
Fasciculus medialis	Inner cord
N. cutaneus antibrachii lateralis	Cutaneous branch of musculo-cutaneous nerve
N. cutaneus antibrachii medialis	Internal cutaneous nerve
Ramus volaris	Anterior branch
Ramus ulnaris	Posterior branch
N. axillaris	Circumflex nerve

B.N.A. Terminology.	Old Terminology.
N. interosseus volaris	Anterior interosseous
Ramus palmaris N. mediani	Palmar cutaneous branch of the median nerve
Nn. digitales volares proprii	Collateral palmar digital branches of median nerve
Ramus dorsalis manus	Dorsal cutaneous branch of ulnar nerve
Ramus cutaneus palmaris	Palmar cutaneous branch of ulnar nerve
N. radialis	Musculo-spiral nerve
N. cutaneus brachii posterior	Internal cutaneous branch of musculo-spiral nerve
N. cutaneus antibrachii dorsalis	External cutaneous branches of musculo-spiral nerve
Ramus superficialis	Radial nerve
N. interosseus dorsalis	Posterior interosseous nerve
Nn. digitales dorsales	Dorsal digital nerves
N. ilio-hypogastricus	Ilio-hypogastric nerve
Ramus cutaneus lateralis	Iliac branch of ilio-hypogastric nerve
Ramus cutaneus anterior	Hypogastric branch of ilio-hypogastric nerve

B.N.A. Terminology.	Old Terminology.
N. genito-femoralis	Genito-crural nerve
N. lumbo-inguinalis	Crural branch of genito-crural nerve
N. spermaticus externus	Genital branch of genito-crural nerve
N. cutaneus femoris lateralis	External cutaneous nerve
N. femoralis	Anterior crural nerve
N. saphenus	Long saphenous nerve
Ramus infrapatellaris	Patellar branch of long saphenous nerve
N. ischiadicus	Great sciatic nerve
N. peronæus communis	External popliteal nerve
Ramus anastomoticus peronæus	Nervus communicans fibularis
N. peronæus superficialis	Musculo-cutaneous nerve
N. peronæus profundus	Anterior tibial nerve
N. tibialis	Internal popliteal and posterior tibial nerves
N. cutaneus suræ medialis	Nervus communicans tibialis
N. suralis	Short saphenous nerve
N. plantaris medialis	Internal plantar
N. plantaris lateralis	External plantar
N. pudendus	Pudic nerve

THE HEART AND BLOOD-VESSELS

Heart.

Atrium	Auricle
Auricula cordis	Auricular appendix
Incisura cordis	Notch at apex of heart
Trabeculæ carneæ	Columnæ carneæ
Tuberculum intervenosum	Intervenous tubercle of Lower
Sulcus longitudinalis anterior	Anterior interventricular groove
Sulcus coronarius	Auriculo-ventricular groove
Limbus fossæ ovalis	Annulus ovalis
Valvula venæ cavæ	Eustachian valve
Valvula sinus coronarii	Valve of Thebesius

Arteries.

Sinus aortæ	Sinuses of Valsalva
A. profunda linguæ	Ranine artery
A. maxillaris externa	Facial artery
A. alveolaris inferior	Inferior dental artery
Ramus meningeus accessorius	Small meningeal artery
A. buccinatoria	Buccal artery
A. alveolaris superior posterior	Posterior superior dental artery
Aa. alveolares superiores anteriores	Anterior superior dental arteries
Ramus carotico-tympanicus	Tympanic branch of int. carotid
A. chorioidea	Anterior choroidal artery
A. auditiva interna	Auditory artery
Rami ad pontem	Transverse arteries (branches of basilar artery)
A. pericardiacophrenica	Arteria comes nervi phrenici
Rami intercostales	Anterior intercostal arteries
Truncus thyreo-cervicalis	Thyroid axis
A. transversa scapulæ	Suprascapular artery
A. intercostalis suprema	Superior intercostal
A. transversa colli	Transversalis colli
A. thoracalis suprema	Superior thoracic artery
A. thoraco-acromialis	Acromio-thoracic artery
A. thoracalis lateralis	Long thoracic artery
A. circumflexa scapulæ	Dorsalis scapulæ
A. profunda brachii	Superior profunda
A. collateralis radialis	Anterior branch of superior profunda
A. collateralis ulnaris superior	Inferior profunda
A. collateralis ulnaris inferior	Anastomotica magna
Ramus carpeus volaris	Anterior radial carpal

B.N.A. Terminology.	Old Terminology.
Ramus carpeus dorsalis	Posterior radial carpal
Aa. metacarpeæ dorsales	Dorsal interosseous arteries
A. volaris indicis radialis	Radialis indicis
Arcus volaris superficialis	Superficial palmar arch
Arcus volaris profundus	Deep palmar arch
A. interossea dorsalis	Posterior interosseous artery
A. interossea recurrens	Posterior interosseous recurrent artery
A. interossea volaris	Anterior interosseous artery
Ramus carpeus dorsalis	Posterior ulnar carpal
Ramus carpeus volaris	Anterior ulnar carpal
Aa. digitales volares communes	Palmar digital arteries
Aa. digitales volares propriæ	Collateral digital arteries
Arteriæ intestinales	Intestinal branches of sup. mesenteric
A. suprarenalis media	Middle capsular artery
A. hypogastrica	Internal iliac artery
A. umbilicalis	Obliterated hypogastric
A. pudenda interna	Internal pudic artery
A. epigastrica inferior	Deep epigastric artery
A. spermatica externa	Cremasteric artery
Aa. pudendæ externæ	Superficial and deep external pudic arteries
A. circumflexa femoris medialis	Internal circumflex artery
A. circumflexa femoris lateralis	External circumflex artery
A. genu suprema	Anastomotica magna
A. genu superior lateralis	Superior external articular artery
A. genu superior medialis	Superior internal articular artery
A. genu media	Azygos articular artery
A. genu inferior lateralis	Inferior external articular artery
A. genu inferior medialis	Inferior internal articular artery
A. malleolaris anterior lateralis	External malleolar artery
A. malleolaris anterior medialis	Internal malleolar artery
A. peronæa	Peroneal artery
Ramus perforans	Anterior peroneal artery
A. malleolaris posterior lateralis	Posterior peroneal artery
A. malleolaris posterior medialis	Internal malleolar artery
Rami calcanei laterales	External calcanean artery
Rami calcanei mediales	Internal calcanean artery
A. plantaris medialis	Internal plantar artery
A. plantaris lateralis	External plantar artery
Aa. metatarsæ plantares	Digital branches
Aa. digitales plantares	Collateral digital branches

Veins.

V. cordis magna	Great cardiac vein
V. obliqua atrii sinistri	Oblique vein of Marshall
Lig. venæ cavæ sinistræ	Vestigial fold of Marshall
Vv. cordis minimæ	Veins of Thebesius
Sinus transversus	Lateral sinus
Confluens sinuum	Torcular Herophili
Plexus basilaris	Basilar sinus
Sinus sagittalis superior	Superior longitudinal sinus
Sinus sagittalis inferior	Inferior longitudinal sinus
Sinus spheno-parietalis	Sinus alæ parvæ
V. cerebri internæ	Veins of Galen
V. cerebri magna	Vena magna Galeni
V. terminalis	Vein of the corpus striatum
V. basalis	Basilar vein
V. transversa scapulæ	Suprascapular vein
V. thoraco-acromialis	Acromio - thoracic vein
Vv. transversæ colli	Transversalis colli veins
V. thoracalis lateralis	Long thoracic vein
V. azygos	Vena azygos major
V. hemiazygos	Vena azygos minor inferior
V. hemiazygos accessoria	Vena azygos minor superior
V. hypogastrica	Internal iliac vein
V. epigastrica inferior	Deep epigastric vein
V. saphena magna	Internal saphenous vein
V. saphena parva	External saphenous vein

Lymphatics.

Cisterna chyli	Receptaculum chyli

THE VISCERA.

Digestive Apparatus.

Arcus glosso-palatinus	Anterior pillar of fauces
Arcus pharyngo-palatinus	Posterior pillar of fauces
Gl. lingualis anterior	Gland of Nuhn
Ductus submaxillaris	Wharton's duct
Gl. parotis accessoria	Socia parotidis
Ductus parotideus (Stenonis)	Stenson's duct
Dentes præmolares	Bicuspid teeth
Dens serotinus	Wisdom tooth
Papillæ vallatæ	Circumvallate papillæ
Recessus pharyngeus	Lateral recess of pharynx
Tela submucosa	Pharyngeal aponeurosis
Plicæ circulares	Valvulæ conniventes
Gl. intestinales	Crypts of Lieberkuhn
Valvula coli	Ileo-cæcal valve
Columnæ rectales	Columns of Morgagni

B.N.A. Terminology.	Old Terminology.
Plicæ transversales recti	Valves of Houston
Valvula spiralis	Valve of Heister
Noduli lymphatici aggregati (Peyeri)	Peyer's patches
Intestinum jejunum	Jejunum
Intestinum ileum	Ileum
Noduli lymphatici lienales (Malpighii)	Malpighian corpuscles

Respiratory Apparatus.

Larynx

Prominentia laryngea	Adam's apple
Incisura thyreoidea superior	Superior thyroid notch
M. ary-epiglotticus	Aryteno-epiglottidean muscle
M. vocalis	Internal thyro-arytenoid muscle
M. thyreo-epiglotticus	Thyro-epiglottidean muscle
Appendix ventriculi laryngis	Laryngeal sac
Plica vocalis	True vocal cord
Plica ventricularis	False vocal cord
Ligamentum ventriculare	Superior thyro-arytenoid ligament
Ligamentum vocale	Inferior thyro-arytenoid ligament
Glottis	Glottis vera
Rima vestibuli	Glottis spuria
Cartilago thyreoidea	Thyroid cartilage
Membrana hyothyreoidea	Thyro-hyoid membrane
Cartilago corniculata (Santorini)	Cartilage of Santorini
Tuberculum epiglotticum	Cushion of epiglottis
Pars intermembranacea (rimæ glottidis)	Glottis vocalis
Pars intercartilaginea (rimæ glottidis)	Glottis respiratoria
Conus elasticus (membranæ elasticæ laryngis)	Crico-thyroid membrane
Glandula thyreoidea	Thyroid gland

B.N.A. Terminology.	Old Terminology.
Glomus caroticum	Intercarotid gland or body

Nose

Concha nasalis suprema (Santorini)	Highest turbinate bone
Concha nasalis superior	Superior turbinate bone
Concha nasalis media	Middle turbinate bone
Concha nasalis inferior	Inferior turbinate bone

Urogenital Apparatus.

Corpuscula renis	Malpighian corpuscles
Paradidymis	Organ of Giraldés
Appendix testis	Hydatid of Morgagni (male)
Ductus deferens	Vas deferens
Gl. urethrales	Glands of Littré
Glandula bulbo-urethralis (Cowperi)	Cowper's gland
Folliculi oophori vesiculosi	Graafian follicles
Cumulus oophorus	Discus proligerus
Tuba uterina	Fallopian tube
Epoophoron	Parovarium
Appendices vesiculosi	Hydatids of Morgagni (female)
Ductus epoophori longitudinalis	Gärtner's duct
Orificium internum uteri	Internal os (of uterus)
Orificium externum	External os
Processus vaginalis	Canal of Nuck
Glandula vestibularis major	Bartholin's gland

Peritoneum.

Bursa omentalis	Lesser peritoneal sac
Foramen epiploicum	Foramen of Winslow
Lig. phrenico-colicum	Costo-colic ligament
Excavatio recto-uterina (cavum Douglasi)	Pouch of Douglas
Lig. gastro-lienale	Gastro-splenic omentum

THE SENSE ORGANS.

The Eye.

Sclera	Sclerotic coat
Lamina elastica anterior (Bowmani)	Bowman's membrane
Lamina elastica posterior (Descemeti)	Descemet's membrane
Spatia anguli iridis	Spaces of Fontana
Angulus iridis	Irido-corneal junction
Zonula ciliaris	Zonule of Zinn
Septum orbitale	Palpebral ligament
Fascia bulbi	Capsule of Tenon
Commissura palpebrarum lateralis	External canthus
Commissura palpebrarum medialis	Internal canthus
Tarsus superior	Superior tarsal plate
Tarsus inferior	Inferior tarsal plate
Lig. palpebrale mediale	Internal tarsal ligament
Raphe palpebralis lateralis	External tarsal ligament
Tarsal glands	Meibomian glands

The Ear.

Canalis semicircularis lateralis	External semicircular canal
Ductus reuniens	Canalis reuniens
Ductus cochlearis	Membranous cochlea
Recessus sphæricus	Fovea hemispherica
Recessus ellipticus	Fovea hemi-elliptica
Paries jugularis	Floor of tympanum
Paries labyrinthica	Inner wall
Fenestra vestibuli	Fenestra ovalis
Fenestra cochleæ	Fenestra rotunda
Paries mastoidea	Posterior wall
Antrum tympanicum	Mastoid antrum
Paries carotica	Anterior wall
Processus lateralis	Processus brevis (of malleus)
Processus anterior	Processus gracilis

TEXT-BOOK OF ANATOMY.

INTRODUCTION.

ANATOMY is a comprehensive term, which includes several closely related branches of study. Primarily it is employed to indicate the study of the parts which build up the body, and the relationship which these present to each other. But the structure of an individual is not the same at all stages of its life, for many changes occur during the period of its existence. The ovum and the spermatozoon, which are the starting-points of every individual, are very different from the finished organism as represented by the adult, and the series of changes through which the organism passes until its structure is perfected and full growth is attained constitute the phenomena of **development**. The general term "development" includes not only the various and striking structural changes which occur during the intra-uterine life of the individual, to the study of which the term **embryology** is more specially applied, but also many growth processes which occur after birth, such as the later stages in the ossification and growth of the bones, the eruption of the two series of teeth, the adjustment of the vascular system to its new requirements, etc. The actual observation of the processes by which the parts of the body are gradually formed, and of the structural arrangements by means of which a temporary connexion is established between the ovum and the mother, through which an interchange of nutritive and other matters between the two takes place, renders embryology one of the most interesting of all the departments of anatomy. The term **ontogeny** also is used to denote the development of the individual. There is, however, another form of development, slower, but just as certain in its processes, which affects not only the individual, but all the members of the animal group to which it belongs. The theory of descent or evolution leads us to believe that between man of the present day and his remote ancestors there is a wide structural gap, which, if the geological record were perfect, would be seen to be completely occupied by long-lost intermediate forms. In the process of evolution, therefore, structural changes have gradually taken place which have modified the entire race. These evolutionary phases constitute the ancestral history or **phylogeny** of the race. Ontogeny and phylogeny are intertwined in a remarkable manner, and present certain extraordinary relationships. In other words, the ancestral evolutionary development appears to be so stamped upon an individual that it repeats certain of the phylogenetic stages with more or less clearness during the process of its own individual development. Thus, at an early period in the embryology of man evanescent gill-pouches appear which are comparable with those of a fish, whilst a study of the development of his heart shows that it passes through transitory structural conditions similar, in many respects, to the permanent conditions of the heart in certain of the lower animals. It is in connexion with this that the phrase has arisen that every animal in its individual development or ontogeny climbs up its own genealogical tree—a saying which, taking it even in the broadest sense, is only partially true.

The broader conceptions of anatomy, which are obtained by taking a general survey of the structural aspects of the entire animal kingdom, constitute **morphology.** The morphologist investigates the laws of form and structure, and in his generalisations he gives attention to detail only in so far as this is necessary for the proper establishment of his views. The knowledge of anatomy which is required by the student of medicine is different. It is essentially one of detail, and often details important from the practical and utilitarian points of view have little or no morphological value. This want of balance in the interest attached to anatomical facts, according to the aspect from which they are examined, so far from being unfortunate, affords the teacher the means of making the study of anatomy at once fascinating and instructive. Almost every fact which is brought under the notice of the student can be accompanied by a morphological or a practical application. These possibilities of application lighten a study which, presented to the student of medicine in any other way, would be at once dry and tedious.

Certain terms employed in morphology require early and definite explanation. These are homology, serial homology, and homoplasy. The same organ repeated in two different animals is said to present a case of **homology.** But the morphological identity between the two organs must be proved beyond dispute before the homology between them can be allowed. In deciding the identity the great and essential test is that the two organs in question should have a similar developmental origin. Thus, the fore-limb of a quadruped is homologous with the upper limb of man; the puny collar-bone of a tiger, the fibrous thread which is the only representative of this bone in the horse, and the strongly marked clavicle of the ape or man, are all, strictly speaking, homologous with one another. Homologous organs in different animals usually occupy a similar position and possess a similar structure, but not invariably so. It is not uncommon for a muscle to wander somewhat from its original position, and many cases could be quoted in which parts have become completely transformed in structure, either from disuse or for the purpose of meeting some special demand in the animal economy. In the study of the muscles and ligaments instances of this will be brought under the notice of the reader.

Often organs which perform totally different functions are yet perfectly homologous. Thus the wing of a bat or the wing of a bird, both of which are subservient to flight, are homologous with the upper limb of man, the office of which is the different one of prehension. Identity or correspondence in the function performed by two organs in two different animals is not taken into consideration in deciding questions of homology. The gills of a fish and the lungs of a higher vertebrate perform very much the same physiological office, and yet they are not homologous. The term **analogy** is often used to express functional correspondence of this kind.

In the construction of vertebrates and certain other animal groups a series of similar parts are repeated along a longitudinal axis, one after the other. Thus the series of vertebræ which build up the backbone, the series of ribs which gird round each side of the chest, the series of intercostal muscles which fill up the intervals between the ribs, the series of nerves which arise from the brain and spinal medulla, are all examples of this. An animal exhibiting such a condition of parts is said to present the **segmental type** of organisation. In the early stages of development this segmentation is much more strongly marked, and is to be seen in parts which subsequently lose all trace of such a subdivision. The parts thus repeated are said to be **serially homologous.** But there are other instances of serial homology besides those which are manifestly produced by segmentation. The upper limb is serially homologous with the lower limb: each is composed of parts which, to a large extent, are repeated in the other, and the correct adjustment of this comparison between the several parts of the upper and lower limbs constitutes one of the most difficult and yet interesting problems of morphology.

Homoplasy is a term which has been introduced to express a form of correspondence between organs in different animals which cannot be included under the term homology. Two animal groups, which originally have sprung from the same stem-form, may independently develop a similar structural character which is altogether absent in the ancestor common to both. Thus the common ancestor of man and the carnivora in all probability possessed a smooth brain, and yet the human brain and the carnivore brain are both richly convoluted. Not only this, but certain anatomists seek to reconcile the convolutionary pattern of the one with the convolutionary pattern of the other. What correspondence there is does not, in every instance, constitute a case of homology, because there is not in every case a community of origin. Correspondence of this kind is included under the term "homoplasy." Another example is afforded by the heart of the mammal and that of the bird. In both of these groups the ventricular portion of the heart consists of a right and a left chamber, and yet the ventricular septum in the one is not homologous with the corresponding septum in the other, because the common ancestor from which both have sprung possessed a heart with a single ventricular cavity, and the double-chambered condition has been a subsequent and independent development in the two groups.

Systematic Anatomy.—The human body is composed of a combination of several systems of organs, and the several parts of each system not only present a certain similarity in structure, but also fulfil special functions. Thus there are—

1. The *skeletal system*, composed of the bones and certain cartilaginous and membranous parts associated with them, the knowledge of which is known as **osteology.**
2. The *articulatory system*, which includes the joints or articulations, the knowledge of which is termed **arthrology.**
3. The *muscular system*, comprising the muscles, the knowledge of which constitutes **myology.**
4. The *nervous system*, in which are included the brain, the spinal medulla, the ganglia of the spinal and cerebral nerves, the sympathetic ganglia, and the various nerves proceeding from and entering these. The knowledge of these parts is expressed by the term **neurology.** In this system the organs of sense may also be included.
5. The *blood vascular* and *lymphatic system*, including the heart, blood-vessels, the lymph vessels, and the lymph glands. **Angeiology** is the term applied to the knowledge of this system.
6. The *respiratory system*, in which we place the lungs, windpipe, and larynx.
7. The *digestive system*, which consists of the alimentary canal and its associated glands, and parts such as the tongue, teeth, liver, pancreas, etc.
8. The *urogenital system*, composed of the urinary organs and the reproductive organs—the latter differing in the two sexes.

The term **splanchnology** denotes the knowledge of the organs included in the respiratory, digestive, and urogenital systems.

9. The *integumentary system* consists of the skin, nails, hair, etc. The knowledge of this system is termed **dermatology.**

The numerous organs which form the various systems are themselves built up of tissues, the ultimate elements of which can be studied only by the aid of the microscope. The knowledge of these elements and of the manner in which they are grouped together to form the various tissues of the body forms an important branch of anatomy, which is termed **histology**.

The structure of the human body may be studied in two different ways. The several parts may be considered with reference to their relative positions, either as they are met with in the course of an ordinary dissection, or as they are seen on the surface of a section through the body. This is the *topographical method.* On the other hand, the several systems of organs may be treated separately and in sequence. This constitutes the *systematic method,* and it is the plan which is adhered to in this treatise.

Descriptive Terms.—Anatomy is a descriptive science founded on observation, and in order that precision and accuracy may be attained it is necessary that we should be provided with a series of well-defined descriptive terms. It must be clearly understood that all descriptions are framed on the supposition that the body is in the erect position, with the arms by the side, and the hands held so that the palms look forwards and the thumbs laterally. An imaginary plane of section, passing longitudinally through the body so as to divide it accurately into a right and a left half, is called the **median plane**, Fig. 1 (M.P.). When the right and left halves of the body are studied it will be found that both are to a large extent formed of similar parts. The right and left limbs are alike; the right and left halves of the brain are the same; there are a right and a left kidney and a right and a left lung, and so on. So far the organs are said to be **symmetrically** arranged. But still a large amount of **asymmetry** may be observed. Thus, the chief bulk of the liver lies to the right side of the median plane, and the spleen is an organ which belongs wholly to the left half of the body. Indeed, it is well to state that perfect symmetry never does exist. There always will be, and always must be, a certain want of balance between symmetrically placed parts of the body. Thus the right upper limb is, as a rule, constructed upon a heavier and more massive plan than the left, and even in those organs where the symmetry appears most

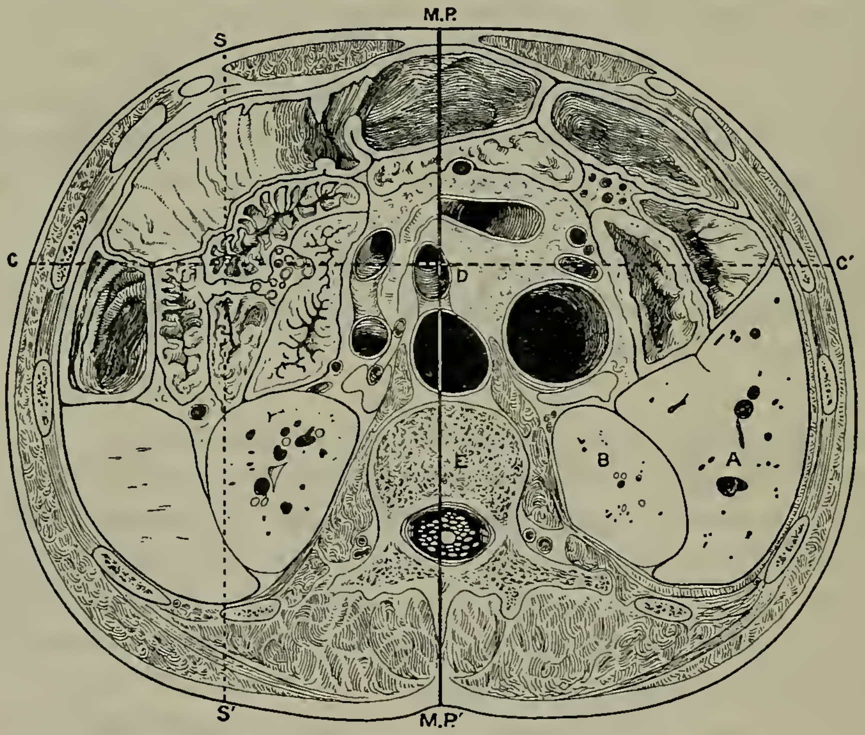

Fig. 1.—Horizontal Section through the Trunk at the Level of the First Lumbar Vertebra.

perfect, as for instance the brain and spinal medulla, it requires only a closer study to reveal many points of difference between the right and left halves.

The line on the front of the body along which the median plane reaches the surface is termed the **anterior median line**; whilst the corresponding line behind is called the **posterior median line.**

It is convenient to employ other terms to indicate other imaginary planes of section through the body. The term **sagittal**, therefore, is used to denote any plane which cuts through the body along a path which is parallel to the median plane (S S′); and the term **coronal** or **frontal** is given to any vertical plane which passes through the body in a path which cuts the median plane at right angles (C C′). The term **horizontal**, as applied to a plane of section, requires no explanation.

Any structure which lies nearer to the median plane than another is said to be **medial** to it; and any structure placed further from the median plane than another is said to lie **lateral** to it. Thus in Fig. 1, A is lateral to B; whilst B is medial to A.

The terms internal and external are applied to the walls of hollow cavities or organs; thus, the ribs possess external surfaces, that is, surfaces away from the cavity of the thorax, and internal surfaces adjacent to the cavity.

The terms **anterior** and **ventral** are synonymous, and are used to indicate a structure (D) which lies nearer to the front or ventral surface of the body than another structure (E) which is placed nearer to the back or dorsal surface of the body, and which is thus said to be **posterior** or **dorsal.** In some respects it would be well to discard the terms "anterior" and "posterior" in favour of "ventral" and "dorsal," seeing that the former are only applicable to man in the erect attitude, and cannot be applied to an animal in the prone or quadrupedal position. They are, however, so deeply ingrained into the descriptive language of the human anatomist that they cannot be entirely discarded. A similar objection may be raised to the terms **superior** and **inferior**, which are employed to indicate the relative levels at which two structures lie with reference to the upper and lower ends of the body. The equivalent terms of **cephalic** or **cranial** and **preaxial** are, therefore, sometimes used in place of "superior," and **caudal** and **postaxial** in place of "inferior."

The terms **proximal** and **distal** should be applied only in the description of the limbs. They denote relative nearness to or distance from the root of the limb. Thus, the hand is distal to the forearm, whilst the arm or brachium is proximal to the forearm.

HUMAN EMBRYOLOGY.

By A. H. Young and Arthur Robinson.

Rewritten by Arthur Robinson.

The **ontogenetic** or **developmental history** of every human individual is separable into two main periods, **pre-natal** and **post-natal**.

It is to the knowledge of the phenomena of the earlier or pre-natal period that the term **human embryology** is applied, and, as pre-natal development takes place in an organ called the uterus, it is frequently spoken of as *intra-uterine development.*

The period of pre-natal development extends through nine lunar months, and may be divided into three sub-periods: (1) the **pre-embryonic period**, during which the **zygote**, from which the embryo is formed, shows no definite separation into embryonic and non-embryonic portions. That period possibly lasts about fourteen days; (2) the **period of the embryo**, in which the zygote is definitely separated into embryonic and non-embryonic portions, but the embryonic part has not yet assumed a clearly human form. The embryonic period terminates at the end of the second month; (3) the **fœtal period**, which commences at the end of the second month, when the embryo assumes a definitely human form and is called, thenceforth, a fœtus. The fœtal period ends at birth, when the fœtus becomes a child and *post-natal development* commences.

Only the general phenomena of the pre-natal period of development are considered in this section; the details of the pre- and post-natal development of the various organs and systems will be dealt with in the sections devoted to the descriptions of their adult conditions.

THE STRUCTURE OF ANIMAL CELLS.

The human body is formed by the multiplication and differentiation of animal cells, therefore it is essential that the student should possess a knowledge of the main features and capabilities of such cells before he commences the study of the details of human embryology.

Animal cells differ from each other in minor points of structure, in association with the positions they occupy and the functions they perform; nevertheless, they all possess some common and essential structural features, and, in the younger stages of their history, some common capabilities.

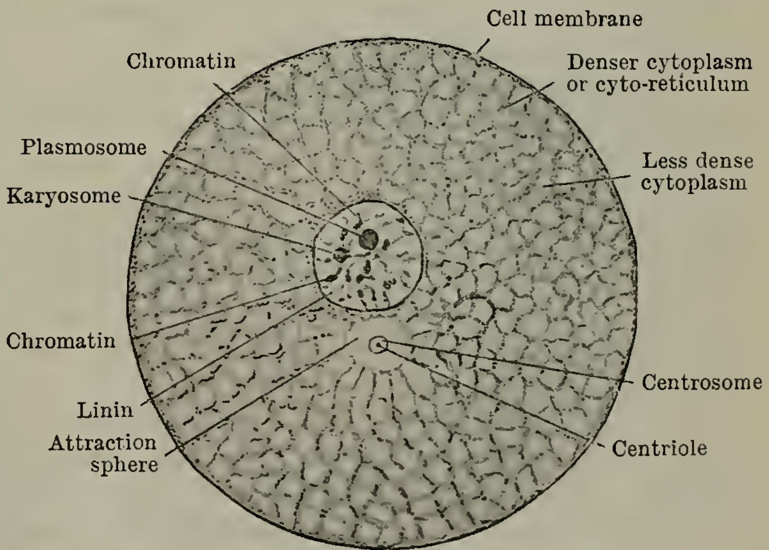

Fig. 2.—Diagram of an Animal Cell.

The constituent parts of a typical animal cell are:—

The **cell body** surrounded by the **cell membrane** and containing:—

(*a*) The **nucleus** with its **nucleolus** or **nucleoli**;
(*b*) The **centrosome** with one or more **centrioles**;
(*c*) **Chondriosomes.**

In addition there may be other substances, in the form of granules, or globules, or both, which are sometimes temporary and sometimes permanent parts of the cell.

All the essential parts of the cell consist of a substance called **protoplasm.**

In its simplest form protoplasm is the semifluid, viscous, irritable, and contractile substance which forms the "physical basis of life." It consists of C., H., N., O., and S., combined together, in different ways and in differing proportions, to form various modifications of protoplasm which possess definite physical and chemical characteristics, and which receive, therefore, different names.

The Cell Body.—The protoplasm of the cell body is called **cytoplasm.** It consists of two fluid or semi-fluid substances of different densities, of which one, the more dense and less abundant, forms thin films round the globules of the less dense and more abundant substance. When examined under the microscope the films of the more dense substance appear as a network which encloses the globules of the less dense substance, and they are frequently spoken of as the *cyto-reticulum,* whilst the less dense portions are called either *cytolymph* or *hyaloplasm*; but as both parts are either fluid or semi-fluid, neither of them offers an obstruction to the passage of the other contents of the cell from one position to another.

The Cell Membrane.—Most animal cells, with the exception of leucocytes (white blood corpuscles), are surrounded by a thin and more resistant layer of substance called the cell membrane. It is either a condensation of the cytoplasm or it is secreted by the cytoplasm.

The Nucleus.—The constituent parts of the nucleus are (1) chromatin, (2) linin, (3) karyoplasm, and (4) the nuclear membrane. It contains one or more nucleoli which may be (*a*) karyosomes or (*b*) plasmosomes or both.

The **chromatin** consists of granules which are easily and strongly stainable. They are embedded in or connected with the linin.

The **linin** forms a network in which the chromatin granules are usually embedded. It is either unstainable or very slightly stainable, and is therefore frequently spoken of as *achromatin.*

The **karyoplasm** is a more fluid protoplasm which occupies the interstices of the linin reticulum.

The Nucleoli.—(*a*) The *karyosomes* usually lie in the nodes of the linin reticulum. They stain like chromatin and are probably aggregated nodules of that substance. (*b*) The *plasmosomes* are globules of a form of protoplasm called *plastin,* whose reactions to stains are not the same as those of chromatin. One is usually present, but there may be two or more. They lie in the karyoplasm.

Some nucleoli appear to be compounds of chromatin and plastin, and are therefore called *karyo-plasmosomes.*

The **nuclear membrane** surrounds the nucleus, except at certain periods of cell division, but whether it is formed from the nuclear substance or from the surrounding cytoplasm is uncertain.

The **centrosome** is a small deeply staining spherical body which lies in the cytoplasm, usually in the immediate neighbourhood of the nucleus. In its interior there are usually one or more still more deeply staining particles called **centrioles.**

The cytoplasm in a small area around the centrosome is often visibly different from the remainder of the cell protoplasm, usually clearer. This specialised area is known as the *attraction sphere.*

The **chondriosomes,** which themselves consist of minute particles called *mitochondria,* are believed to play very important parts in the life-history of the cells, but their exact functions are not yet definitely known. They appear as fine rods or filaments which are embedded in the denser parts of the cytoplasm.

Their reactions to some stains are very similar to those of chromatin, but in other respects, especially in their behaviour under the influence of organic acids, such as acetic acid, they differ widely from chromatin.

In addition to the various parts already noted, many cells, at some or all periods of their existence, contain (1) granules of substance formed by the activity of the cytoplasm from materials which it absorbs from its surroundings; (2) vacuoles filled with fluid; (3) granules or masses of lipoid or fatty substance;

and (4) particles or small masses of chromatic substance which have been extruded from the nucleus and which are called *chromidia.*

The various structures mentioned are found in cells, in the positions indicated, in the so-called *resting stage,* which is the period intervening between any two periods of cell division. It is during the resting stage that cells grow and perform the functions deputed to them.

THE LIFE-HISTORY AND CAPABILITIES OF ANIMAL CELLS.

Every animal cell is formed by the division of a pre-existing cell called the *mother cell.* The mother cell divides into two equal parts—the *daughter cells,* each of which, under ordinary conditions, possesses all the capabilities of its mother.

Reproduction of Cells.—Ordinary tissue cells increase in number by the division of the pre-existing cells into equal parts, and each part possesses similar capabilities. Every new cell has a definite life-history; it grows, performs its proper functions, and ceases to exist, either by dividing into two daughter cells, or by dying and breaking up into fragments which disappear.

Whilst the multiplication rate exceeds the death-rate in any given tissue or organ, that tissue or organ grows. When the multiplication rate and the death-rate are equal, the tissue or organ is in a state of equilibrium. As soon as the death-rate exceeds the multiplication rate, decay and atrophy set in; and when the decay and atrophy have proceeded to such an extent that an important tissue or organ can no longer perform its proper functions, general death ensues.

General decay and death are, therefore, the natural results of the loss of multiplication power of the cells of the body, but life may persist after multiplication power is lost, so long as the cells last produced retain their capabilities, and death may result whilst multiplication power of the cells is retained, if the newly produced cells are incapable of performing their proper functions. Nevertheless, speaking generally, it may be said that cell multiplication is a vital necessity, and it takes place in two ways—(1) by **amitotic** and (2) by **mitotic division** of pre-existing cells.

Amitotic Division.—The phenomena of amitotic division of cells are much simpler, so far as they are known, than those of mitotic division. First the nucleus is divided by an advancing constriction; thereafter, the cell body is constricted and divided, and so two similar daughter cells are formed.

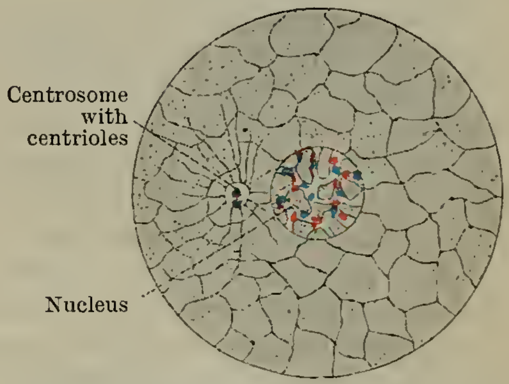

Fig. 3.—Schema of Animal Cell in Resting Stage.

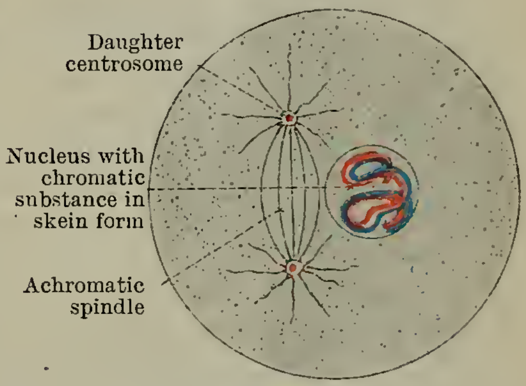

Fig. 4.—Schema of Animal Cell in Early Part of Prophase of Homotype Mitosis.

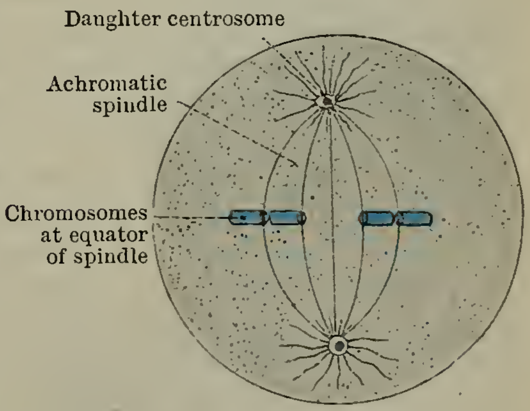

Fig. 5.—Schema of Animal Cell at Completion of Prophase of Homotype Mitosis.

Whether the daughter cells produced by amitotic division can live and in their turn divide by amitotic or mitotic division is not known, therefore it is uncertain whether or not the process of amitosis is degenerative or formative. At all events, so far as information is at present available, the process of amitosis is relatively unimportant as compared with that of mitosis.

Mitotic Division.—Mitosis or mitotic division is the more common, the more important and the more complicated method of cell division.

There are, however, two forms of mitosis, *homotype* and *heterotype.* Of the two homotype mitosis is so much the more common that it may be regarded as the usual form, for heterotype mitosis, which is also known as *meiosis,* is limited to one of the two cell divisions which occur during the maturation of the germ cells, though it is said to have been met with in the cell divisions which occur during the growth of some malignant tumours.

Homotype Mitosis. — The phenomena of homotype mitosis occur in four phases termed (1) the prophase, (2) the metaphase, (3) the anaphase, and (4) the telophase.

The Prophase.—During the prophase the centrosome and the nucleus undergo very obvious changes.

The centrosome divides into two daughter centrosomes, of which one passes to one and the other to the opposite side of the nucleus.

At the same time a spindle of achromatic fibrils appears, and extends from one daughter centrosome to the other.

In some cases the achromatic spindle is formed entirely outside the nucleus (Fig. 4); but, more often, it passes through the nucleus and is derived from the linin reticulum of the nucleus.

The peripheral fibrils of the spindle are the mantle fibrils, those which form the core of the spindle are the central fibrils.

At the same time fibrils radiate peripherally from the daughter centrosomes into the surrounding cytoplasm, and the whole structure, so formed, the daughter centrosomes, the spindle, and the radiating fibrils constitute, collectively, the *achromatic figure.*

The nuclear transformation, however, affects not only the linin of the nucleus, but also the nucleoli, the nuclear membrane, and the chromatin.

The nucleoli, whether they are karyosomes, or plasmosomes, or both, disappear; sometimes after passing from the nucleus into the cytoplasm, but, more commonly, independently of such migration.

The chromatin, which during the resting period is dispersed in the linin network, in what appears to be an irregular and inconstant manner, is aggregated, at the commencement of the prophase, into small nodules, called *chromomeres,* which are strung together on the linin network to form a series of nodulated filaments which are called **chromosomes.**

The filamentous chromosomes of the early prophase are bent, twisted, and intimately intermingled, so that, for a time, they simulate a convoluted skein (Fig. 4), and, indeed, in some cases the individual filaments are united end to end. Such a condition is, however, but a transitory connection of the individual chromosomes which soon reassert their independence.

Gradually the thread-like chromosomes become shorter until the chromomeres are so compressed together that they are no longer distinguishable from one another.

The process of shortening is called *synizesis.*

When the shortening is completed the chromosomes appear in the form of rods, hooks, or V-shaped bars, of varying size, which are gathered together at the equator of the achromatic spindle, where they form, collectively, the *equatorial plate* of the prophase (Fig. 5). At this period, which is the end of the prophase, each chromosome is attached at some point of its extent to one or more of the mantle fibrils of the achromatic spindle.

At the end of the prophase the nucleus, as such, and the nucleoli have disappeared, and have been replaced by an achromatic spindle with an equatorial plate of chromosomes.

The Metaphase.—During this phase each chromosome divides into two equal daughter chromosomes (Fig. 6).

The division commences at the point where the chromosome is attached to the achromatic spindle and, as it proceeds, it becomes evident that one daughter chromosome is attached by one or more of the mantle fibrils of the achromatic spindle to one centrosome and the other to the opposite centrosome.

When the division is completed the metaphase is ended and two daughter equatorial plates are present.

The division of the chromosomes is often indicated in the prophase by the appearance of fine clear lines which run through the long axes of the chromosomes, but it occurs during the metaphase.

The Anaphase.—In the anaphase the daughter chromosomes of each daughter equatorial plate move along the mantle fibrils of the achromatic spindle towards the corresponding daughter centrosome, and, as they approach the immediate neighbourhood of the daughter centrosome, the body of the cell begins to be divided by a circular constriction, which appears at the level of the equator of the achromatic spindle. The appearance of the constriction indicates the end of the anaphase and the commencement of the telophase (Fig. 7).

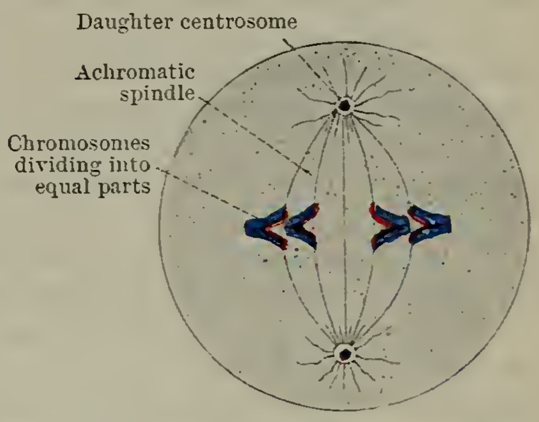

FIG. 6.—SCHEMA OF ANIMAL CELL IN METAPHASE OF HOMOTYPE MITOSIS.

The Telophase.—In this terminal period of mitotic cell division the circular constriction of the cell body deepens until the cell is divided into two daughter cells.

As the division of the cell body proceeds the constituent parts of the daughter chromosomes become dispersed along a linin network which is formed in the immediate neighbourhood of the corresponding daughter centrosome. A nuclear membrane appears around the linin network and nucleoli appear in the meshes of the network. Thus a new daughter nucleus is formed in each daughter cell, and as the daughter nucleus is evolved the portions of the achromatic figure external to it disappear.

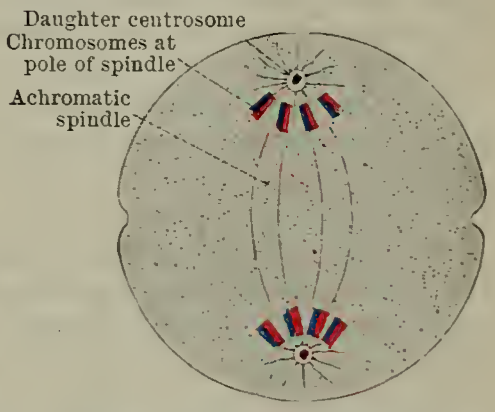

FIG. 7.—SCHEMA OF ANIMAL CELL AT END OF ANAPHASE OF HOMOTYPE MITOSIS.

The result of mitotic division, therefore, is the formation of two daughter cells from a mother cell, each daughter cell having the same constituent parts, and the same number of chromosomes in its nucleus as the mother cell from which it was derived, but it is necessarily smaller than the mother cell (Fig. 8).

The Resting Stage.—During the resting stage, which lasts for a variable time, the daughter cells grow until they attain the adult size and they perform the function of the group of cells to which they belong.

The capability of cells to perform functions depends upon the availability of proper nutriment, warmth, and moisture, their chromatin contents, their relative positions in the body of which they form a part, and the provision of means whereby the products of the cell activity can be removed.

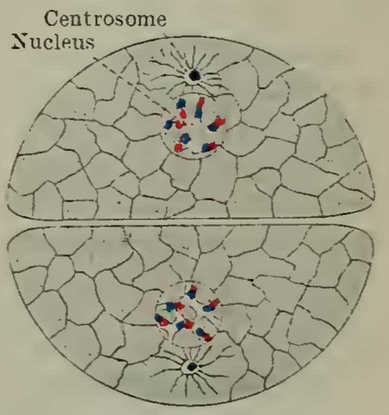

FIG. 8.—SCHEMA OF ANIMAL CELL AT END OF TELOPHASE OF HOMOTYPE MITOSIS. The cell has divided into two daughter cells. Red and blue indicate the original paternal and maternal derivatives.

As the chromosomes of the mother cells are split longitudinally, during homotype mitosis, each daughter cell receives exactly the same number of chromosomes and presumably the same number of chromomeres as the mother cell from which it was derived, and in the case of cells in fully differentiated tissues it seems probable that the chromosomes carry with them the same possibilities for functional capability that the mother cell possessed. This, however, cannot always be the case in the early stages of development, before the different tissues of the body are differentiated from one another, for in those stages some of the daughter cells of a group of mother cells take part in the formation of one, and others in the formation of other tissues which ultimately perform quite different functions. It must be assumed, therefore, that whilst the number of the chromosomes in the various daughter cells is the same, the qualities of their chromomeres may be different.

The Period of Cell Life.—The period of cell life varies, but in all cases it ultimately ends in death; for a time comes when cells no longer transmit to their descendants the power of division, or the capability of growth and function. If it were not so, growth and function, or at least maintenance and function, would continue uninterruptedly, and, in the absence of accident or disease, individual life would continue for ever, and " old age " would be unknown.

It appears, therefore, that the ancestors of certain tissue cells are capable of producing only a certain number of descendants, which grow to the normal size and perform their proper functions for a more or less fixed period, whilst in other cases the power of division appears to be transmitted continuously, but the more remote descendants become less and less capable of performing their proper functions. The result in both cases is the same: gradual decay, terminating in death.

No individual cell has an indefinite period of life, but there are certain cells, called germ cells, upon which the continuance of life depends.

Germ cells are of two kinds: female germ cells or oocytes, which lie in the ovaries, which are the genital glands of females, and male germ cells or sperm cells, which are formed in the testicles, which are the genital glands of males.

The primitive female and male germ cells undergo many mitotic divisions, resulting in the formation of numerous descendants, but a time eventually comes when each of the numerous descendants of the primitive germ cells is only capable of producing four more descendants, by means of two final divisions which are spoken of as the maturation divisions of the germ cells.

In the case of the female germ cells the final descendants are one relatively large cell, called the *mature oocyte,* and three much smaller cells which are known as *polar bodies.*

The final descendants of each male germ cell are four *spermatozoa.*

The three polar bodies always die, and each mature ovum and spermatozoon also dies, unless it meets and unites with a mature germ cell of the opposite sex to form a new cell called a **zygote.**

The zygote formed by the union of a mature ovum with a spermatozoon is a rejuvenated cell, and there are produced from it, by numerous mitotic divisions, a multitude of descendants, some of which become germ cells, and repeat the history already noted, whilst others, called somatic cells, form the tissues of a new individual in which the germ cells are lodged.

How the period of life of somatic cells is fixed is not known, but there are reasons for believing that it is fixed at the moment the zygote is formed, with the result that some of the new individuals, or offsprings, formed from different zygotes die before they are born, and others live to periods which vary from a few minutes to one hundred or more years after birth.

Eventually, however, all die, some being killed by accident, others by micro-organic attacks, but many because they are unable to live any longer in spite of the aid of physicians and surgeons, who, at most, can only prolong slightly the period of life originally fixed by nature.

Heterotype Mitosis or **Meiosis.**—The number of chromosomes in the somatic and primitive germ cells of different groups of living creatures varies, so far as is known, from two to two hundred and eight, but the number in the cells of any given group is always the same, and it is believed that they are arranged in pairs, called *homologous chromosomes,* one member of each pair being derived from the previous male parent and the other from the previous female parent.

In one of the last divisions of the descendants of the germ cells, the so-called maturation divisions, the homologous chromosomes are separated, one of them going to one and the other to the other daughter cell, and the process by which this result is attained is called heterotype mitosis or meiosis.

In mammals, including human beings, meiosis occurs in the first of the two maturation divisions.

During the early prophase the homologous chromosomes approach one another and join together side by side (Fig. 16) forming *diploid* or twin chromosomes, the process of junction being called *syndesis*. Thus the apparent number of chromosomes is reduced to half the original number of the so-called *haploid chromosomes*, which are the ordinary chromosomes present in somatic and non-maturing germ cells.

At the end of the prophase of the meiotic division the diploid chromosomes are assembled at the equator of the achromatic spindle where they are attached to the mantle fibrils (see p. 17).

When the metaphase commences the homologous chromosomes separate from one another and, during the anaphase, they pass to the opposite ends of the achromatic spindle; therefore, when the cell divides, in the telophase, one daughter cell contains one group of haploid chromosomes which are the homologues of the haploid chromosomes in the other daughter cell, and each daughter cell has only half the number of haploid chromosomes which were present in the mother cell.

In other words, the meiotic division is a reduction division by means of which homologous chromosomes are separated from one another, with the result that the mother's inheritance of homologous chromosomes is equally divided between the two daughter cells.

It is known that a cell which contains only half the typical number of chromosomes can divide once, therefore from each original cell which underwent heterotype mitosis four grand-daughter cells may be produced. It is still uncertain, however, whether or not cells which contain only half the typical number of chromosomes can further subdivide, or whether they can continue to live and function. So far as the observations made can be relied upon, it appears that such cells either die or they unite with another cell containing half the typical number of chromosomes to produce a new cell which contains the typical number of chromosomes and which possesses also the capability of reproducing itself by division.

The Gametes.—Gametes are cells by means of which life and hereditary characteristics are transmitted from one generation to another.

They are derived from cells called primitive germ cells, whose origin will be considered in association with the development of the cells of the zygote (see p. 25).

They are of two kinds: female gametes or mature oocytes, and male gametes or spermatozoa.

Each form has its own special characteristics, but they are both peculiar cells, inasmuch as each possesses only half the chromosome inheritance of its parent; moreover each is incapable, under ordinary circumstances, of undergoing ordinary cell division, and must either die or unite with a gamete of the opposite sex to produce a new rejuvenated cell called a zygote.

As the result of the union of the chromosome inheritance of the two gametes the zygote possesses the same number of homologous chromosomes as the parent of each gamete possessed, and it is capable of undergoing repeated divisions of its substance, by means of which large numbers of cells are formed and from them a new individual is evolved. The new individual is similar in all essential respects to the two individuals from which the gametes whose union produced the zygote were derived; that is, it is similar in all essential respects to its parents, using the term parent in its ordinary sense.

The germ cells, from which the gametes are evolved, pass through their developmental stages in special sex glands, the female germ cells in the ovaries of females, and the male germ cells in the testicles of males.

After the descendants of the primitive germ cells have increased, by homotype mitosis, to a number which is probably fixed and unchangeable, but which is not definitely known, they begin to increase in size, that is, they enter upon a period of growth. At that time the female germ cells are called **oocytes of the first order**, oocytes I, and the male germ cells are called **spermatocytes of the first order**, spermatocytes I. Both the oocytes I and the spermatocytes I possess all the essential parts of a typical animal cell, and, in addition, each has special peculiarities which differentiate it both from the germ cells of the opposite sex and also from ordinary animal cells. Therefore the oocyte and the spermatocyte must be considered separately; but before this is done it must again be noted that each oocyte I and each spermatocyte I is capable of producing only four descendants. The mitotic cell divisions by which the descendants are produced are called the

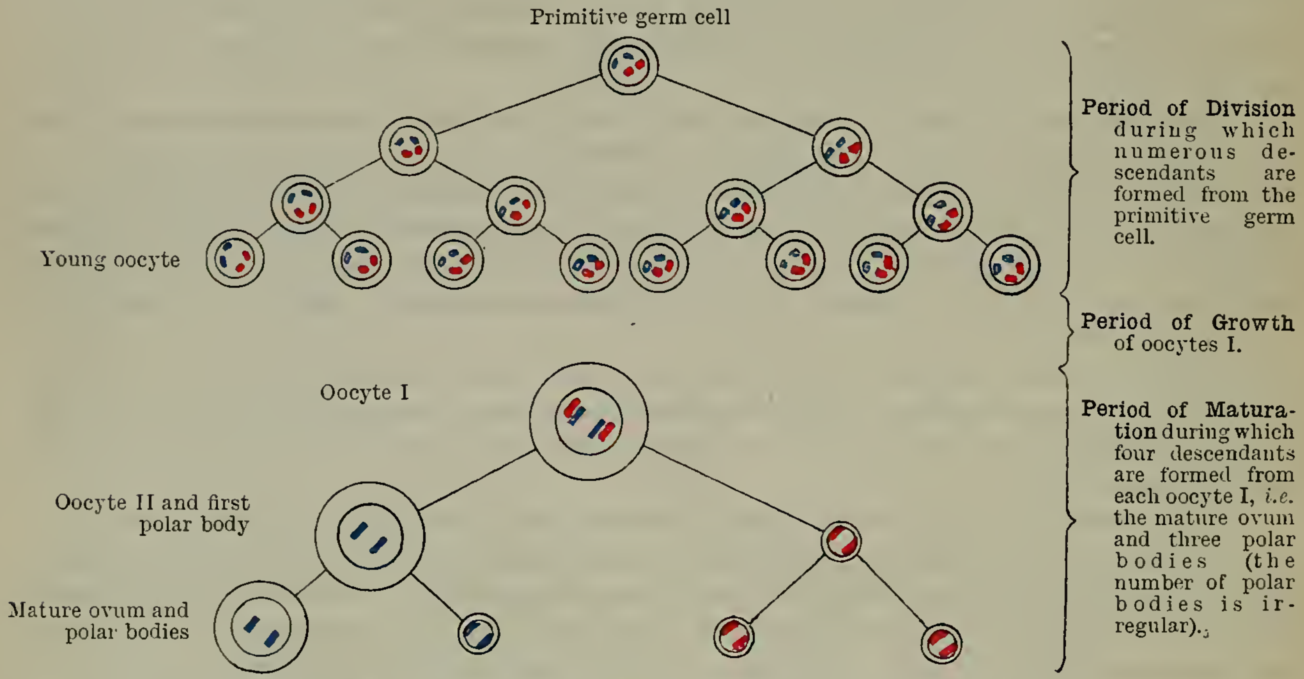
Primitive germ cell
Young oocyte
Oocyte I
Oocyte II and first polar body
Mature ovum and polar bodies
Period of Division during which numerous descendants are formed from the primitive germ cell.
Period of Growth of oocytes I.
Period of Maturation during which four descendants are formed from each oocyte I, i.e. the mature ovum and three polar bodies (the number of polar bodies is irregular).

Fig. 9.—Schema of the Developmental History of the Mature Ovum.

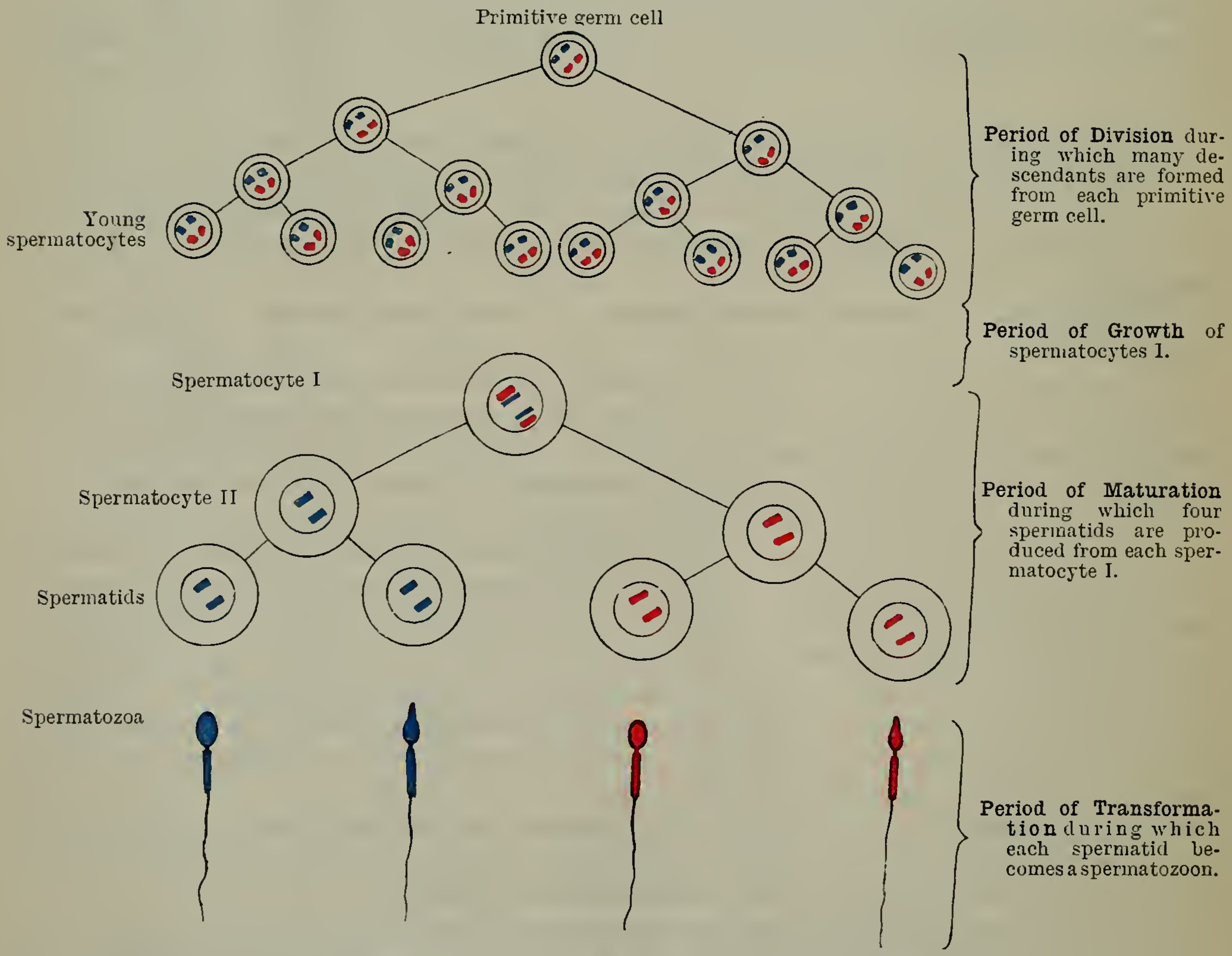
Primitive germ cell
Young spermatocytes
Spermatocyte I
Spermatocyte II
Spermatids
Spermatozoa
Period of Division during which many descendants are formed from each primitive germ cell.
Period of Growth of spermatocytes I.
Period of Maturation during which four spermatids are produced from each spermatocyte I.
Period of Transformation during which each spermatid becomes a spermatozoon.

Fig. 10.—Schema of the Developmental History of Spermatozoa.

maturation divisions, and they result, in the case of the oocyte, in the formation of one large functional cell—the **mature oocyte**, and three small impotent cells—the **polar bodies**; whilst in the case of the spermatocyte the four descendants are of equal size and each becomes transformed into a presumably potent **spermatozoon**.

THE OVUM.

When each oocyte I commences its growth it lies in the cortical part of the ovary, surrounded by a single layer of cells which are known collectively as the membrana granulosa (Fig. 11), and the oocyte and the membrana granulosa constitute, together, a **primary ovarian follicle** (O.T. Graafian Follicle).

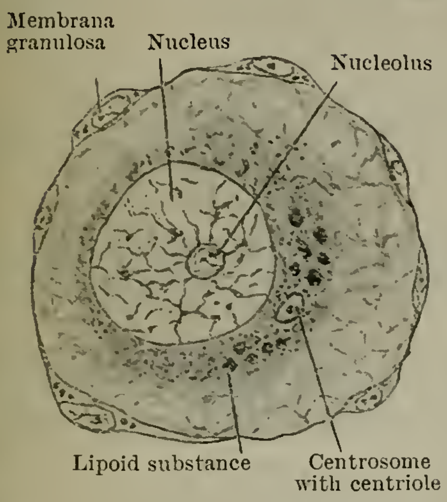

FIG. 11.—A HUMAN OOCYTE AT THE BEGINNING OF THE GROWTH PERIOD. Oocyte 38 μ × 33 μ. The small black granules in the granulosa cells are lipoid granules.

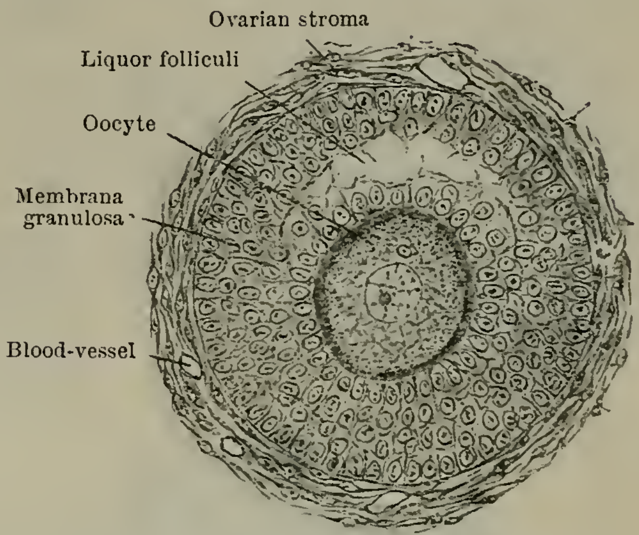

FIG. 12.—A HUMAN OVARIAN FOLLICLE AT THE COMMENCEMENT OF THE VESICULAR STAGE. Diameter of follicle 155 μ × 155 μ × 120 μ.

As growth proceeds the oocyte increases in size until it attains a diameter of from 100 μ to 200 μ and so becomes a relatively large cell.

During the growth period changes occur in both the surroundings and in the contents of the oocyte.

The changes in the surroundings include increase in number of the cells of the membrana granulosa, changes in their form, subdivision of them into two groups by the appearance of a cavity amidst them, and the formation of a new envelope, called the *oolemma*, around the oocyte.

The first membrana granulosa cells which are flat plates become cubical, then they increase in number, by homotype mitosis, until they form several layers, thereafter a fluid-filled cavity appears amidst the cells, separating them into two multicellular layers, one around the oocyte and the other bounding the periphery of the cavity. The primary ovarian follicle is thus converted into a *vesicular ovarian follicle* (Figs. 12 and 13).

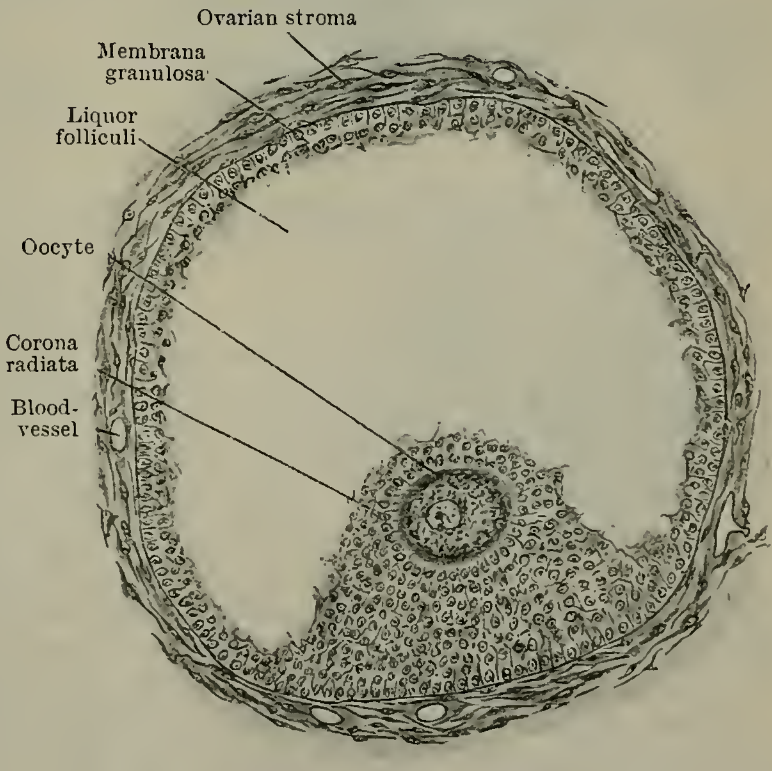

FIG. 13.—A HUMAN VESICULAR OVARIAN FOLLICLE. Diameters of follicle 620 μ × 465 μ × 465 μ.

As the cavity of the vesicular follicle rapidly increases in size the section of the membrana granulosa which surrounds the oocyte, and which is known as the *ovarian cumulus*, becomes widely separated by the liquor folliculi, from the peripheral or boundary part of the membrana, except in a small area where the two parts always remain in continuity; therefore, when the vesicular follicle is fully developed, the ovarian cumulus with the contained oocyte and its oolemma projects from the wall into the cavity of the follicle (Fig. 13).

The oolemma begins to appear around the oocyte as soon as the membrana cells have formed two layers, and it increases in thickness until the maturation of the oocyte commences, when it is an elastic pellucid membrane (zona pellucida), sometimes faintly striated (zona striata), varying from 7 μ to 10 μ in thickness.

The oolemma is probably formed by the cells of the membrana granulosa, and it appears to be traversed by processes of the immediately adjacent membrana cells, which gradually assume an elongated columnar form constituting the *corona radiata* (Figs. 14 and 23).

It is the fine prolongations of the corona radiata cells, passing through the oolemma to the surface of the oocyte, which give rise to the striated appearance which has already been noted.

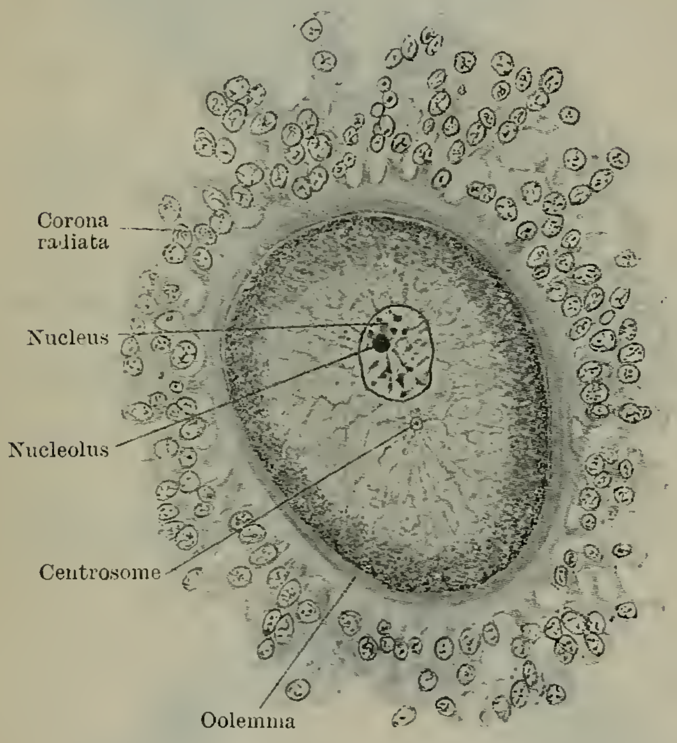

Fig. 14.—A Human Oocyte near the End of the Growth Period. Diameter of oocyte exclusive of oolemma 140 $\mu \times 110 \mu \times 84 \mu$. Average thickness of oolemma 5 μ.

The changes which take place in the oocyte itself during the growth period concern the contents of the cytoplasm, and the position and relative size of the nucleus.

At the commencement of the growth period oocyte I is an approximately spherical cell, but it soon becomes ovoid and it retains its ovoid form in all subsequent periods.

It consists of a cell body, in which lies a relatively large excentrically placed nucleus and a centrosome. The centrosome lies near the central pole of the nucleus and contains one or two centrioles (Fig. 11).

The nucleus possesses one or two karyo-plasmatic nucleoli (see p. 8), and its chromatic substance is dispersed through the linin reticulum.

Vitelline substance or deutoplasm is already present in the oocyte; it lies in the cytoplasm, around the nucleus, and it is most abundant at the central pole of the nucleus around the centrosome (Fig. 11).

As growth proceeds the deutoplasm becomes more diffused, but it is always most abundant in the central part of the cytoplasm, around the nucleus which gradually attains a central position in the oocyte (Fig. 12).

Later, at the termination of the growth period, the nucleus migrates to the periphery of the oocyte, the centrosome disappears, and the process of maturation commences. At this period the nucleus, as contrasted with the oocyte, is relatively smaller than it was at the commencement of the growth period, but it is actually larger than it was at that time. In other words, during the growth period the body of the oocyte grows more rapidly than the nucleus.

When growth is completed, and all the above-mentioned changes have taken place, the full-grown oocyte I lies in the ovarian cumulus of a vesicular ovarian follicle in the cortical part of the ovary, and it consists of a cell body which contains a nucleus, numerous highly refractive granules, called yolk granules, and chondriosomes.

It possesses no proper cell membrane continuous with the cytoplasm, but it is enclosed in a definite sheath, called the oolemma, zona pellucida, or zona striata.

The diameter of the cell body measured along its major axis varies from 100 μ to 200 μ, for full-grown oocytes are not all of the same size, and the diameter of the nucleus is about one-fourth that of the oocyte, that is, it varies from 25 μ to 50 μ.

The mature oocyte differs from a typical cell partly on account of its relatively large size as compared with other animal cells, but mainly because it does not possess a demonstrable centrosome, and also because it is surrounded by a special protective envelope, the oolemma.

The nucleus of the fully grown oocyte is frequently called the germinal vesicle and the nucleolus the germinal spot, whilst the cell body is spoken of as the vitellus or yolk, consequently the cell membrane, which some observers have described, but which does not exist, has been termed the vitelline membrane, therefore the space which sometimes appears between the body of the oocyte and the oolemma is called the *perivitelline space.*

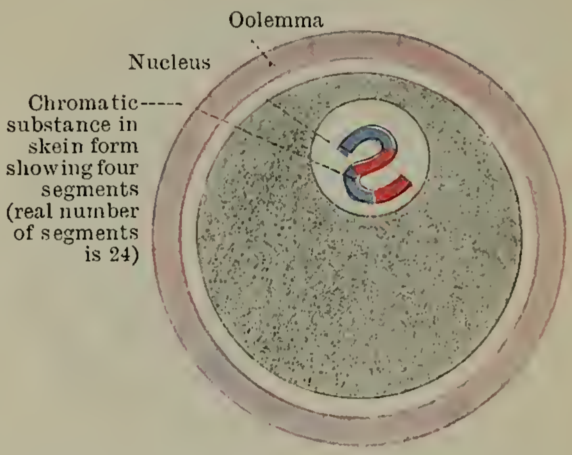
Oolemma
Nucleus
Chromatic substance in skein form showing four segments (real number of segments is 24)

Fig. 15.—Schema of Maturation of Ovum, Early Part of Prophase of First Division.

The amount of deutoplasm or yolk substance in the human ovum is relatively small as contrasted with the amount present in the oocytes of fishes, amphibians, reptiles, and birds. Human oocytes are said, therefore, to be oligolecithal or small yolked; the term telolecithal being applied to oocytes, such as those of the frog, in which the amount of deutoplasm is considerable, whilst the oocytes of birds, of many reptiles, and of monotremes amongst mammals, in which the deutoplasm greatly preponderates over the cytoplasm, are called eutelolecithal.

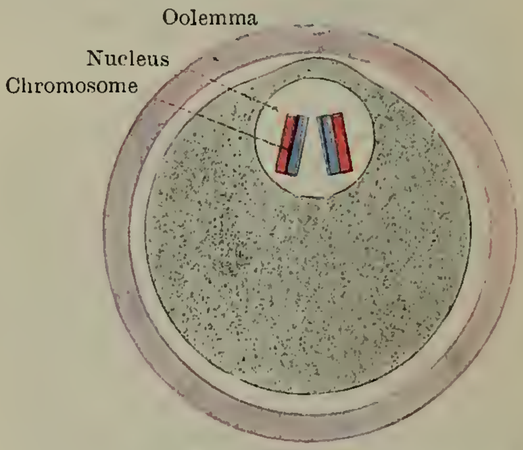

Fig. 16.—Schema of Maturation of Ovum in Prophase of First Division. The chromatic thread has divided into twin chromosomes. Each twin may be assumed to consist of a maternal and a paternal part.

The deutoplasmic granules serve as a store of nutritive material which is utilised during some of the early stages of the growth of the zygote in mammals, and up to the period of birth in many other vertebrates.

The Maturation of the Oocyte.—Maturation is the term applied to the phenomena which occur during the two cell divisions which take place after the full growth of the oocyte is terminated.

We have no thoroughly satisfactory knowledge of the phenomena of maturation in the case of human oocytes and must therefore, at present, presume that they are the same as those which occur and which have been clearly demonstrated in many other mammals.

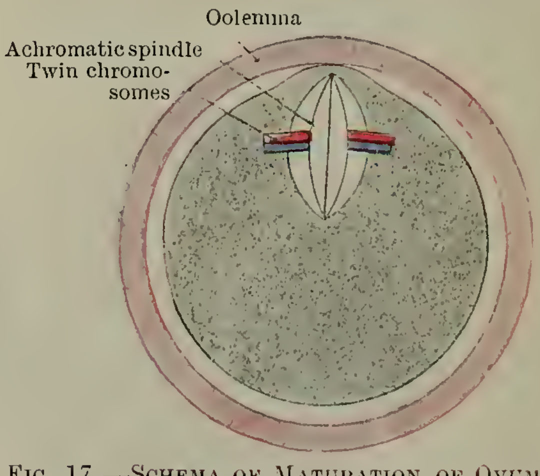

Fig. 17.—Schema of Maturation of Ovum at End of Prophase of First Division. The twin chromosomes lie at the equator of the achromatic spindle.

If that is so then the first of the two divisions is meiotic (see p. 12) or heterotypical. During its progress the nuclear membrane and the nucleolus or nucleoli disappear, and an achromatic spindle appears at one pole of the oocyte, in the situation previously occupied by the nucleus.

The spindle has no centrosomes at its extremities, and, at first, its long axis lies parallel with the surface of the oocyte.

The chromosomes are aggregated together in pairs as twin or diploid chromosomes, they are therefore only half the number of the haploid chromosomes originally present in the oocyte, and, at the end of the prophase, they lie at the periphery of the equator of the spindle. When this condition is attained the spindle rotates on its long axis, and one pole, carrying a little cytoplasm around it, projects beyond the general surface of the oocyte, forming the *first polar projection* (Fig. 19).

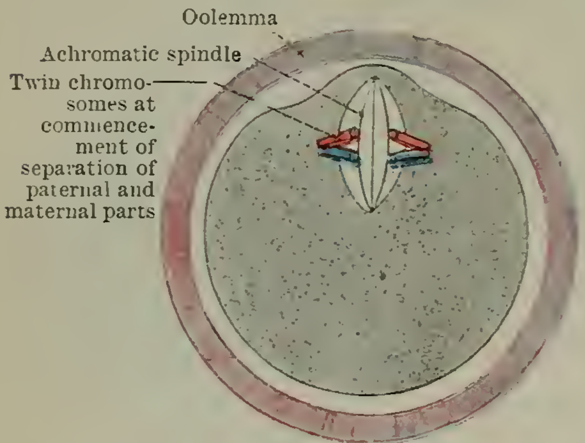
Oolemma
Achromatic spindle
Twin chromosomes at commencement of separation of paternal and maternal parts

Fig. 18.—Schema of Maturation of Ovum in Metaphase of First Division. One pole of the spindle projects into the first polar bud, and the maternal and paternal parts of the chromosomes are separating from each other.

During the metaphase the two halves of each twin chromosome separate from one another, two haploid chromosomes being formed from each diploid chromosome.

In the anaphase the halves of each twin chromosome travel to the opposite poles of the achromatic spindle, therefore those which travel to the peripheral pole enter the first polar projection (Figs. 18, 19).

During the telophase the first polar projection, with its included haploid chromosomes and the peripheral part of the achromatic spindle, is cut off from the main part of the oocyte, and the first maturation division is completed; *oocyte I* being divided into a large segment, *oocyte II*, and a small segment, the first polar body, both of which lie inside the oolemma and each of which contains half the number of haploid chromosomes originally present in oocyte I (Figs. 19, 23).

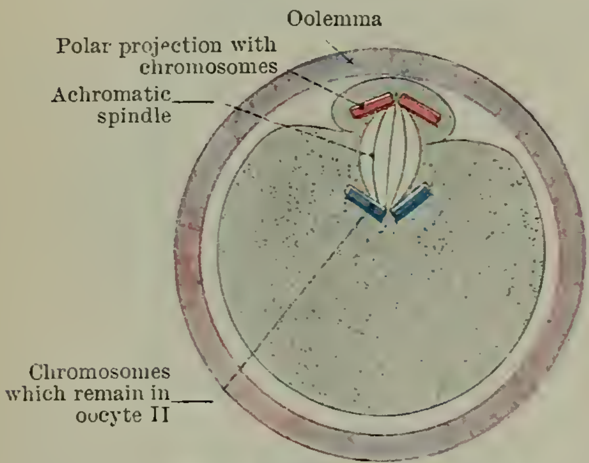
Oolemma
Polar projection with chromosomes
Achromatic spindle
Chromosomes which remain in oocyte II

Fig. 19.—Schema of Maturation of Ovum at End of the Anaphase of the First Division. Two chromosomes (paternal or maternal) lie in the first polar bud and two in the larger part of the ovum which becomes oocyte II.

After the first maturation division is completed a nucleus may appear in the first polar body and a new achromatic spindle is formed in oocyte II. The new achromatic spindle lies at the periphery of oocyte II near the first polar body, and the haploid chromosomes of the oocyte are grouped at its equator (Figs. 20, 24).

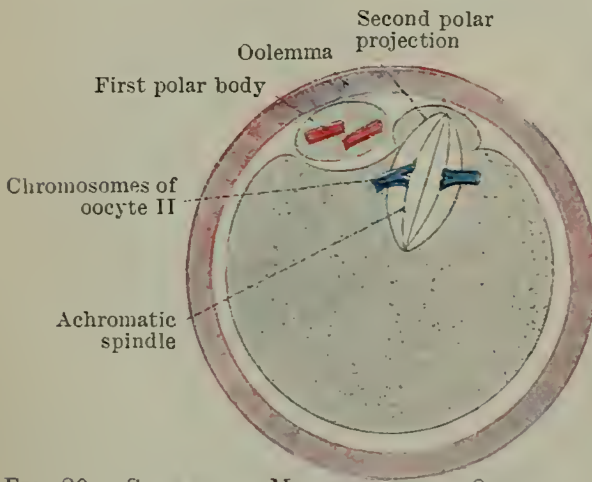

Fig. 20.—Schema of Maturation of Ovum at the Commencement of the Metaphase of the Second Division.

When the condition described is attained the vesicular ovarian follicle ruptures, and the liquor folliculi, carrying with it the oocyte surrounded by its corona radiata of granulosa cells, is forced through the orifice in the surface of the ovary and is swept into the uterine tube.

If oocyte II does not now meet and unite with a spermatozoon to form a zygote it passes through the uterine tube, the uterus, and the vagina and is cast out of the body and dies; but if it meets and is penetrated by a spermatozoon it undergoes a second maturation division.

The phenomena of the second maturation division are those of homotype mitosis; one pole of the achromatic spindle, already present in oocyte II (Fig. 20), projects beyond the general surface of the oocyte carrying with it a small amount of cytoplasm, and so forming the *second polar projection*, thereafter each of the haploid chromosomes at the equator of the achromatic spindle, which it must be remembered are only half as numerous as those originally present in oocyte I, splits longitudinally into equal parts. The opposite halves of the divided chromosomes then travel to the opposite ends of the achromatic spindle, consequently one group enters the second polar projection and the other remains in the body of the oocyte (Fig. 21).

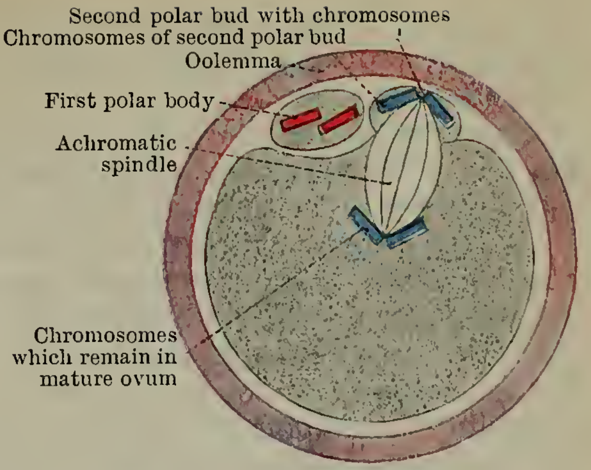
Second polar bud with chromosomes
Chromosomes of second polar bud
Oolemma
First polar body
Achromatic spindle
Chromosomes which remain in mature ovum

Fig. 21.—Schema of Maturation of Ovum at End of Anaphase of Second Division. The chromosomes of oocyte II have separated into equal parts which have passed to the opposite poles of the spindle.

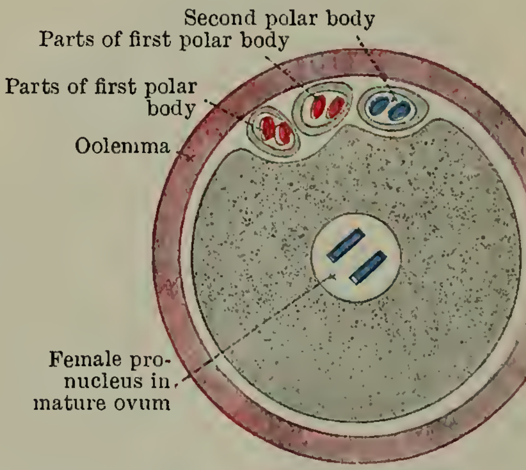
Second polar body
Parts of first polar body
Parts of first polar body
Oolemma
Female pronucleus in mature ovum

Fig. 22.—Schema of Maturation of Ovum. End of Telophase of Second Division where the four descendants of oocyte I are the mature ovum, with half the original number of chromosomes, and three polar bodies.

When the chromosomes reach the ends of the achromatic spindle the second polar projection is cut off from the body of the oocyte to form the *second polar body*. Thus oocyte II is segmented, in the second maturation division, into a smaller part the second polar body, and a larger part the *mature oocyte*, each of which contains half the number of haploid chromosomes which was present in oocyte I.

As soon as the second polar body is separated off a nuclear membrane appears around the chromosomes in the body of the oocyte, a linin reticulum is formed within the membrane, and the particles of the chromosomes are distributed along the reticulum; a nucleolus also is developed, and the new nucleus, thus formed, is called the **female pronucleus**.

As the female pronucleus is evolved the head and body of the spermatozoon already in the oocyte are transformed into a nucleus, the **male pronucleus** and two centrosomes. The male pronucleus naturally contains only half the number of haploid chromosomes which were present in the spermatocyte I from which it descended (p. 14).

When the maturation of the oocyte is completed, therefore, the mature oocyte contains a female pronucleus, a male pronucleus, and two centrosomes.

As the second polar body is separated off the first polar body not uncommonly divides into two parts. When that occurs the result of the two maturation divisions of the oocyte is the formation of three small cells destined to disappear, the three polar bodies, and one large cell, the mature oocyte, all of which are enclosed within the oolemma (Fig. 22).[1]

If the mature oocyte does not meet with a spermatozoon it passes through the genital passages and is cast off and lost; or it breaks down, whilst still in the genital passages, into a detritus which disappears; but if it meets and unites with a spermatozoon a **zygote** is formed, from which a new individual may arise, and in that case the polar bodies persist until

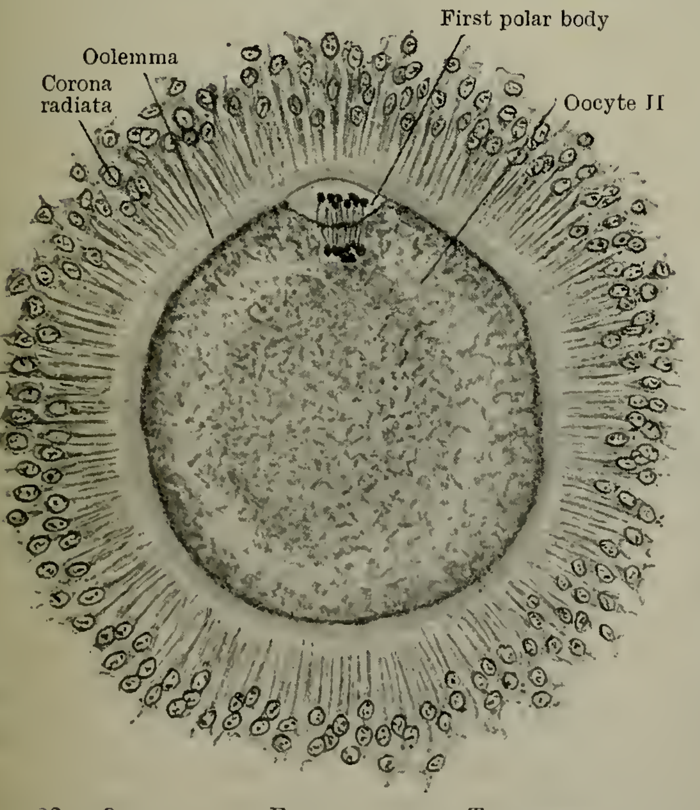

Fig. 23.—Oocyte of a Ferret in the Telophase of the First Maturation Division. Diameter of oocyte exclusive of oolemma, 150 μ × 125 μ × 110 μ.

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[1] Professor Arthur Thomson of Oxford believes that, in the case of the human oocyte, the second maturation division occurs whilst the oocyte is still in the ovary, therefore before it is penetrated by a spermatozoon.

the zygote has undergone one or two divisions; but sooner or later they disappear, probably breaking down into fragments which are absorbed by the cells of the zygote.

Spermatocytes.—When the male germ cells reach the period of growth they are called **spermatocytes of the first order**, or spermatocytes I, which correspond, morphologically, with oocytes I (Fig. 10).

The spermatocytes lie in the walls of the tubules of the testes or male sex glands, where their descendants become converted into spermatozoa.

They differ from the oocytes I in three important respects: (1) they have no protective membrane corresponding with the oolemma of the oocyte; (2) they are not enclosed in follicles; (3) the spermatocytes are not surrounded by definite encircling layers of cells similar to the cells of the stratum granulosum.

As the spermatocytes lie in the walls of the tubules of the testes they are intermingled with other cells, the supporting and nurse cells, amidst which they undergo their maturation divisions, and their descendants become embedded in the nurse cells, where they are converted into spermatozoa. To a certain extent, therefore, the nurse cells may be looked upon as corresponding with the cells of the ovular cumulus which surround the growing oocyte.

After it has reached its full growth each spermatocyte I, like each oocyte I, can produce only four descendants, and the descendants, as in the case of the oocyte I, are formed by two successive mitotic divisions, of which the first is heterotypical and produces reduction of the chromosomes, and the second is homotypical.

The two divisions differ from the corresponding divisions of the oocytes in three important respects: (1) centrosomes are present; (2) the four grand-daughter cells produced are of equal size and presumably of equal value, so far as capability of uniting with a mature ovum to form a zygote is concerned; (3) each of the four grand-daughter cells possesses two centrosomes.

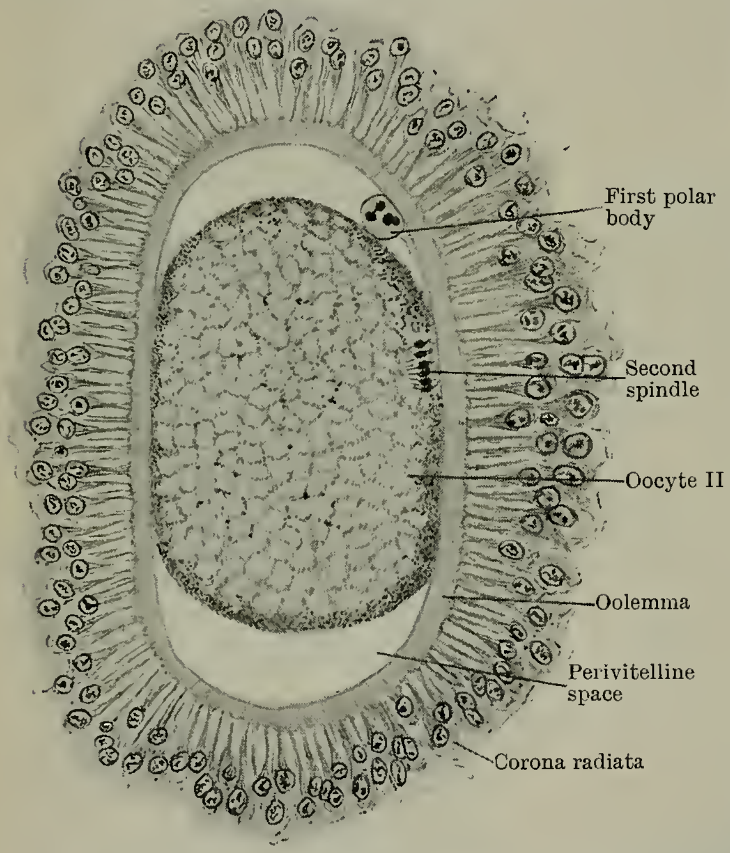

Fig. 24.—Oocyte of a Ferret after Separation of the First Polar Body. Diameters of oocyte exclusive of oolemma, 110 $\mu \times 110 \mu \times 41 \mu$.

In the prophase of the first or heterotype division the nucleus and nucleolus disappear in the ordinary way. The centrosome divides, and an achromatic spindle appears, which has the daughter centrosomes at its poles and half the typical number of chromosomes at its equator. The chromosomes are twin chromosomes. During the metaphase the two segments of each twin chromosome separate from each other. In the anaphase they travel to the opposite poles of the achromatic spindle, and consequently, when the cell divides in the telophase, each daughter cell or **spermatocyte** II contains a centrosome and half the typical number of chromosomes (Fig. 10).

The second maturation division, which takes place without the intervention of a resting stage, is of the homotype form. The centrosome divides, a new achromatic spindle appears, and the daughter chromosomes gather at its equator. In the metaphase the chromosomes divide into equal parts, which travel to the opposite poles of the spindle during the anaphase, and when the telophase is completed the grand-daughter cells, which are called **spermatids**, possess a centrosome and half the typical number of chromosomes (Fig. 10). In the resting stage which follows, the chromatic particles become enclosed in a new-formed nucleus, and the centrosome, if it has not already divided, separates into two parts, one which lies nearer the nucleus and is called the *anterior centrosome,* and another, farther from the nucleus, termed the *posterior centrosome* (Fig. 27). Numerous mitochondria are present, and an indefinite structure, called the accessory body, is also found in the cell protoplasm. A spermatid, therefore, differs from a typical animal cell not only because it possesses the chromatic substance of only half the typical number of chromosomes, but also because it possesses an accessory body and two centrosomes.

From Spermatid to Spermatozoon.—The reader will have noted that the female gametes become mature and ready for conjugation with male gametes directly after the second maturation division is completed. In the case of the male germ cells, however, the spermatids which result from the second maturation division have still to undergo a complicated process of transformation before they become converted to spermatozoa or mature male gametes. The process of transformation takes place in association with the nurse cells in which the developing spermatozoa become embedded.

The details of the process of transformation are difficult to follow, and the knowledge regarding them is still to some extent indefinite. Certain points, however, are well established; but before they are considered it is necessary that the reader should be acquainted with the anatomy of an adult spermatozoon.

THE SPERMATOZOON.

A spermatozoon is a minute organism consisting of a head, a neck, a body, a tail, and an end-piece. Its total length is about 50 μ, that is, its length is about the same as the diameter of the nucleus of the ovum.

The **head** has the form of a laterally compressed ovoid. It is separable into anterior and posterior portions, and the anterior portion is more or less completely covered by a head-cap, which culminates in a sharp ridge. The length of the head is about 4·5 μ.

The **neck** is an extremely short constricted region which intervenes between the head and the body. At its anterior end, where it joins the head, there is a deeply staining **anterior centrosome**, and at its posterior end a similarly deep-staining **posterior centrosome**, from which a deep-staining **axial filament** extends posteriorly through the body and tail into the end-piece (Fig. 26).

The Body.—The body is a little longer than the head, and its constituent parts are: (1) a portion of the axial filament; (2) a portion of the axial sheath; (3) the spiral sheath; (4) the mitochondrial sheath; (5) the end-ring.

The **axial sheath** is a thin layer of protoplasm immediately surrounding the **axial filament.**

The **spiral sheath** consists of a **spiral fibril** embedded in indifferent protoplasm, and the **mitochondrial sheath,** which surrounds the spiral sheath, is formed by protoplasm containing numerous mitochondria.

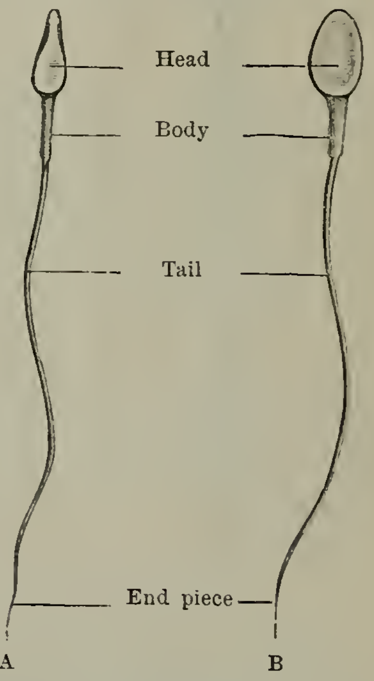

Fig. 25.—Human Spermatozoa (after Retzius).
A, Side view; B, Front view.

The **end-ring** closes the posterior ends of the spiral and mitochondrial sheaths, and it is perforated by the axial filament and its sheath as they pass from the body into the tail.

The **tail** is 28-29 μ long. It consists of prolongations of the axial filament and its sheath, and it ends in the short thin *end-piece.*

The Transformation of the Spermatid into the Spermatozoon.—As the transformation progresses the nucleus of the spermatid becomes the head of the spermatozoon. The axial filament grows out from the posterior centrosome of the spermatid, which divides into two parts, one of which becomes the posterior centrosome of the neck of the spermatozoon, whilst the other becomes the end-ring of the body of the spermatozoon.

The anterior centrosome of the spermatid becomes the anterior centrosome of the neck of the spermatozoon. The cytoplasm of the spermatid forms the axial sheath, the indifferent protoplasm of the spiral sheath and mitochondrial sheath. The origin of the spiral filament and the origin of the head-cap are uncertain, but it is stated that, in some animals, the head-cap is formed from the accessory body, which is not shown in Fig. 27.

The Object of the Reduction of the Chromosomes.—The most striking phenomenon of the process of the maturation of the gametes is the reduction of the chromosomes. The constancy of the reduction tends to emphasise its importance, but, as we have no definite knowledge of the functions of the chromatic substance, the object of the reduction can only be surmised. The evidence which has been accumulated tends to the conclusion that the particles of the chromatic substance are the bearers of hereditary tendencies and capabilities.[1] If this is the case, then they are the means by which ancestral possessions, in the morphological sense, are transmitted from generation to generation. There is evidence also, first ascertained by Mendel and substantiated and increased in recent years by his followers, which lends probability to the belief that the tendency carriers form two main groups: (1) those which carry certain tendencies; (2) those which carry opposite tendencies. The bearers of tendencies and the bearers of their opposites are allelomorphic or alternative to each other, and are called *allelomorphs.* Thus the particles which bear tallness and dwarfness respectively are allelomorphs, that is, they are alternative to each other.

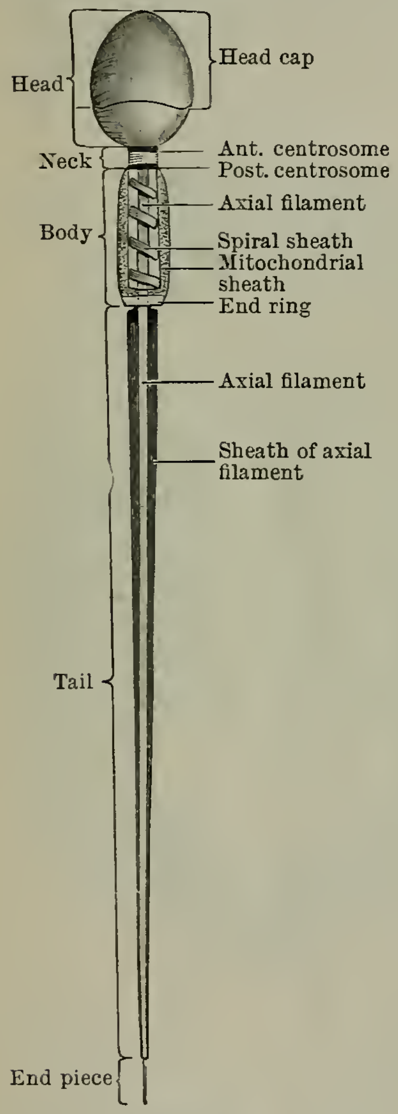

FIG. 26.—STRUCTURE OF A HUMAN SPERMATOZOON (after Meeves).

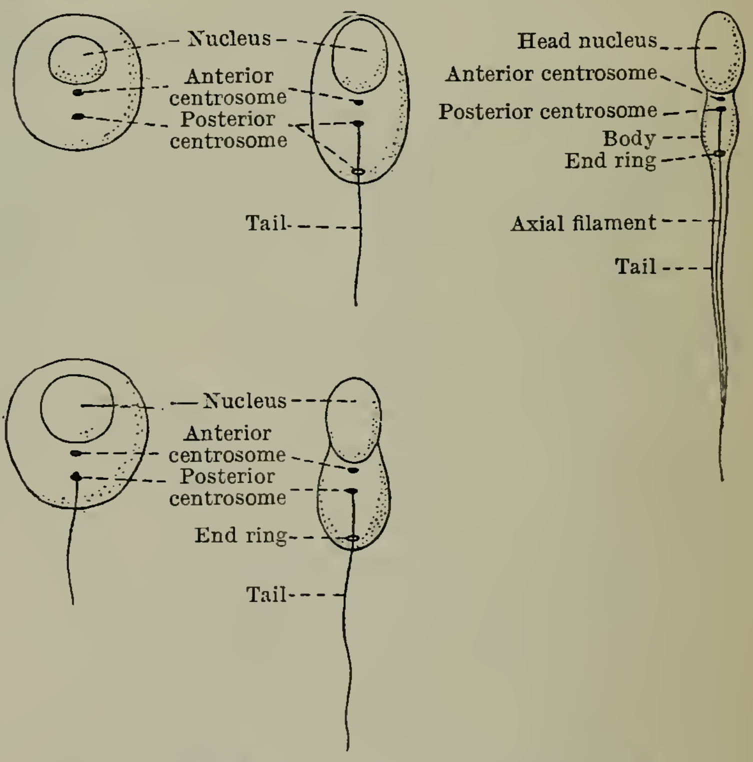

FIG. 27.—SCHEMA OF TRANSFORMATION OF SPERMATID INTO SPERMATOZOON (after Meeves, modified).

Further, the facts which are known suggest the idea that in the primitive germ cells, and their descendants which contain the typical number of chromosomes, the character-bearing particles are arranged in pairs of which both elements may bear the same tendencies, or one may bear one tendency and the other the opposite.

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[1] It must be understood that this function, if it exists, does not prevent the chromatic particles possessing other functions, and that there is no evidence that the potency of a tendency depends upon amount of chromatic substance.

For example, if red and blue be supposed to be opposite tendencies carried by different particles or allelomorphs, then the germ cells of any given animal, male or female, may contain either a pair of red-bearing particles, a pair of blue-bearing particles, or a red- and a blue-bearing particle associated together as a pair.

The reduction of the chromosomes during the maturation divisions of the germ cells is an admitted fact, and it is believed that the reduction is a necessary preliminary to the union of a male and a female gamete to form a zygote from which a new individual may arise. It is assumed that the purpose of the reduction is the segregation of the different tendency bearers from each other in order that they may enter into new combinations. If this assumption is correct, then every mature germ element or gamete contains only one element of any given pair of tendency bearers—in the supposititious case under consideration, either the red or the blue bearer—but not both; and the object of the reducing division is the segregation of the allelomorphs in order that they may enter into new and possibly into different combinations, producing new and possibly varied results.

If, in the case of any given group of animals, the mature germ cells of some of both sexes contain the blue-bearing particles and others the red-bearing particles, it necessarily follows that three possible results may ensue when impregnation occurs, that is when two mature germ cells unite to form a zygote.

(1) A female gamete bearing red tendency particles may fuse with a male gamete bearing red tendency particles; (2) a female gamete bearing blue tendency particles may meet and fuse with a male gamete bearing blue tendency particles; (3) a female gamete bearing red tendency particles may meet and fuse with a male gamete bearing blue tendency particles. The constitution of the zygotes formed may be stated as follows:—

RR BB RB,

and the character of the individual developed from the zygote will vary according to the combination. If two red tendency bearing gametes meet, the individual will be red; if two blue tendency bearing gametes meet, the individual produced will be blue; but when a gamete bearing red tendency particles unites with a gamete bearing blue tendency particles the individual will be either red or blue or a combination of the two, the result depending upon the relative potency or dominance of the two tendencies.

Further exposition of this interesting subject would be out of place in a text-book of anatomy, but it is of such great importance in association with the transmission of hereditary characteristics and hereditary diseases that every medical student should make himself familiar with its possibilities by consulting the works of Bateson, Punnet, Doncaster, and other writers and observers who are attempting to solve the complicated problems which it presents.

Fertilisation or Syngamy.

The process of union of the male and female gametes to form a zygote is termed fertilisation or syngamy. It commences when a spermatozoon enters an oocyte II but it is not completed until the nuclear elements of the two have united.

The process has not been seen in the human subject but it may be assumed that all its essential features are the same as those which have been found to occur in other mammals. This assumption is the more justifiable because the phenomena of the maturation of the oocyte and fertilisation have been found to take place in the same manner, and to be essentially similar in detail, in several very different groups of mammals.

It has already been pointed out that, after the spermatozoon enters oocyte II the latter divides and becomes the second polar body and the mature oocyte in which a female pronucleus is formed. It has also been noted that the female pronucleus contains half the number of haploid chromosomes which was present in oocyte I before the maturation commenced. As the female pronucleus forms, the head and body of the spermatozoon which lies in the mature oocyte are transformed into two centrosomes and a male pronucleus. The male pronucleus is smaller than the female pronucleus, and it also contains only half the number of haploid chromosomes which was present in the spermatocyte I from which it descended.

As soon as the female and male pronuclei are established they approach each other (Fig. 29), meet, and fuse together to form a single nucleus (Fig. 28), called the *first segmentation nucleus*, which contains the full number of haploid chromosomes, that is, the number which was present in the oocyte I and the spermatocyte I from which the mature oocyte and the spermatozoon were respectively descended.

When fertilisation is completed, therefore, a new structure called a **zygote** is formed. It lies, together with the polar bodies, inside the oolemma, and it consists of a cell body which contains a nucleus, the first segmentation nucleus, and two centrosomes, which lie at opposite poles of the nucleus.

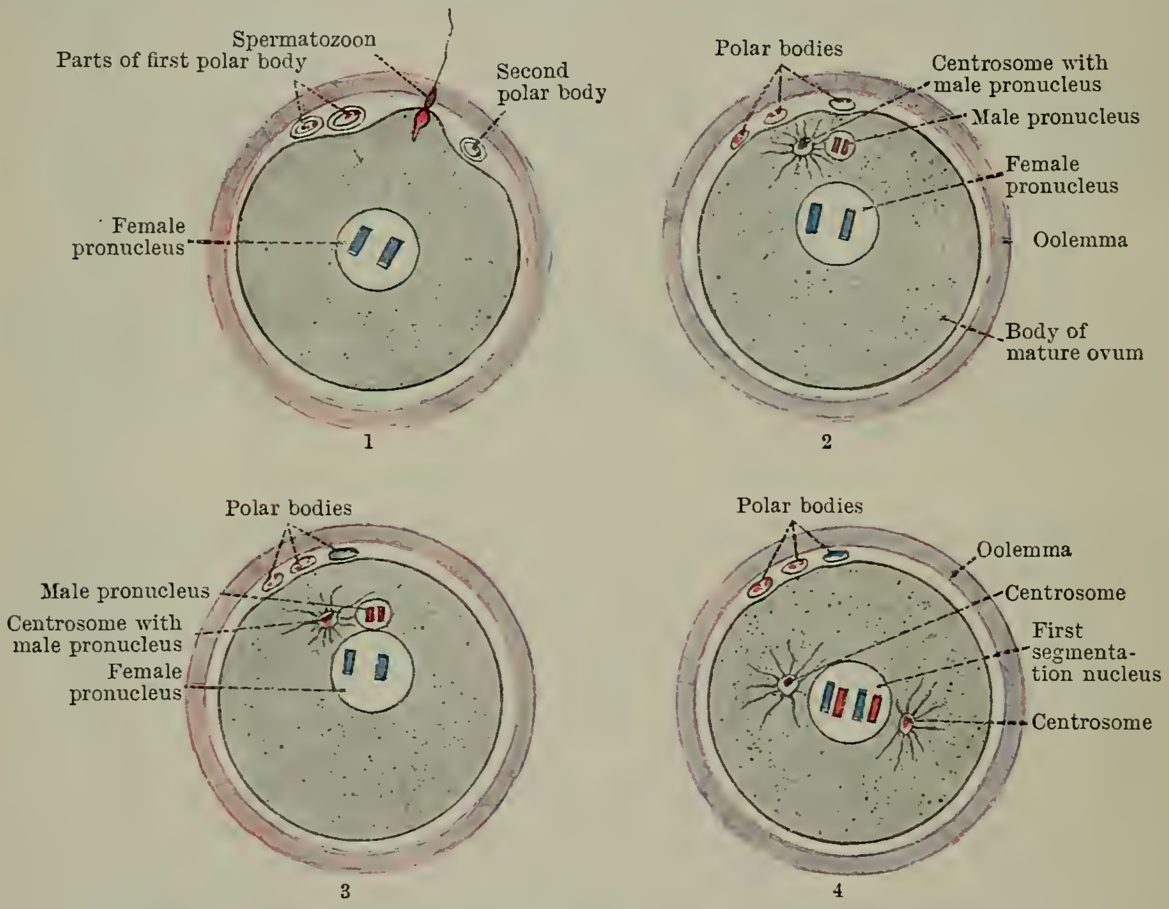

Fig. 28.—Schema of the Fertilisation of the Mature Ovum and the Formation of the Zygote.

The number of chromosomes in the first segmentation nucleus is that typical for the cells of the group of animals to which the zygote belongs, half of them being derived from the female and half from the male ancestor of the zygote.

The only essential difference in appearance between an oocyte I and a zygote is the presence of two centrosomes in the zygote, but oocyte I is a cell almost at the end of its life period, and with the hope of producing only one capable descendant whose chances of life are small, whilst the zygote is a rejuvenated cell with great possibilities, for it is endowed with the potentialities of its parents and is capable of producing a new individual.

The Determination of Sex.

Sex is determined at the time of the union of the gametes and it is dependent upon the absence or presence of a special chromosome or group of chromosomes called sex chromosomes.

The evidence upon which the above assertion rests is quite definite in the cases of many invertebrates, but it is less certain in the case of some vertebrates. Moreover, it is known that, in the cases of certain animals, sex can be controlled by external factors acting upon the oocyte and upon the zygote, and by alterations of the environment of the zygote; nevertheless, when a sex chromosome is present, it is the dominant factor in the production of sex.

In some forms the presence of a sex chromosome in the zygote results in the production of a male offspring, in others in the production of a female offspring. In the human subject it is believed that it determines the female sex and that it passes into the zygote with the spermatozoon.

According to Winiwarter, each human oocyte I has 48 chromosomes and each spermatocyte I 47 chromosomes, therefore each mature oocyte has 24 chromosomes, but some spermatozoa have 24 and others 23 chromosomes. The 24th chromosome of a spermatozoon is the sex chromosome, and when a spermatozoon carrying 24 chromosomes unites with a mature oocyte the zygote formed will possess 48 chromosomes, and the offspring developed from it will be a female, whilst the zygote formed by the union of a mature oocyte and a spermatozoon carrying only 23 chromosomes will only possess 47 chromosomes and the offspring which arises from it will be a male.

In the earliest periods of its life the sex of the offspring cannot be told, but whilst it is still an embryo (see p. 7) it becomes quite evidently either a male or a female.

SEGMENTATION.

Immediately after its formation the zygote is separated, by a series of consecutive mitotic divisions, into a large number of cells which are grouped together in the form of a solid spherical mass, called a **morula** on account of the mulberry-like appearance of its surface. This period of division is called the period of segmentation (Figs. 30-33).

The segmentation divisions are of the homotype form, and there is evidence which tends to the conclusion that the earliest divisions, by which the zygote is divided first into two and then into four parts, are quantitatively and qualitatively equal. After a time, however, the divisions result in the formation of cells of different sizes and different capabilities, definite and circumscribed functions being allocated to certain groups of cells and their descendants. It is probable that at this time cells are set apart which are the progenitors of the germ cells of the next generation, and which therefore retain all the capabilities of their ancestors. These cells are the means by which the species is reproduced and the hereditary tendencies are transmitted from generation to generation. At the same time other cells are set apart for the production of the tissues and organs of the individual which will be produced from the zygote, and in which the germ cells and their descendants will be lodged and protected till they attain their maturity.

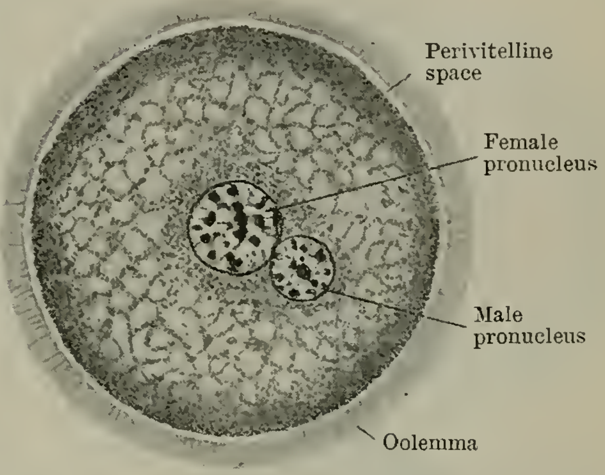

FIG. 29.—ZYGOTE OF A FERRET JUST BEFORE THE FUSION OF THE PRONUCLEI. Diameters of zygote exclusive of oolemma, 100 $\mu \times 93 \mu \times 90 \mu$.

The morula is formed inside the oolemma and as the cell divisions which produce it proceed, but before they are completed, the polar bodies disappear.

After the morula is established one of the first definite changes which occur in its constitution is the differentiation of its cells into an outer layer and an inner mass (Fig. 32).

In the human subject, as in many other mammals, the cells of the outer layer constitute the **trophoblast** or trophoblastic ectoderm, which plays a most important part in the nutrition of the embryo and fœtus. It enters into the formation of the **chorion**, or outermost envelope of the growing zygote, which is subsequently differentiated into a placental and a non-placental portion and which serves, in the first instance, as both a protective and a nutritive covering.

In many mammals the cells of the inner mass soon separate into two main groups, the ecto-mesoderm and the entoderm; but it appears probable that, in the human subject, they differentiate into three groups, **ecto-mesoderm, primary mesoderm**, and **entoderm.**

In the majority of mammals, immediately before, or as the differentiation of the inner mass occurs, a cavity appears in the zygote. The cavity is called the **segmentation cavity**, and as soon as it appears the morula is converted into a **blastula**. The segmentation cavity enlarges until it separates the inner mass from the outer layer, except at one pole of the zygote, where the inner mass and the outer layer remain in contact. It appears, however, from the evidence available, that a segmentation cavity is not formed in the human zygote. Instead the primary mesoderm proliferates and extends until it separates the remainder of the inner mass, that is the amniotic ectoderm, the ecto-mesoderm, and the entoderm from the outer layer or trophoblast, and, simultaneously, cavities appear in the ectodermal and entodermal masses of cells. Thus the human morula becomes a blastula (Fig. 35).

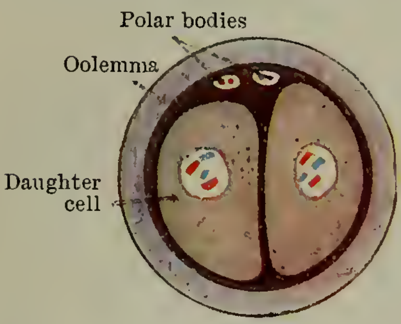

Fig. 30.—Segmentation of Zygote. 2-Cell Stage.

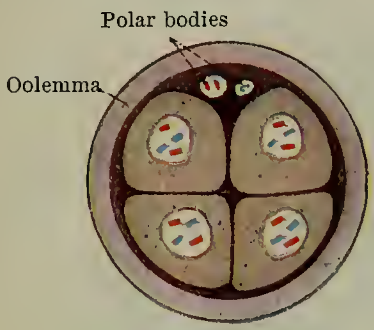

Fig. 31.—Segmentation of Zygote. 4-Cell Stage.

When the above-mentioned changes have occurred the zygote consists of three spheres, one large and two small. The large sphere is bounded by the trophoblast; it contains the two small spheres and the jelly-like mass of primary mesoderm derived from the primary mesoderm segment of the inner mass (Fig. 35).

The two small vesicles lie ex-centrically in the interior of the larger vesicle. The larger and more external of the two is the ecto-mesodermal vesicle. It is separated from the trophoblast, peripherally, and the entodermal vesicle, centrally, by the surrounding primary mesoderm.

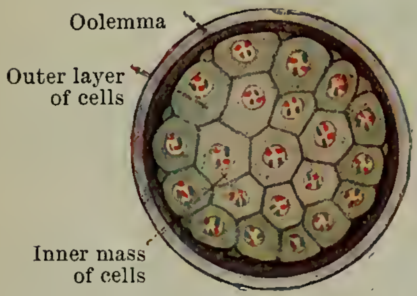

Fig. 32.—Segmentation of Zygote. Morula Stage.

The early appearance of the mesoderm in the zygote and its insinuation at so early a period between the ectoderm and the entoderm are peculiarities limited to the human subject. In most mammals the mesoderm does not appear until the embryonic area and its primitive streak are defined.

The Embryonic Area.—The area where the two inner vesicles lie in apposition with each other is the region of the zygote from which the embryo will be formed; it is called, therefore, the **embryonic area**, and at the time of its definition it consists of three layers, ectoderm, primary mesoderm, and entoderm.

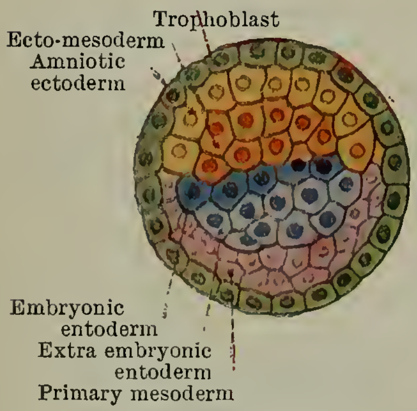

Fig. 33.—Differentiation of Zygote and Cells (Hypothetical).

The remainder of the zygote is utilised for the formation of membranes and appendages necessary for the protection, nutrition, respiration, and excretion of the offspring during the period of intrauterine life.

It is uncertain whether the mesoderm which is present in the area at this period takes part in the formation of the embryo or is replaced at a later period by mesoderm derived from the cells of the ecto-mesodermal vesicle; the latter certainly forms a large part of the mesoderm of the embryo.

The Extra-Embryonic Cœlom.—The extra-embryonic cœlom is a space which appears as two clefts, one on each side of the embryonic area, in the primary mesoderm (Fig. 36). The clefts fuse together round the periphery of the embryonic area, and the single space so formed expands rapidly until the mesoderm which originally filled the greater part of the larger vesicle becomes converted into a thin layer which lines the inner surface of the trophoblast and covers the outer surfaces of the epithelial walls of the extra-embryonic parts of the two inner vesicles (Fig. 38).

The extra-embryonic cœlom does not extend into the embryonic area, and it never completely separates the ecto-mesodermal vesicle from the inner surface of the trophoblast; on the contrary, the primary mesoderm on the outer surface of the ecto-mesodermal vesicle retains its continuity with the mesoderm on the inner surface of the trophoblast until the termination of intrauterine life, and it takes part, as will be seen later, in the formation of the umbilical cord, which connects the fœtus with the placenta (p. 60).

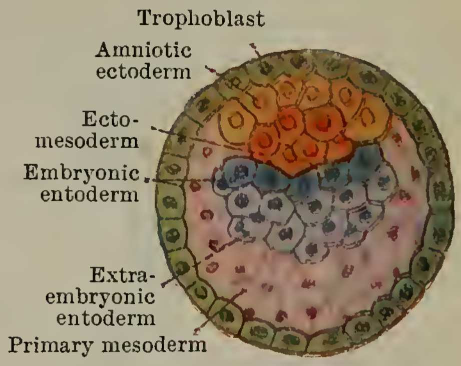

FIG. 34.—FURTHER DIFFERENTIATION OF ZYGOTE (Hypothetical).

The Differentiation of the Embryonic Area.—As the embryonic area is the area of contact between the ecto-mesodermal and the entodermal vesicles it is, at first, circular in outline. As growth continues the area becomes oval, and a linear streak, the **primitive streak**, appears in that part of the oval which becomes the posterior part of the area (Fig. 37).

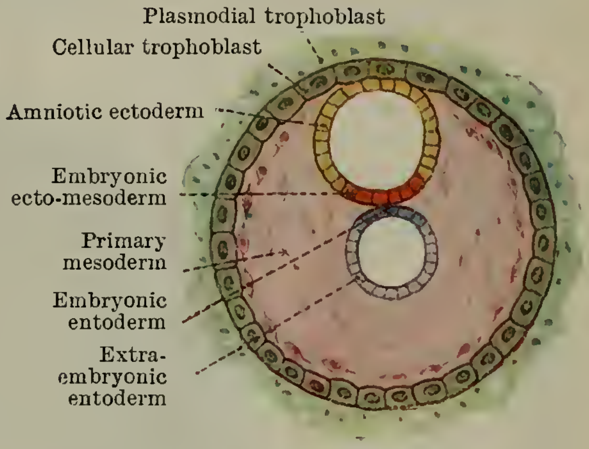

FIG. 35.—SCHEMA OF DIFFERENTIATION OF ZYGOTE (Bryce's Ovum).

At the same time the position of the mesodermal elements of the wall of the ecto-mesodermal vesicle is revealed, for the primitive streak is a thickened ridge of cells which grows from the ecto-mesoderm and projects against the entoderm in the posterior part of the embryonic area, pushing aside the primitive mesoderm which intervened between the adjacent parts of the walls of the ecto-mesodermal and the entodermal vesicles. The deeper cells of the ridge, those next the entoderm, are the mesodermal elements of the primitive ecto-mesoderm, and, by proliferation, they form the larger part, if not the whole, of the embryonic mesoderm and also an organ, called the **notochord.** The mesoderm produced from the primitive streak may be termed the **secondary mesoderm.**

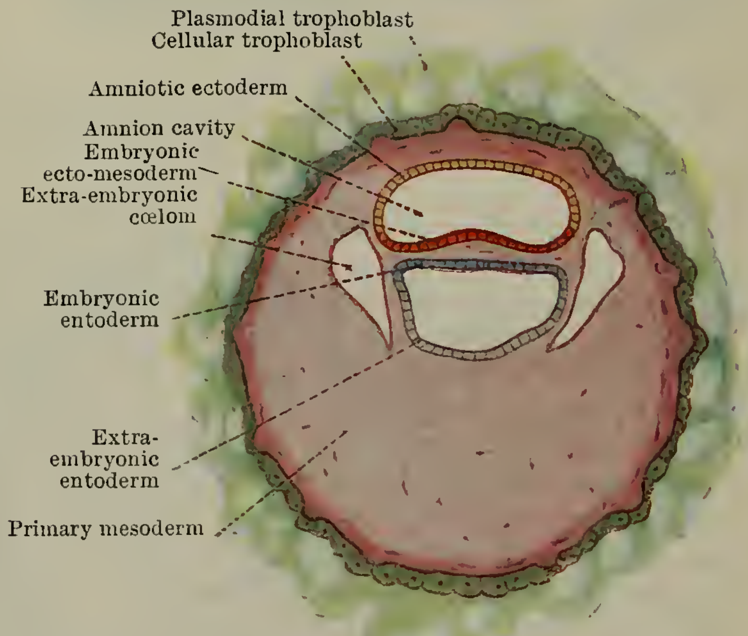

FIG. 36.—SCHEMA OF DIFFERENTIATION OF ZYGOTE (Peter's Ovum).

Immediately after the formation of the primitive streak a groove, the **neural groove**, appears in the anterior part of the embryonic area. It is formed by the longitudinal folding of a thickened plate of ectoderm, the **neural plate**, which is the rudiment of the whole of the central and peripheral portions of the nervous system, except perhaps the olfactory nerves, and the end organs of the sensory nerves. From it also are derived the cells of the primitive sheaths of the nerve-fibres and the chromaffin cells of the supra-renal glands and other chromaffin bodies.

The lateral walls of the neural groove are called the **neural folds.**

Almost from the first the anterior ends of the neural folds are united together a short distance posterior to the anterior end of the embryonic area. Their posterior ends, which remain separate for a time, embrace the anterior part of the primitive streak. In the meantime, however, a groove, the **primitive groove,** has appeared on the surface of the primitive streak. The anterior end of the primitive groove deepens, until it forms a perforation which passes, through the anterior end of the streak and the subjacent entoderm, into the cavity of the entodermal vesicle. As this perforation passes from the floor of the posterior part of the neural groove into that part of the entodermal vesicle which afterwards becomes the primitive enteron or alimentary canal, it is called the **neurenteric canal.** The neurenteric canal is but a transitory passage, and it disappears in man and other mammals before the neural groove is converted into a closed neural tube.

After the appearance of the primitive groove and the neurenteric canal the posterior ends of the neural folds converge, across the anterior part of the primitive streak and groove, and fuse together posterior to the neurenteric canal. The primitive streak is thus divided into two portions. (1) An anterior portion, which lies at first in the floor of the neural groove, and, later, in the floor or ventral wall of the posterior end of the spinal medulla; and (2) a posterior portion, which remains on the surface and takes part in the formation of the median portion of the posterior end of the body, forming the perineum, and the median part of the ventral wall of the body, from the perineum to the umbilicus. It is through the perineal section of the posterior part of the primitive streak that, at a later period of embryonic life, the anal and urogenital orifices of the body are formed.

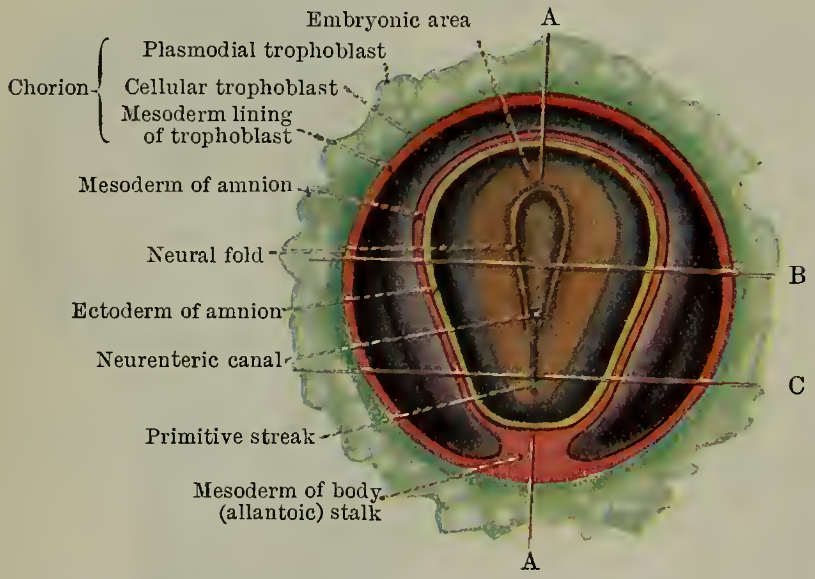

FIG. 37.—SCHEMA OF DORSAL SURFACE OF EMBRYONIC AREA OF ZYGOTE AFTER THE REMOVAL OF PART OF THE CHORION AND PART OF THE AMNION.

The Formation of the Notochord and the Secondary Mesoderm.—The notochord and the secondary mesoderm are formed from the primitive streak; the notochord from its anterior extremity, and the secondary mesoderm from its lateral margins and posterior end.

As soon as the primitive streak is established its anterior end becomes a node or centre of growth by means of which the length and, to a certain extent, the breadth of the body are increased. The portion of the body formed by the activity of the anterior end of the streak is the dorsal portion, from the back part of the roof of the nose, anteriorly, to the posterior end of the trunk. The perineum and the ventral wall of the body, from the perineum to the umbilicus, are formed from the posterior part of the primitive streak. Nevertheless, the primitive streak undergoes little or no increase in length; indeed, as growth continues, it becomes relatively shorter as contrasted with the total length of the embryonic region, for the new material, formed by its borders and its anterior extremity, is transformed into the tissues of the embryo as rapidly as it is created.

The Notochord.—The notochord, or primitive skeletal axis, is formed by the proliferation of cells from the anterior end of the primitive streak. On its first appearance it is a narrow process of cells, the **head process,** which projects forwards from the anterior boundary of the neurenteric canal, between the ectoderm and the entoderm. Shortly after its appearance the head process wedges its way between the entoderm cells, and from that period onwards, as the posterior parts are formed, by continued proliferation from the front end of the primitive streak, they are at once intercalated in the dorsal wall of the entodermal sac, where they remain, forming a part of the dorsal wall of the entodermal cavity (Fig. 39), for a considerable time. At a later period the notochordal cells are excalated from the entoderm, and then they form a cylindrical rod of cells which occupies the median plane, lying between the floor of the ectodermal neural groove and the entodermal roof of the primitive alimentary canal, which, in the meantime, has been more or less moulded off from the dorsal part of the entodermal sac (Fig. 43). For a still longer time the caudal end of the notochord remains connected with the anterior end of the primitive streak, and its cephalic end is continuous with the entoderm of a small portion of the embryonic area; which lies immediately in front of the anterior end of the neural groove and which becomes bilaminar by the disappearance of the primary mesoderm. This region, because it afterwards forms the boundary membrane between the anterior end of the primitive entodermal canal and the primitive buccal cavity or stomatodæum, is called the **bucco-pharyngeal membrane** (Fig. 61, p. 47). It disappears about the third week of embryonic life, and immediately afterwards the anterior end of the notochord separates from the entoderm, but the posterior end remains continuous with the primitive streak, until the formation of the neural tube is completed.

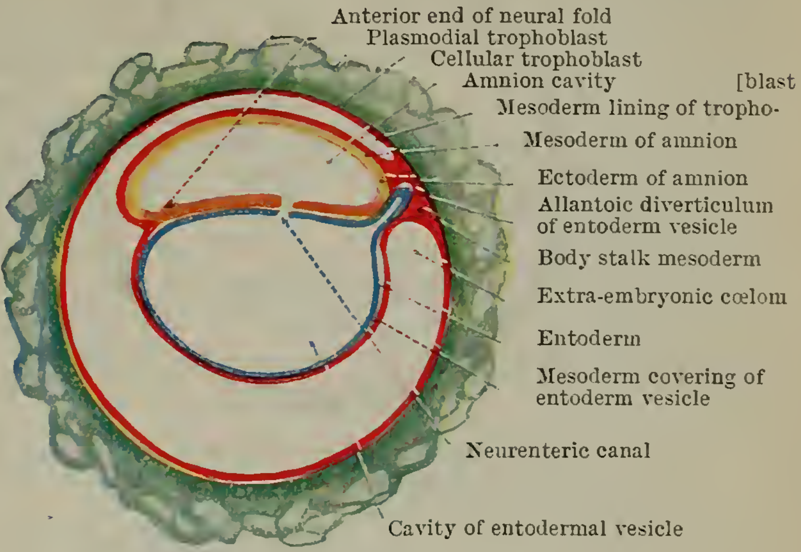
Anterior end of neural fold
Plasmodial trophoblast
Cellular trophoblast
Amnion cavity
Mesoderm lining of trophoblast
Mesoderm of amnion
Ectoderm of amnion
Allantoic diverticulum of entoderm vesicle
Body stalk mesoderm
Extra-embryonic cœlom
Entoderm
Mesoderm covering of entoderm vesicle
Neurenteric canal
Cavity of entodermal vesicle

FIG. 38.—SCHEMA OF SAGITTAL SECTION OF ZYGOTE ALONG LINE A IN FIG. 37.

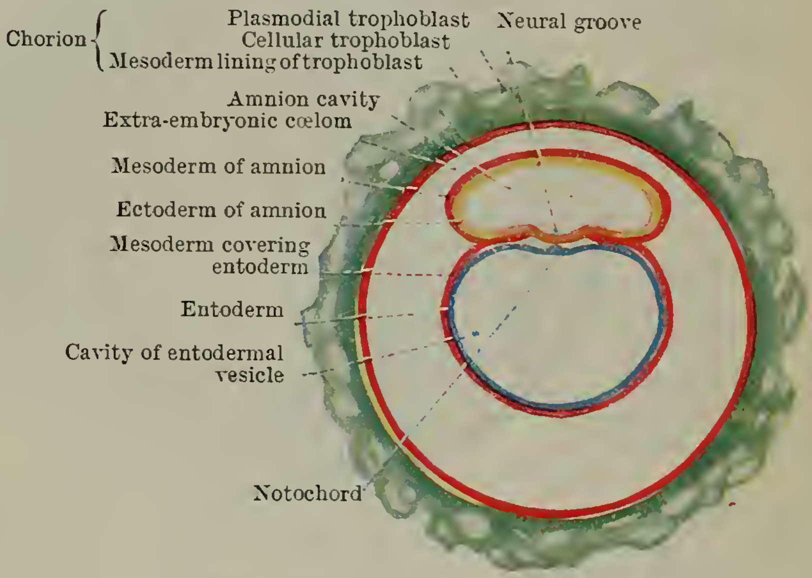

FIG. 39.—SCHEMA OF TRANSVERSE SECTION OF ZYGOTE ALONG LINE B IN FIG. 37.

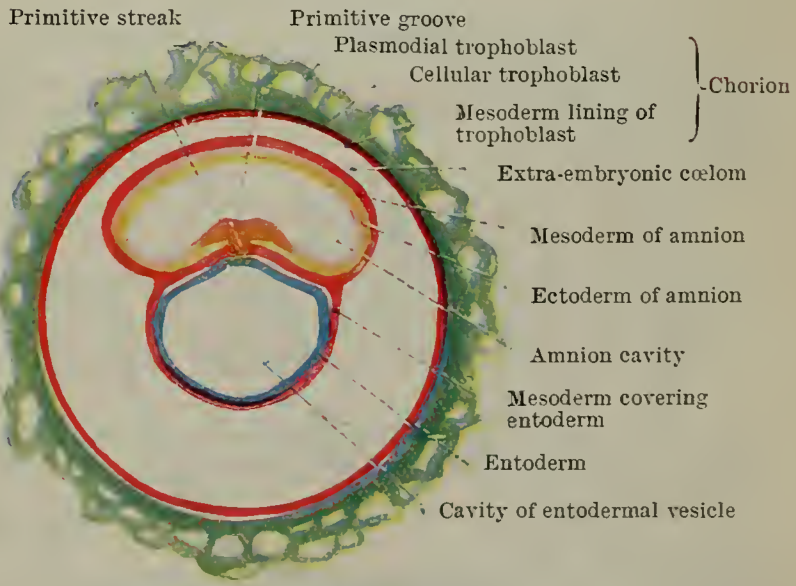

FIG. 40.—SCHEMA OF TRANSVERSE SECTION OF ZYGOTE ALONG LINE C IN FIG. 37.

In the very early stage of its development the caudal end of the notochord is traversed by the neurenteric canal, which, therefore, is frequently spoken of as the notochordal canal.

After a time the cylindrical notochordal rod is surrounded by secondary mesoderm which becomes converted into the vertebral column of the adult. As the vertebral column is formed the notochord is enlarged in the regions of the inter-vertebral fibro-cartilages and for a time assumes a nodulated appearance (Fig. 60).

Ultimately the notochord disappears, as a distinct structure, but remnants of

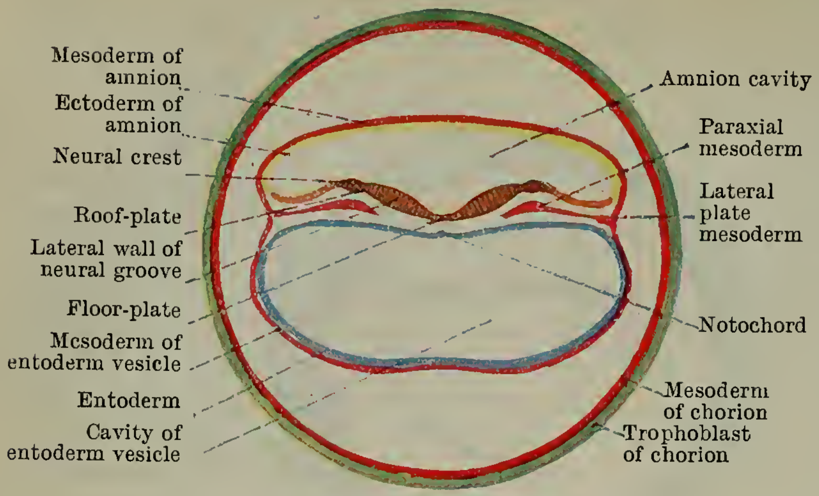

FIG. 41.—TRANSVERSE SECTION OF A ZYGOTE, showing early stage of embryonic secondary mesoderm before the appearance of the embryonic parts of cœlom.

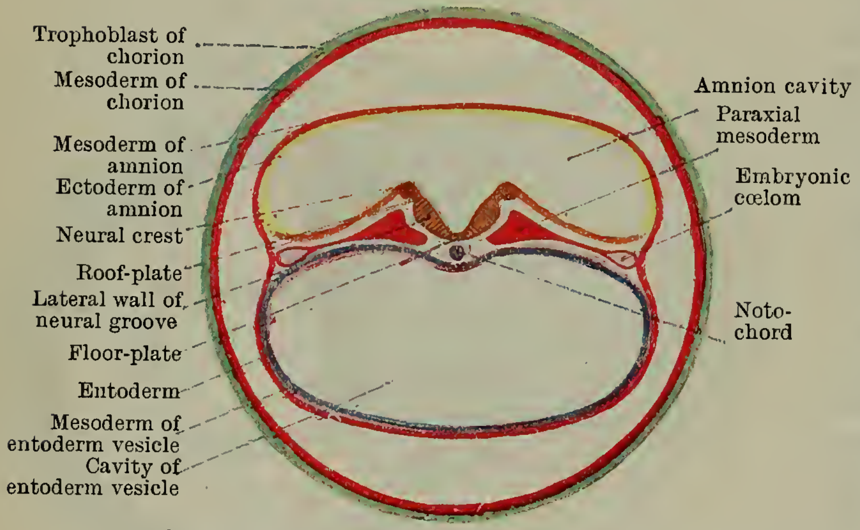

FIG. 42.—TRANSVERSE SECTION OF A ZYGOTE, showing early stage of development of embryonic cœlom and differentiation of mesoderm.

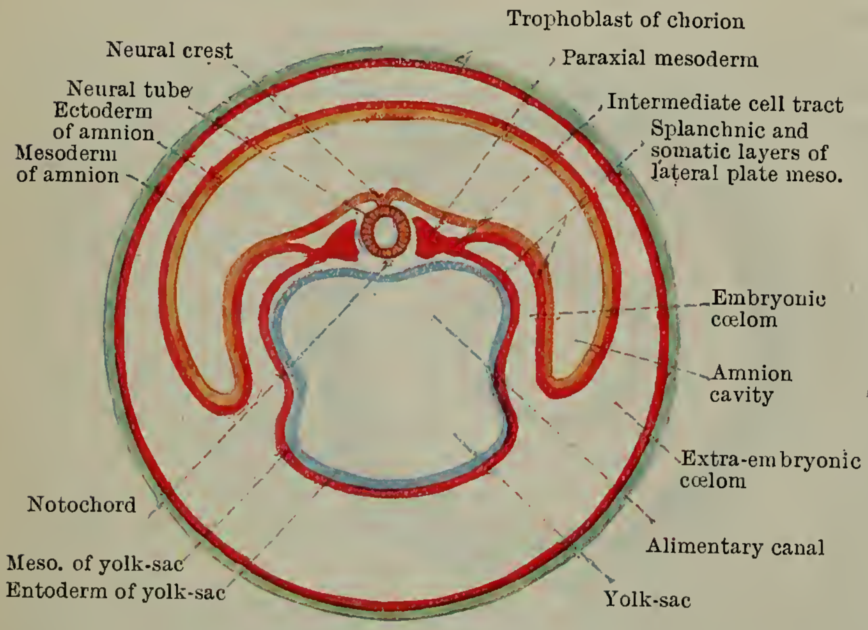

FIG. 43.—TRANSVERSE SECTION OF A ZYGOTE, showing union of intra- and extra-embryonic parts of cœlom and separation of embryonic mesoderm into paraxial bars, intermediate tracts, and lateral plates, with separation of lateral plates into somatic and splanchnic layers by the intra-embryonic part of the cœlom.

it are believed to persist as the pulpy centres of the intervertebral fibro-cartilages. The extension of the notochord into the region of the head is of interest from a morphological, and possibly also from a practical point of view. It extends through the base of the cranium from the anterior border of the foramen magnum into the posterior part of the body of the sphenoid bone. Its presence in the posterior part of the skull suggests that that region was, primitively, of vertebral nature. As the notochord passes through the occipital portion of the skull it pierces the basilar portion of the occipital region first from within outwards and then in the reverse direction. It lies, therefore, for a short distance, on the ventral surface of the rudiment of the occipital bone, in the dorsal wall of the pharynx, and it is possible that some of the tumours which form in the dorsal wall of the pharynx are due to the proliferation of remnants of its pharyngeal portion.

The Differentiation of the Secondary Mesoderm.—It has already been noted that a portion of the inner mass of the human zygote becomes converted directly into mesoderm which may be called, for convenience, *primary mesoderm*. It was stated also that the wall of the larger of the two inner vesicles of the zygote consists of ecto-mesoderm, that term being intended to convey the idea that the cells of the wall of the larger inner vesicle were the progenitors of both ectodermal and mesodermal cells.

As soon as the larger of the two inner vesicles is formed two areas of its wall are defined : (1) the part in contact with the smaller inner or entodermal vesicle and (2) the remainder. As future events prove, the cells of the larger area, which is not in contact with the entodermal vesicle, simply produce ectodermal descendants which line the inner surface of a sac-like covering of the embryo termed the amnion; they are, therefore, the predecessors of the *amniotic ectoderm.*

The cells of the larger inner vesicle, which lie adjacent to the smaller entoderm vesicle, and are merely separated from the entoderm by a thin layer of primary mesoderm, take part in the formation of the embryo; forming, with the entoderm, the embryonic area from which the embryo is evolved. These cells are the forerunners of both ectoderm and mesoderm, and as the mesoderm developed from them is differentiated after the formation of the primary mesoderm it may be termed **secondary mesoderm** or **primitive streak mesoderm**; the latter term being applied because it is differentiated in a linear region called the primitive streak (p. 27). It is the formation and fate of this primitive streak mesoderm which is now to be considered.

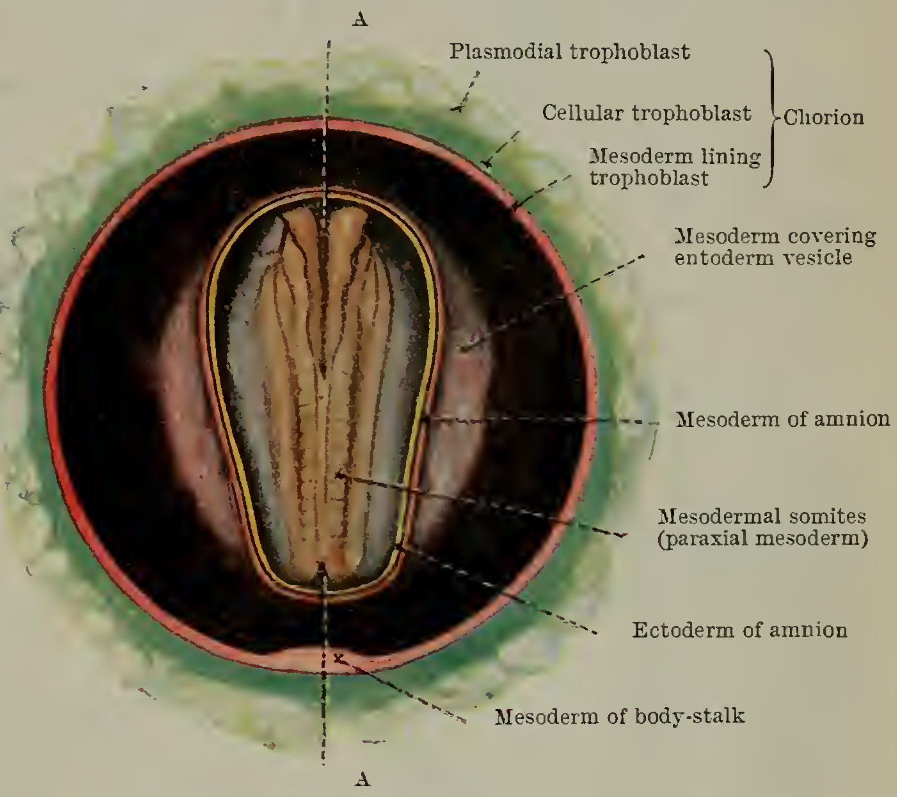

Fig. 44.—Schema of Dorsal Aspect of Embryo, showing partial closure of neural groove.

Portions of the chorion and amnion have been removed.

The neural folds have fused, except in the cephalic and caudal regions, both the cephalic and the caudal ends of the embryo have been bent ventrically and thirteen mesodermal somites have been formed.

At first the embryonic area is circular in outline, at a later period it becomes ovoid, and in the narrower or caudal portion of the ovoid area a linear thickening appears; this is the **primitive streak** (Figs. 37, 40). It is formed by the proliferation of the ecto-mesodermal cells of the wall of the larger inner vesicle. The deeper cells of the streak, which displace the primary mesoderm from the median plane, and thus come into contact with the entoderm, are the rudiments of the secondary or primitive streak mesoderm (Fig. 40). The superficial cells form part of the surface ectoderm of the embryo.

At the anterior end of the primitive streak the mesodermal elements of the streak fuse with the subjacent entoderm and through the fused mass a perforation, the neurenteric canal (p. 28), is formed (Fig. 38).

The canal itself soon disappears, but the cells of its walls form a nodal growing point, and by their proliferation the length and breadth of the embryonic area are increased. The mesoderm cells proliferated from the cephalic border of the nodal point are the rudiments of the notochord, which has already been considered (p. 28).

It is uncertain whether or not the mesodermal cells budded off from the nodal point blend with the cells of the primary mesoderm, but there can be little doubt that they form by far the greater part, if not the whole, of the permanent mesoderm of the embryo.

Either by displacement or by union with the primary mesoderm the secondary mesoderm forms a continuous sheet of cells, in the embryonic area, on each side of the median plane.

Each of the lateral sheets is thickest where it abuts against the notochord and the wall of the neural groove, and thinnest at its peripheral margin, where it is continuous with the primary mesoderm of the extra-embryonic area (Fig. 41).

At the cephalic end of the embryonic area the medial margins of the mesodermal sheets fuse together across the median plane, forming a transverse bar of mesodermal cells which may be called the **pericardial mesoderm** (Fig. 54), because the pericardial sac, which envelops the heart, is afterwards developed from it. The area in which this mesoderm lies may be named the pericardial region of the embryonic area (Fig. 54).

Between the bar of pericardial mesoderm, the cephalic end of the neural groove, and the medial margins of the mesodermal plates lies a small segment of the embryonic area from which the primary mesoderm entirely disappears, leaving the ectoderm and entoderm in contact. This is the **bucco-pharyngeal area.** It afterwards becomes the **bucco-pharyngeal membrane** (Figs. 56, 61), which separates the primitive mouth or stomatodæum from the cephalic end of the primitive entodermal alimentary canal. As already stated, the bucco-pharyngeal membrane disappears during the third week, when the stomatodæum and the primitive alimentary canal become continuous with each other.

Between the bucco-pharyngeal area and the cephalic end of the primitive streak the medial margins of the mesodermal plates are separated from one another by the notochord and the neural groove (Fig. 42), and still more caudally they are united with the sides of the streak (Fig. 40).

After the permanent mesodermal plates are definitely established a series of clefts appear in their peripheral margins. The clefts, on each side, soon fuse together to form the bilateral rudiments of the **embryonic cœlom** (Fig. 42).

The septum of cells at the lateral border of the embryonic area on each side, which, for a time, separates the embryonic from the extra-embryonic cœlom, soon disappears, and the cœlom then forms a continuous cavity (Fig. 43).

The embryonic cœlom also extends medially, but the medial extension ceases whilst the cavity is still at some distance from the median plane, except at the cephalic end of the embryonic area, where the two lateral halves of the embryonic cœlom become continuous with one another through the interior of the pericardial mesodermal bar (Figs. 55, 61).

As the embryonic cœlom is forming and extending, a longitudinal constriction appears in each lateral half of the mesoderm, a short distance from its medial border. This constriction separates each plate into three parts: (1) a medial bar, the **paraxial mesoderm**, which lies at the side of the neural groove and the notochord (Fig. 43); (2) the constricted portion, which is called the **intermediate cell tract**; and (3) the part lateral to the constriction, which is called the **lateral plate** (Fig. 43).

The embryonic cœlom is confined, as a rule, in the human subject, to the lateral plate, which it divides into a superficial layer, next the ectoderm, the **somatic mesoderm**, and a deeper layer, next the entoderm, the **splanchnic mesoderm.**

The medial borders of the somatic and splanchnic mesoderm are continuous with one another round the medial border of the cœlom. The lateral border of the somatic mesoderm is continuous, at the margin of the embryonic area, with the mesoderm which covers the outer surface of the amnion, and the lateral border of the splanchnic layer is continuous with the mesoderm on the wall of the extra-embryonic or yolk-sac portion of the entodermal sac.

The Paraxial Mesoderm.—Each paraxial mesodermal bar soon assumes the form of a triangular prism with the apex directed ventro-medially, towards the notochord, and the base dorso-laterally, towards the surface ectoderm.

The cephalic portion of each paraxial bar, as far caudalwards as the middle of the hind-brain (see p. 38), remains unsegmented, but the remainder is cut into a number of segments, the **mesodermal somites**, by a series of transverse clefts (Fig. 44). The first cleft appears in the region of the hind-brain, and the others are formed successively, each caudal to its predecessor. Only three or four somites lie in the region of the head; the remainder are in the body area of the embryonic region. The segmentation of the paraxial bars commences before their elongation is completed, and the posterior somites are separated off as the paraxial bars are extended by the continued proliferation from the nodal point at the anterior end of the primitive streak.

When they are first defined the somites are solid masses of cells, but in a short time a cavity—the cœlom of the somite or **myocœle**—is developed in each mass.

In many animals the myocœle is continuous through the intermediate cell tract with the more lateral parts of the cœlom, but that is not usually the case in human embryos.

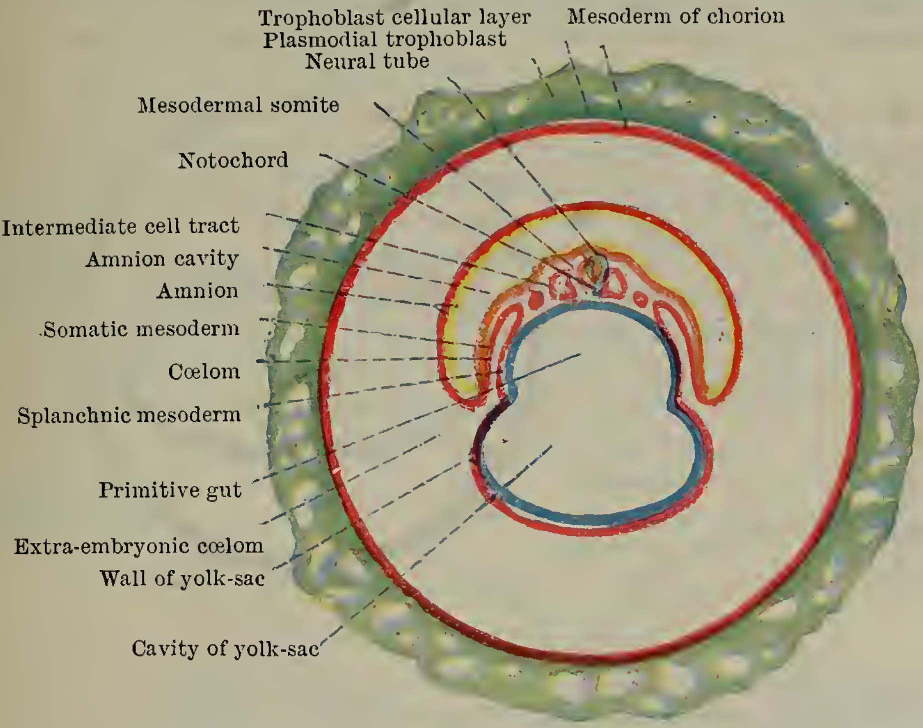

FIG. 45.—TRANSVERSE SECTION OF THE ZYGOTE SHOWN IN FIG. 44, showing the differentiation of the mesoderm.

The apical portion of the hollow mesodermal somite is its **scleratogenous segment.** The cells of the scleratogenous section of the somite undergo rapid proliferation. Some of the newly formed scleratogenous cells invade the myocœle; others migrate towards the notochord; finally, the scleratogenous cells separate from the remainder of the somite, and as they increase in number they migrate along the sides of the notochord and the neural tube, which has been formed in the meantime from the neural groove, and join with their fellows of the opposite side, and with their cephalic and caudal neighbours. In this way is formed, around the neural tube and the notochord, a continuous sheath of mesoderm, the **membranous vertebral**

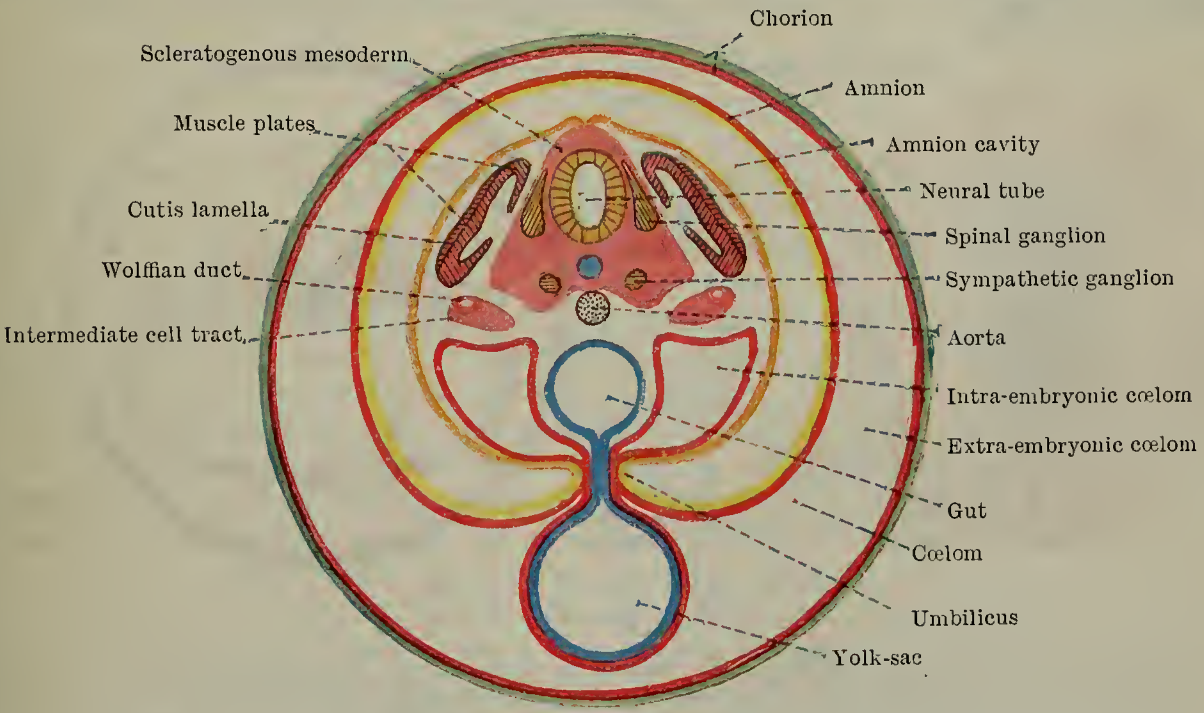

FIG. 46.—SCHEMA OF A TRANSVERSE SECTION OF A ZYGOTE, showing differentiation of mesoderm and extension of amnion.

column, from which are differentiated, in later stages, the vertebral column and its ligaments, and the membranes of the brain and the spinal medulla.

After the separation of the scleratogenous segments of the mesodermal somites, the remainders of the somites, each of which consists of a flat plate with incurved dorsal and ventral margins, constitute the **muscle plates** from which the striped muscle fibres are derived.

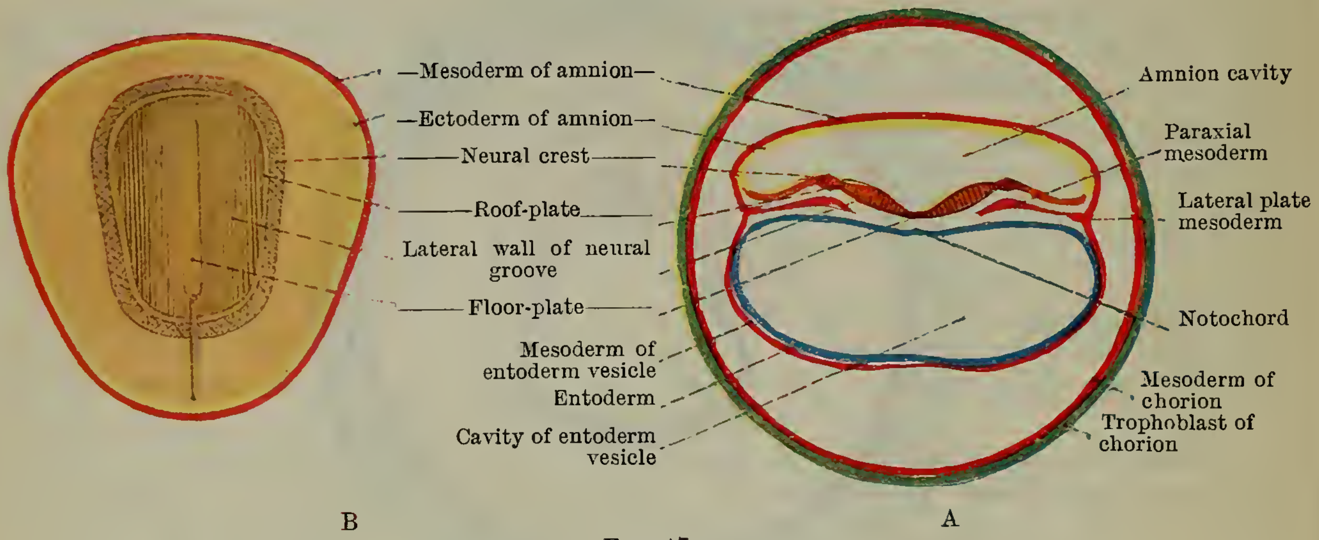

Fig. 47.

A. Transverse section of a zygote, showing the constituent parts.
B. Diagram of embryonic area showing parts of neural plate and primitive streak.

In the opinion of some observers the outermost portion of each of the above-described plates is developed into subcutaneous connective tissue cells; consequently it is spoken of as the *cutis lamella*. According to this view the muscle cells are formed from the innermost cells and the incurved margins of the plates.

The Intermediate Cell Tracts.—The intermediate cell tracts are the rudiments of the internal organs of the genital system and the temporary and permanent urinary system, with the exception of the urinary bladder and the urethra.

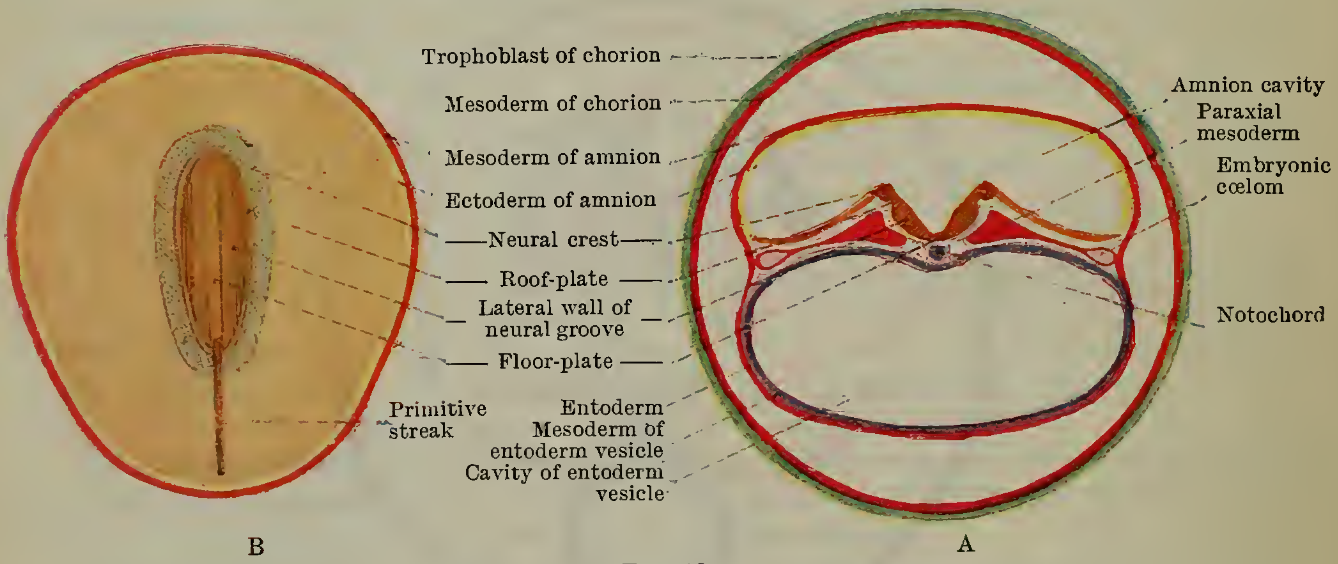

Fig. 48.

A. Diagram of a transverse section of a zygote, showing the formation of a neural groove in the embryonic area
B. Diagram of a surface view of the embryonic area of the same zygote.

The Lateral Plates.—From the cells of the lateral plates are formed the lining endothelial cells of the great serous cavities of the body—the pleuræ, the pericardium, and the peritoneum; the majority of the connective tissues, with the exception of those of the vertebral column and the head, the greater part or all the mesoderm of the limbs, and, probably, the unstriped muscle fibres of the walls of the alimentary canal and the blood-vessels.

The Cephalic Mesoderm.—It has already been noted that the mesoderm of the head becomes segmented only in the region of the caudal part of the hind-brain, where four cephalic mesodermal somites are formed on each side. From the scleratogenous portions of these somites are developed the occipital part of the skull and the corresponding portions of the membranes of the brain, and from their muscle plates the intrinsic muscles of the tongue.

The unsegmented part of the cephalic mesoderm gives rise to the remaining muscles and connective tissues of the head region.

The Mesenchyme.—Before the embryonic area becomes an embryo, there appear, between the more definite layers of mesoderm and the adjacent entoderm and ectoderm, a number of cells of irregular form and wandering habits, but which are undoubtedly of mesodermal nature that constitute the **mesenchyme.**

Early Stages of the Development of the Nervous System.—No definite trace of the nervous system is present until the primitive streak has formed and the embryonic area has passed from a circular to a pear-shaped form. Then an area of thickened ectoderm, the **neural plate**, appears in the anterior part of the embryonic area. It commences a short distance posterior to the anterior end of the area, and its posterior extremity embraces the anterior end of the primitive streak. Its lateral margins fade into the surrounding ectoderm, and, at first, cannot be definitely defined; but, as the elongation of the plate continues, coincidently with the elongation of the embryonic area, the lateral margins of the plate are elevated, as the mesoderm beneath them thickens, and so they become distinct. As the lateral margins of the neural plate are raised the plate is necessarily folded longitudinally, and the sulcus so formed is called the **neural groove**. Each side wall of the neural groove, formed by the corresponding half of the neural plate, is a **neural fold**. At a very early period the neural folds unite anteriorly to form the anterior boundary of the neural groove, and, somewhat later, they unite posteriorly, posterior to the neurenteric canal and across the anterior end of the primitive streak. After the lateral boundaries and the anterior and posterior extremities of the neural groove are defined, the lateral margins of the neural folds converge until they meet and fuse in the median plane, and the neural groove is thus converted into the **neural tube**, which possesses a floor or ventral wall, formed by the central part of the original neural plate and called the **basal plate** or floor-plate; a dorsal wall or **roof-plate**, and two lateral walls formed by the lateral parts of the neural plate.

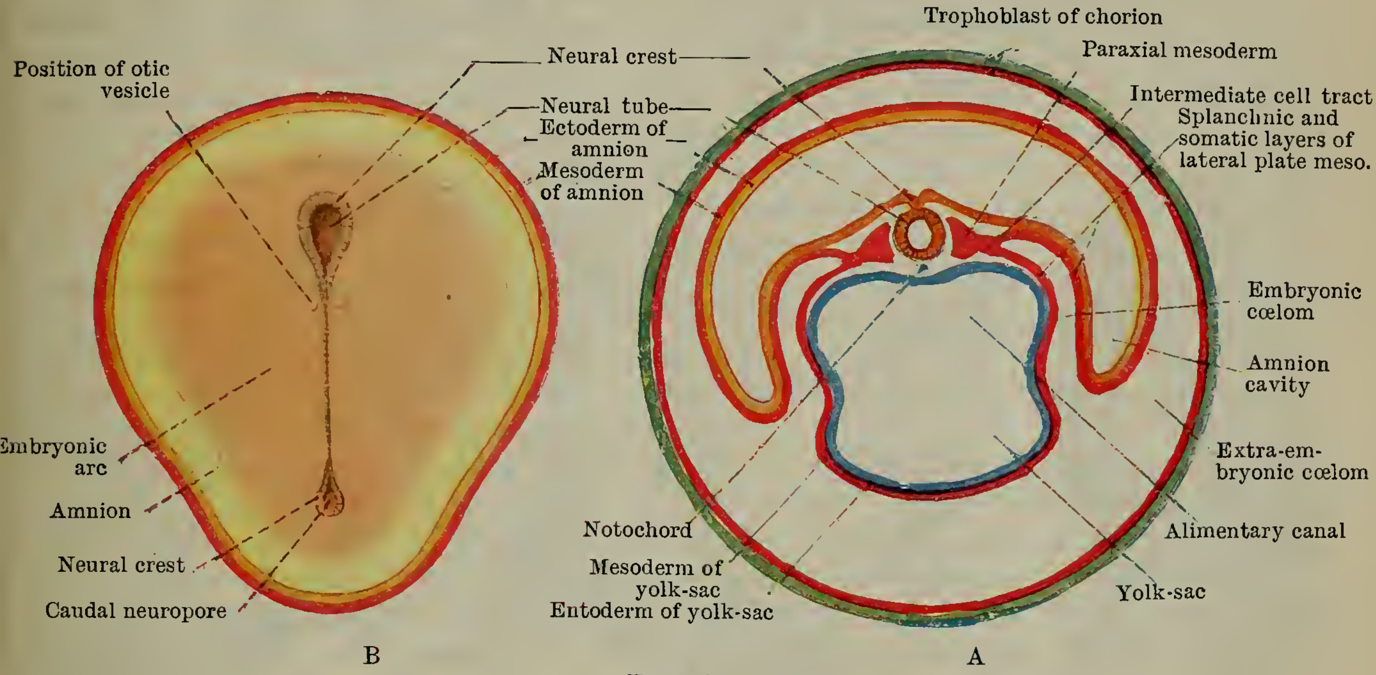

Fig. 49.

A. Diagram of a transverse section of a zygote, in which the neural tube has formed but has not separated from the surface ectoderm.

B. Diagram of embryonic area of same zygote. Compare with surface view of embryo in Fig. 44.

The fusion of the lateral margins of the neural plate to form the roof-plate of the neural tube commences in the cervical region, and from there extends cranialwards and caudalwards, therefore the last parts of the roof-plate which are formed are its anterior and its posterior extremities; consequently, for a time, the **neural canal**, which is the cavity of the tube, opens on the surface at its anterior and posterior ends; the anterior opening being called the **anterior neuropore,** whilst the open part at the posterior end is termed the **posterior neuropore** (Fig. 49). Eventually, however, about the third week of embryonic life, both apertures are closed and, for a time, the neural canal becomes a completely closed cavity.

As the margins of the neural groove rise and converge they carry with them the adjacent ectoderm to which they are attached, and which forms part of the surface covering of the embryo; consequently, when the lateral margins of the folds meet and unite, the tube, which is completed by their fusion, is embedded in the body of the embryo, but, for a time, its dorsal wall is attached to the surface ectoderm by a ridge of cells, formed by the fused lateral margins of the neural plate. This ridge is called the **neural crest** (Figs. 47-50).

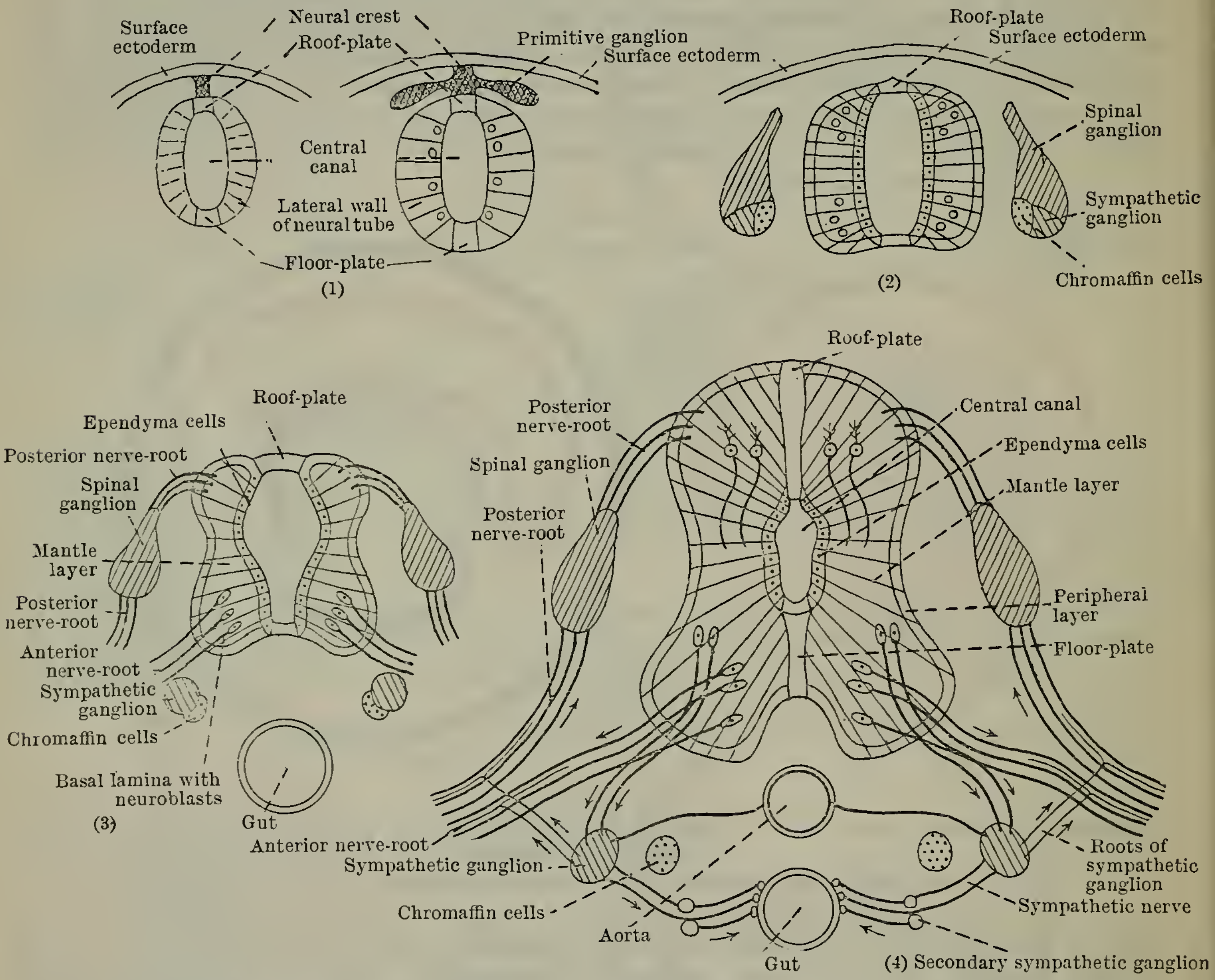

FIG. 50.—DIAGRAMS illustrating the formation of (1) the rudiments of the primitive ganglion from the neural crest. (2) The differentiation of different parts of the primitive ganglion into permanent ganglion root, sympathetic ganglion, and masses of chromaffin cells. (3) The formation of the anterior and posterior nerve-roots. (4) The differentiation of the walls of the neural tube into ependymal matter and peripheral layers.

The cells of the primitive ganglion which form the primitive sheaths of the nerves are not shown in the diagrams.

The neural crest is the rudiment of the cerebral and spinal nerve ganglia, the sympathetic ganglia, the chromaffin cells of the chromaffin organs, and the cellular sheaths of the peripheral nerves; whilst the walls of the neural tube become transformed into the various constituent parts of the central nervous system, the brain and spinal medulla, the retinæ of the eye-balls, and the optic nerves.[1]

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[1] It is stated, by some observers, that some of the sympathetic nerve cells are derived from the ventral parts of the lateral walls of the neural tube.

The Formation of the Nerve Ganglia, the Chromaffin Tissues, and the Primitive Nerve Sheaths.—The **primitive ganglia** grow as cell buds from the neural crest which, for a time, connects the dorsal wall of the neural tube with the surface ectoderm. In the body region they correspond in number with the spinal nerves and with the primitive segments into which the mesoderm becomes divided, but in the cephalic region their arrangement is more irregular, and some of the ganglia of the cerebral nerves receive additional cell elements from the surface ectoderm or the entoderm.

Simultaneously with the appearance of the cell buds which form the primitive ganglia, the neural crest disappears, and directly after the ganglia are formed they lose their connexion with both the neural tube and the surface ectoderm and become isolated cell clumps. At this period, therefore, the nervous system consists of the neural tube and the primitive ganglia.

After the primitive ganglia have lost their connexion with the neural tube they increase in size by the proliferation of their constituent cells, and they migrate ventrally along the sides of the neural tube, but the migration ceases before the ventral ends of the ganglia reach the level of the ventral wall of the tube. As the migration proceeds clumps of cells are budded off from the ventral ends of the ganglia. These secondary cell buds are the rudiments of the sympathetic ganglion cells and of the chromaffin tissue which is found in the sympathetic nerve plexuses, the medulla of the suprarenal glands, and in the carotid glands. In the first instance the secondary cell buds which form the sympathetic ganglia wander ventrally and medially, from the ventral ends of the primitive ganglia, until they attain the positions, afterwards occupied by the ganglia of the sympathetic trunks, on the ventro-lateral aspects of the vertebral column. From the primary sympathetic ganglia buds of cells are given off; these buds wander still further ventrally to become the cells of the ganglia of the cardiac, cœliac, and other great ganglionic nerve plexuses, as well as to form the chromaffin cells of the chromaffin organs.

The exact manner in which the cells of the primitive sheaths of the nerves originate from the primitive ganglia is not known, but it has been shown by Harrison, in the case of the frog, that if the primitive ganglia are destroyed, the primitive sheaths of the nerves are not formed. Presumably, therefore, in the frog the cellular sheaths of the nerves are derived from cells produced by the primitive ganglia, and it may be assumed that they have a similar origin in the human subject.

After the rudiments of the sympathetic system, the chromaffin cells, and the cellular sheaths of the nerves have separated, the remains of the primitive ganglia become the permanent spinal and cerebral nerve ganglia.

In the early stages these ganglia are completely isolated structures which lie along the sides of the neural tube between the lateral walls of the tube medially, and the mesoderm somites laterally.

Some time after the ganglia of the cerebral and spinal nerves become isolated their cells give off processes which become nerve-fibres. These fibres grow out both from the dorsal and the ventral ends of the ganglia, and, together with the ganglia, they form, in the cranial region, certain of the cerebral nerves, and, in the spinal region, the posterior roots of the spinal nerves.

The fibres which grow out of the dorsal ends of the ganglia enter the walls of the neural tube, and by their means the ganglia regain connexion with the tube.

The fibres which grow out from the ventral end of each spinal ganglion unite with the fibres of the corresponding anterior nerve-root, which, in the meantime, has grown out from the cells of the ventral part of the lateral wall of the spinal portion of the neural tube, and form with them a spinal nerve-trunk.

The Differentiation of the Neural Tube.—Before the neural groove is converted into a closed tube, an expansion of its anterior part indicates the separation of the neural rudiment into cerebral and spinal sections, the dilated portion being the rudiment of the **brain** and undilated part the rudiment of the **spinal medulla.**

Whilst the cerebral portion is still unclosed, three secondary dilatations of its walls indicate its separation into three sections, the primitive **fore-brain**, the **mid-brain**, and the **hind-brain**; the primitive fore-brain being the most cephalward or anterior and the hind-brain the most caudal or posterior of the three (Fig. 44).

Shortly after the three segments of the brain are defined, and before it becomes a closed tube, a vesicular evagination forms at the cephalic end of each lateral wall of the primitive fore-brain region. These evaginations are the **primary optic vesicles**, and they are the rudiments of the **optic nerves**, the **retinæ**, and the **posterior epithelium of the ciliary body** and the **iris** of the eye-ball.

When the cerebral portions of the neural folds meet and fuse dorsally the cerebral dilatations become the primitive brain vesicles, each vesicle possessing its own cavity and walls, but the cavities of the three vesicles are continuous with one another, and the cavity of the hind-brain vesicle is continuous, caudally, with the central canal of the spinal part of the neural tube.

After the primitive brain vesicles are formed, a diverticulum grows out from the cephalic end of the primitive fore-brain vesicle. This is the rudiment of the **secondary fore-brain**. Its cephalic end soon divides into two lateral halves, which are the rudiments of the **cerebral hemispheres** of the adult brain (Fig. 51).

After their formation the cerebral hemispheres expand rapidly in all directions. They soon overlap the primitive fore-brain and mid-brain (Fig. 69), and, eventually, the hind-brain also, and each gives off from the cephalic end of its ventral wall a secondary diverticulum, the **olfactory diverticulum**, which becomes converted, later, into the olfactory bulb and olfactory tract.

When they first appear the rudiments of the cerebral hemispheres are connected together, across the median plane, by a part of the cephalic end of the wall of the **secondary fore-brain dilatation**, which is called the **lamina terminalis**. This primitive connexion between the two cerebral hemispheres persists throughout the whole of life, and it is supplemented, at a later period, by the formation of three secondary commissures, the corpus callosum and the fornix, which grow through the upper part of the lamina terminalis, and the anterior commissure which grows through its lower part.

The Fate of the Walls of the Primitive Brain Vesicles.—The primitive hind-brain, which is also called the rhombencephalon, is separated in the later stages of development into two parts. (1) A caudal portion which is connected with the medulla spinalis, and which becomes the **medulla oblongata** or myelencephalon of the adult brain. (2) A cephalic portion which is continuous at one end with the medulla oblongata and at the other with the mid-brain. The ventral wall of the cephalic portion of the primitive hind-brain is ultimately converted into the **pons**, and its dorsal wall differentiates into two parts—a caudal part which becomes the **cerebellum**; and a cephalic part which is converted into the **anterior medullary velum** and the **brachia conjunctiva**. The brachia conjunctiva connect the cerebellum with the ventral part of the mid-brain. The pons and cerebellum form the metencephalon of the adult, whilst the brachia conjunctiva and the anterior medullary velum constitute parts of the isthmus rhombencephali (Figs. 51, 69).

The ventral portion of the primitive mid-brain is converted into the two **peduncles of the cerebrum** of the adult brain, and the dorsal portion is transformed into four rounded elevations, the colliculi or **corpora quadrigemina**.

The transformations which take place in the region of the primitive fore-brain or prosencephalon are numerous and complicated; therefore its ventral, lateral, and dorsal walls require separate consideration.

By the expansion of its cephalic (anterior) extremity is formed the **secondary fore-brain**, which becomes divided, as already explained, into the two secondary vesicles which are the rudiments of the **cerebral hemispheres** of the completed brain.

After the formation of the rudiments of the cerebral hemispheres, which constitute the **telencephalon** of the adult, the primitive fore-brain and the undivided stalk of the secondary fore-brain diverticulum become the **diencephalon**.

The cephalic or anterior end of the diencephalon is closed by the lamina terminalis (see above), in association with which are subsequently developed two columns which run dorso-ventrally, the **columns of the fornix**, and three transverse commissures, two of which connect the cerebral hemispheres, the corpus callosum, and the **anterior commissure**, whilst the third is the **optic chiasma** in which the medial fibres of the optic nerves decussate.

From the cephalic or anterior end of the ventral wall of the diencephalon a diverticulum is projected ventrally towards the dorsal wall of the primitive mouth. The ventral end of this diverticulum becomes the posterior lobe of the **hypophysis** (O.T. **pituitary body**) of the adult, the dorsal end becomes the *tuber cinereum*, and the intermediate part is the *infundibulum* which connects the *tuber cinereum* of the adult brain with the posterior lobe of the hypophysis.

Caudal to the hypophyseal diverticulum a single elevation appears in the ventral wall of the diencephalon. It is the **corpus mamillare**, which afterwards separates into the paired **corpora mamillaria** of the adult brain.

Still more caudally the ventral wall of the diencephalon takes part in the formation of the **substantia perforata posterior**, which lies between the two peduncles of the cerebrum and is partly developed from the cephalic or anterior end of the ventral wall of the primitive mid-brain.

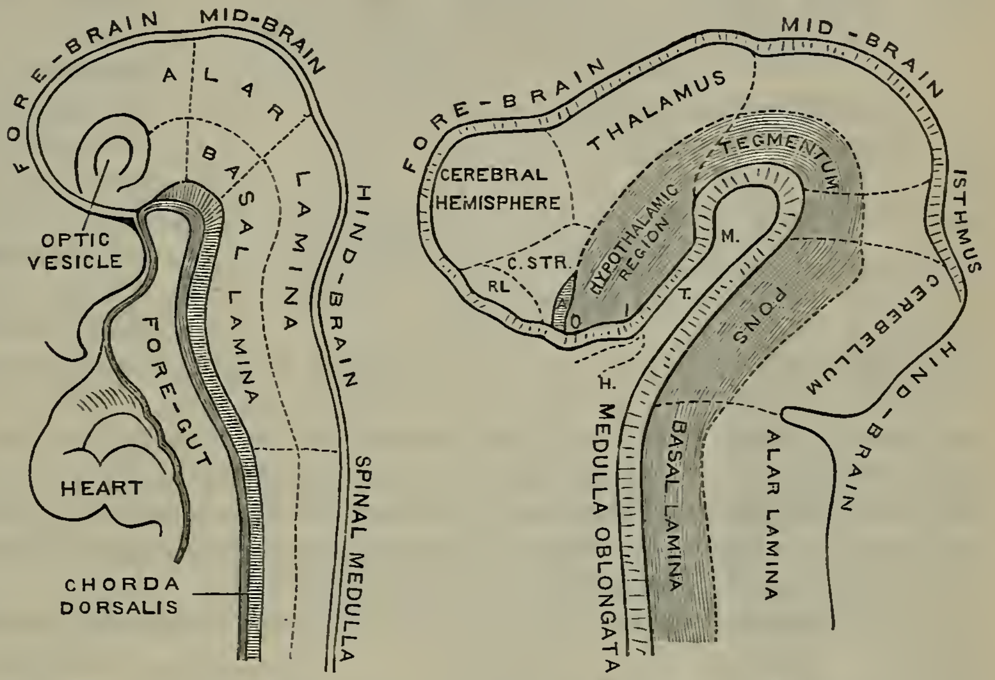

Fig. 51.—Diagrams to illustrate the Alar and Basal Laminæ. In both cases the embryonic brain is represented in mesial section (His).

A. The different subdivisions of the brain are marked off from each other by dotted lines, and the dotted line running in the long axis of the neural tube indicates the separation of the alar from the basal lamina of the lateral wall.

B. Medial section through the brain of a human embryo at the end of the first month. Dotted lines mark off the different regions and also the alar and basal laminæ from each other.

H, Buccal part of hypophysis cerebri; RL, Olfactory lobe; C.Str, Corpus striatum; A, Entrance to optic stalk; O, Optic recess; I, Infundibular recess; T, Tuber cinereum; M, Mamillary eminence.

The greater part of the **dorsal wall** of the diencephalon is ultimately reduced to a single layer of epithelial cells, but near its caudal end a diverticulum is projected dorsally. This is the **epiphysis** or **pineal body**, which remains quite rudimentary in man as contrasted with many other animals. At a later period two transverse bands of fibres appear in the dorsal wall of the diencephalon, one in front of and the other immediately behind the root of the epiphyseal recess. The anterior band is the **dorsal** or **habenular commissure**, and the posterior is the **posterior commissure** of the adult brain.

These structures, collectively, together with a small diverticulum of the epithelial roof, which appears anterior to the dorsal commissure, and is called the supra-pineal recess, constitute the so-called **epithalamus**.

Each lateral wall of the diencephalon is differentiated into a dorsal and a ventral part. The dorsal part forms a large gray mass called the **thalamus**, and on the posterior end of the thalamus are developed two rounded elevations, the **medial** and the **lateral geniculate bodies**, which constitute the **metathalamus** of the adult brain.

The ventral or basal portion of the lateral wall of the diencephalon, together with the adjacent part of the ventral wall, forms the **hypothalamus** of the fully developed brain.

The Fate of the Spinal Portion of the Primitive Neural Tube.—The spinal portion of the neural tube, during the first three months of intra-uterine life, develops equally in its whole extent, but after that period a longer cephalic (superior in the erect posture) and a shorter caudal portion are recognisable. The cephalic portion undergoes still further development and is converted into the spinal medulla of the adult, but in the smaller caudal portion retrogressive changes occur, and it is transformed into the non-functional **filum terminale** of the completed medulla spinalis.

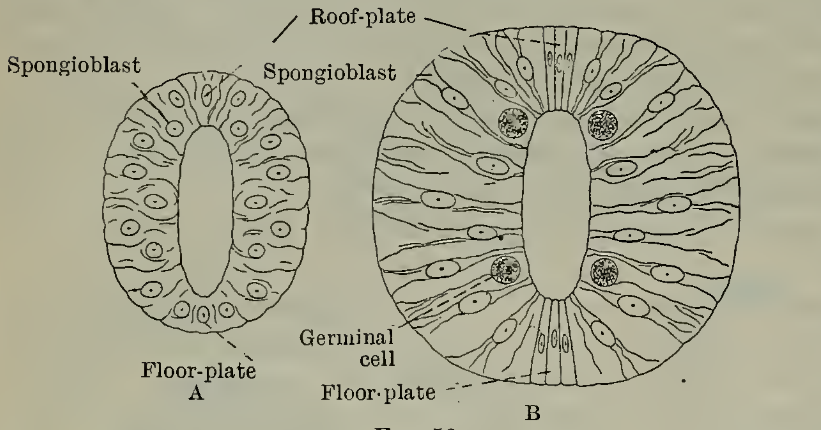

Fig. 52.

A. Diagram of a transverse section of a spinal medulla which has not differentiated into groups of cells.

B. Diagram of a transverse section of a spinal medulla showing positions of germinal cells.

Histological Differentiation of the Walls of the Neural Tube.—In the earliest stages of its development the walls of the neural tube consist of a mass of nucleated protoplasm, more or less distinctly differentiated into cell areas, of columnar form, which extend between and are connected with an **internal limiting membrane**, bounding the neural canal, and an **external limiting membrane**, which surrounds the whole tube. At this time the outline of a transverse section of the primitive neural tube is somewhat ovoid (Fig. 52). The cavity of the tube is compressed laterally into a dorso-ventral cleft, which is bounded by dorsal, ventral, and lateral walls. In the dorsal and ventral walls, called respectively the roof- and floor-plates, the columnar character of the primitive epithelial elements of the medulla spinalis is retained throughout the whole of life, but the peripheral parts of some of the cells are converted into fibrils.

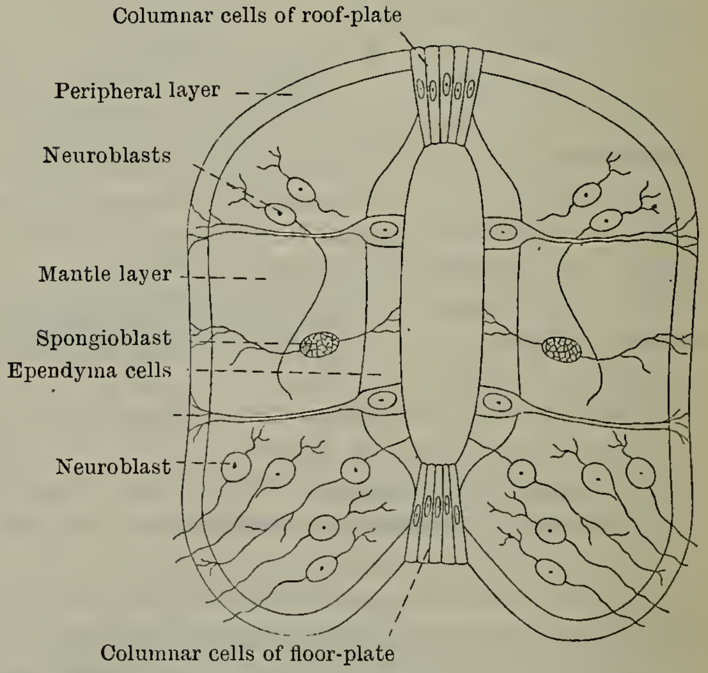

Fig. 53.—Showing Elements of Central Nervous System.

In the lateral walls of the embryonic medulla spinalis some of the cells soon assume a spherical form. These spherical cells have large deeply staining nuclei, and they are termed **germinal cells.**

For many years it was believed that the germinal cells were the predecessors of the primitive nerve elements or **neuroblasts**, and that the remaining cells, called **spongioblasts**, became transformed into the reticular sustentacular tissue of the central nervous system. It appears, however, from the results of more recent researches, that some of the descendants of the germinal cells become spongioblasts whilst others become neuroblasts or primitive nerve-cells. Moreover, there appear to be two groups of germinal cells; the descendants of one group are directly transformed into the ependymal or lining cells of the central canal, whilst those of the other group form in the first instance **indifferent cells**, some of whose descendants become neuroblasts and others spongioblasts. The fate of the cells present before the germinal cells appear, and which do not become germinal cells, is uncertain, but they probably take part in the formation of the spongioblastic tissue.

It is believed, therefore, that all the nerve-cells are the descendants of the germinal cells, and that the spongioblasts which become developed into the cells of the neuroglia or sustentacular reticulum are derived partly from the non-germinal cells of the primitive neural tube and, partly, they are descendants of the germinal cells.

As differentiation proceeds three layers and two membranes are gradually defined in the walls of the neural tube: (1) a central layer of columnar ependyma cells immediately surrounding the central canal; (2) an intermediate or mantle layer consisting of neuroblasts, and their processes the nerve-fibres, intermingled with spongioblasts; (3) a peripheral reticular layer consisting, at first, of processes of the bodies of the spongioblasts. The membranes are an external limiting membrane, surrounding the exterior of the tube, formed by the fused outer ends of the spongioblastic cells, and an internal limiting membrane bounding the central canal and continuous with the inner ends of the ependyma cells. Throughout the whole of the spinal medulla and the brain, the ependyma cells become transformed into the columnar ciliated cells which line the cavities of the adult brain and spinal medulla. The mantle layer becomes converted into the central gray matter of the adult central nervous system.

The peripheral reticular layer, in the spinal region, becomes permeated by nerve-fibres, which are merely processes of the nerve-cells, and it is thus converted into the white matter of the adult spinal medulla. In the brain region it is either transformed in the same way into white matter, or it remains in a more rudimentary condition as a thin peripheral layer of neuroglia on the surface of the gray matter. On the other hand, in the brain region white matter is formed internal to the gray matter by the growth of nerve-fibres which insinuate themselves between the mantle layer externally and the bodies of the ependyma cells internally.

As the histological differentiation of the walls of the neural tube is proceeding each lateral wall is divided into a dorsal part, the **alar lamina**, and a ventral part, the **basal lamina**, by a sulcus-like dilatation of the central canal called the *sulcus limitans*. After the limiting sulci are formed the parts of the walls of the neural tube are a roof-plate, a floor-plate, and two lateral walls, each of which consists of an alar lamina, essentially sensory in function, and a basal lamina, essentially motor in function (Fig. 50).

The Fate of the Cavities of the Primitive Brain.—The cavity of the spinal portion of the primitive neural tube becomes the central canal of the spinal medulla of the adult. The cavities of the primitive brain vesicles are transformed into the ventricles, foramina, and aqueduct of the adult brain. The cavities of the telencephalic divisions of the secondary fore-brain become the **right** and **left lateral ventricles** of the adult brain. The cavity of the undivided portion of the secondary fore-brain vesicle, together with the cavity of the primary fore-brain, become the **third ventricle** or cavity of the diencephalon, and the apertures of communication between the third ventricle and the cerebral hemispheres are the **interventricular foramina** (O.T. **foramina of Monro**).

The cavity of the hind-brain vesicle becomes the **fourth ventricle**, and the cavity of the primitive mid-brain is converted into the **aqueductus cerebri**, which connects the third with the fourth ventricle.

After the anterior and posterior neuropores (p. 36) are closed, the cavity of the neural tube is, for a time, a completely enclosed space. Subsequently the mesoderm, which in the meantime has surrounded the tube, becomes differentiated, in its immediate neighbourhood, into three membranes. The innermost of the three is closely connected with the walls of the neural tube and is called the **pia mater**. The outermost, known as the **dura mater**, is dense and resistant, and the intermediate membrane is a thin lamella called the **arachnoid**.

As the membranes are formed, spaces are differentiated between them. The space between the dura mater and the arachnoid is the **subdural space**, and that between the arachnoid and the pia mater is the **subarachnoid space**.

After a time a median perforation, the **median aperture of the fourth ventricle**, and two lateral perforations pierce the dorsal wall of the fourth ventricle and the pia mater which covers it, and thus the fourth ventricle becomes connected with the subarachnoid space.

THE FORMATION OF THE EMBRYO.

The transformation of the relatively flat embryonic area into the form of the embryo is due, in the first instance, to the rapid extension of the median part of the area, as contrasted with the slower growth of its margins, and the later modelling of the various parts of the embryo is due to different rates of growth in different parts of the embryonic region.

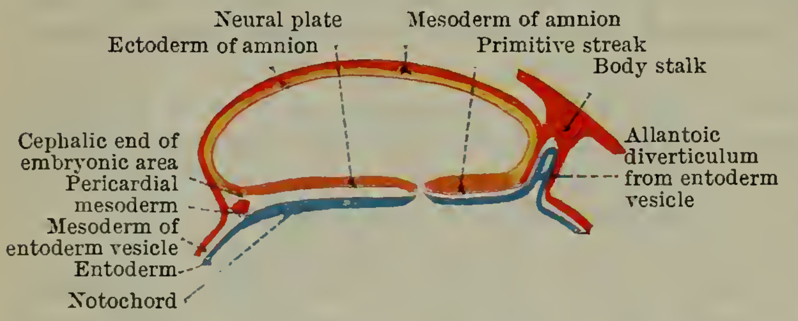

FIG. 54.—SCHEMA OF SAGITTAL SECTION OF EMBRYONIC AREA AND AMNION BEFORE THE FOLDING OF THE AREA HAS COMMENCED.

By the rapid proliferation of cells from the nodal growing point, at the cephalic end of the primitive streak, the cephalo-caudal length of the area is increased, whilst the cephalic and caudal ends of the area remain relatively fixed, consequently the area becomes folded longitudinally. At the same time, the cephalic end of the neural groove is pushed away from the nodal point, until it lies at first dorsal and then cephalad to the cephalic border of the area. As a result of this movement the bucco-pharyngeal and the pericardial areas become reversed in position, and a **cephalic** or **head fold** is formed. This fold is bounded, dorsally, by what is now the cephalic portion of the embryo, ventrally, by the reversed pericardial region, and its cephalic end is formed by the extremity of the head region and the bucco-pharyngeal membrane.

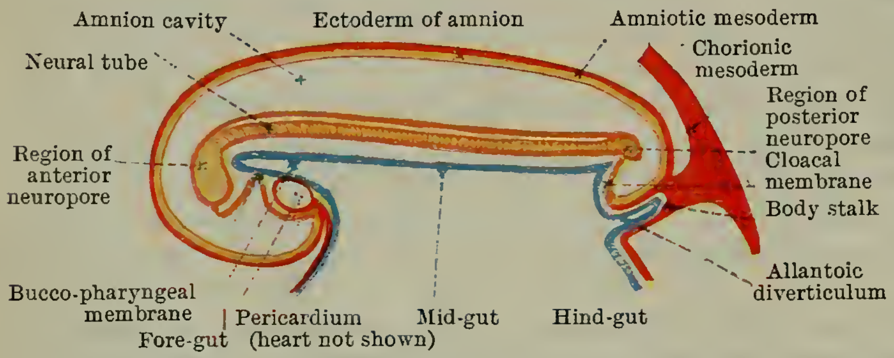

FIG. 55.—SCHEMA OF SAGITTAL SECTION OF EMBRYONIC AREA SHORTLY AFTER THE FOLDING HAS COMMENCED. The pericardial mesoderm is carried into the ventral wall of the fore-gut and the cœlom has extended through it. The cephalic end of the neural tube and the caudal part of the primitive streak are bent ventrally, and the latter now forms the cloacal membrane.

The growth at the nodal point not only produces a head fold, but at the same time it forces the cephalic end of the primitive streak caudally over the caudal end of the embryonic area, thus forming a **tail fold**.

As the head and tail folds of the embryo are produced by the longitudinal increase of the embryonic area, transverse growth of the area results in the formation of right and left **lateral folds** (Figs. 43, 46), and as the various folds are formed the embryo rises, like a mushroom, into the interior of the amnion cavity.

The portion of the entodermal sac which is enclosed within the hollow embryo, formed by the folding of the embryonic area, is the **primitive entodermal alimentary canal**. The part which remains outside the embryo is the **yolk-sac**, and the passage of communication between the two is the **vitello-intestinal duct**.

That portion of the primitive entodermal alimentary canal which lies in the head fold is termed the **fore-gut**, the part in the tail fold is the **hind-gut**, and the intermediate portion which is in free communication with the yolk-sac is the **mid-gut**.

As the extension of the embryonic area and its folding proceed the margin of the area, which remains relatively stationary, becomes the margin of an orifice, on the ventral aspect of the embryo, through which the primitive alimentary canal of the embryo and the intra-embryonic part of the cœlom communicate, respectively, with the yolk-sac and the extra-embryonic portion of the cœlom. This orifice is the **primitive umbilical orifice**.

Not only does the primitive alimentary canal communicate with the yolk-sac, and the intra-embryonic with the extra-embryonic cœlom, at the margin of the umbilical orifice, but also the body walls of the embryo, formed by the somatopleure, become continuous, at the same margin, with the wall of the amnion.

The young embryo is connected also with the inner surface of the chorion by a band of tissue which is part of the median portion of the caudal part of the wall of the amnion sac. The mesoderm in this region is thickened, and contains in its interior a diverticulum, **allantoic diverticulum**, which is primarily derived from the entodermal sac, but is afterwards connected with the hind-gut. This strand consists of ectoderm and mesoderm, and it contains not only the allantoic diverticulum but also the blood-vessels passing between the embryo and the chorion. It was called, by His, the **body stalk**, but the term is not fortunate, for it takes no part in the formation in the body of the embryo. On the other hand, its mesodermal and entodermal constituents represent a diverticulum from the wall of the hind-gut, present in many mammals and known as the **allantois**; it might with advantage, therefore, be termed the **allantoic stalk**.

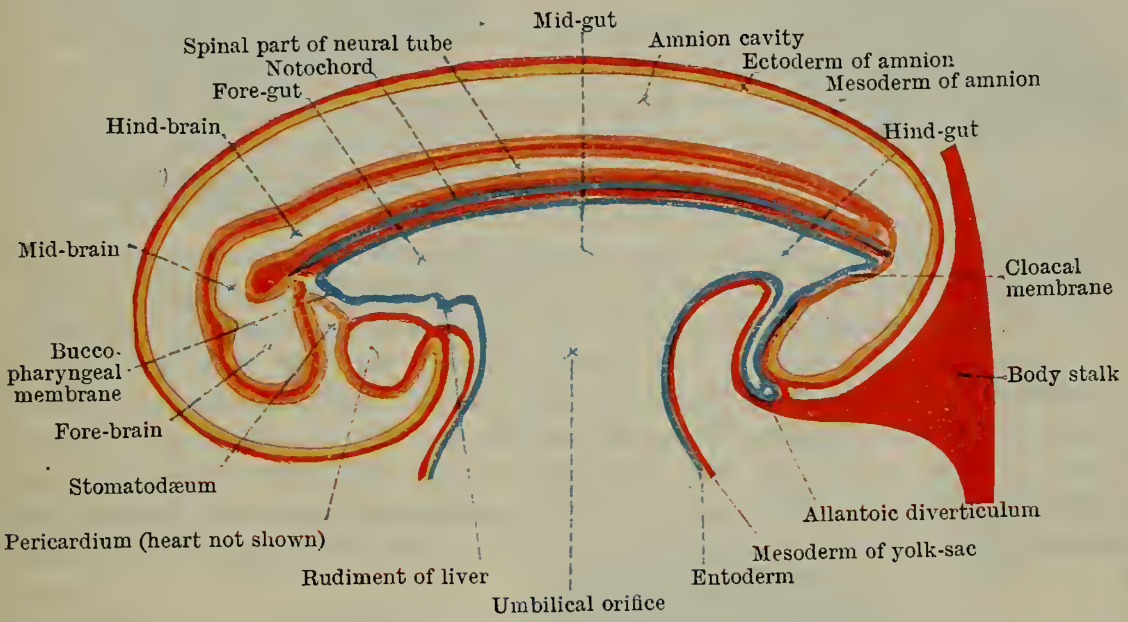

Fig. 56.—Schema of Sagittal Section of Embryo after the Folding has defined both the Fore-gut and Hind-gut Areas.

At first the umbilical orifice is relatively large as contrasted with the total size of the embryo, but as the embryo rapidly extends, in all directions, from the margin of the orifice, the latter soon becomes relatively small. Ultimately the various parts of the margin of the orifice are approximated until they fuse together, closing the opening and forming a cicatrix on the ventral wall of the abdomen which is known as the **umbilicus** or **navel**.

THE EMBRYO.

Whilst the embryonic area is being folded into the form of the embryo, the neural groove on the surface of the area is being converted into the neural tube. After the neural tube is completely closed and separated from the surface, during the third week, the embryo is an elongated organism possessing a larger cephalic end, a smaller caudal end, attached by the body stalk to the chorion (Fig. 55), a continuous and unbroken dorsal surface, a ventral surface separated into cephalic and caudal portions by the umbilical orifice, two lateral surfaces right and left, and it contains within its interior three cavities: (1) The cavity of the neural tube, which becomes the cavities of the brain and the spinal medulla (Fig. 56); (2) the primitive alimentary canal, which is a portion of the entodermal vesicle constricted off during the folding of the embryonic area (Figs. 43, 46); (3) the embryonic cœlom.

The embryonic cœlom consists of a pericardial portion, which lies cranial to the umbilicus and ventral to the fore-gut, and right and left lateral portions, which lie at the sides of the fore-gut, the mid-gut, and the hind-gut.

The right and left portions communicate with one another, ventral to the fore-gut, through the pericardial portion, and ventral to the hind-gut, they also communicate with the extra-embryonic cœlom at the lateral and caudal margins of the umbilical orifice.

At this period the embryo is easily distinguished from the remainder of the zygote, and it is so far developed that indications of its general plan of organisation are discernible.

It has, as yet, no limbs, but the general contour of the head and body are defined. It possesses a notochord or primitive skeletal axis, afterwards replaced by the permanent vertebral column. On the dorsal aspect of the notochord lies the neural tube, which is the rudiment of the future brain and the spinal medulla.

At the sides of the neural tube and the notochord are the mesodermal somites and the nerve ganglia (Figs. 46, 49).

Ventral to the notochord is the primitive alimentary canal (Fig. 56), closed at its cephalic end by the bucco-pharyngeal membrane, and at its caudal end by what was originally the caudal portion of the primitive streak, but which is now called the **cloacal membrane** because it separates the caudal end of the hind-gut, which becomes the **entodermal cloaca**, from the amniotic cavity (Fig. 56).

At the sides of the primitive alimentary canal are the right and left lateral parts of the cœlom, and between the dorsal angle of each half of the cœlom and the mesodermal somites of the same side lies the intermediate cell tract which is the rudiment of the greater part of the genito-urinary system (Figs. 45, 46).

Ventral to the fore-gut is the pericardial mesoderm, traversed by the pericardial portion of the cœlom, which is connected dorsally, on each side, with the corresponding lateral portions of the cœlom; and ventral to the hind-gut is the cloacal membrane. Between the pericardial region at the one end and the cloacal membrane at the other lies the umbilical orifice, through which the mid-gut communicates with the yolk sac, the intra-embryonic part of the cœlom with the extra-embryonic cœlom, and the allantoic diverticulum with the cloaca (Figs. 45, 56).

THE LIMBS.

When it is first defined the embryo is entirely devoid of limbs (Fig. 57). During the third week a superficial ridge appears on each side, along the line of the intermediate cell tract in the interior. This is the **Wolffian ridge**, and upon it the **limb buds**, which are the rudiments of the fore and hind limbs, are formed, as secondary elevations; the fore-limb buds preceding the hind-limb buds in time of appearance (Fig. 58).

Shortly after it has appeared, each limb bud assumes a semilunar outline; it projects at right angles from the surface of the body, and it possesses dorsal and ventral surfaces, and cephalic or preaxial, and caudal or postaxial borders. The bud is the rudiment of the distal segment of the future limb, the hand in the case of the fore-limb, and the foot in the case of the hind-limb.

As the limb-rudiment increases in length the more proximal segments of the limb are differentiated, the forearm and arm in the case of the fore-limb, and the leg and the thigh in the case of the hind-limb. At the same time the limbs are folded ventrally, so that their original ventral surfaces become medial and their original dorsal surfaces lateral, and the convexities of the elbows and knees are directed laterally. At a later period, on account of a rotation which takes place in opposite directions in the fore- as contrasted with the hind-limbs, the convexity of the elbow is turned towards the caudal end of the body and that of the knee towards the cephalic end. It is only at much later periods of development, as the erect posture is assumed, that the convexity of the elbow is directed dorsally and the convexity of the knee ventrally.

The terminal or distal segment of each limb is, at first, a flat plate with a rounded margin, but it soon differentiates into a proximal or basal part and a more flattened marginal portion. It is along the line where these two parts are continuous that the rudiments of the **digits** appear. They become evident as small elevations on the dorsal surface of the limb bud about the fifth week; they extend peripherally, and by the sixth week the fingers project beyond the margins of the hand segment, but the toes do not attain to a corresponding stage of development until the early part of the seventh week.

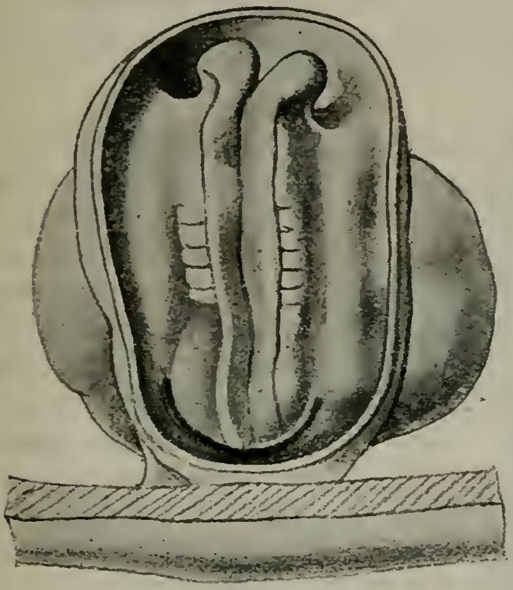

FIG. 57.—VIEW OF DORSAL ASPECT OF A HUMAN EMBRYO—1·38 mm. long, before the appearance of the limbs. (From Keibel and Elze, *Normaltafeln.*)

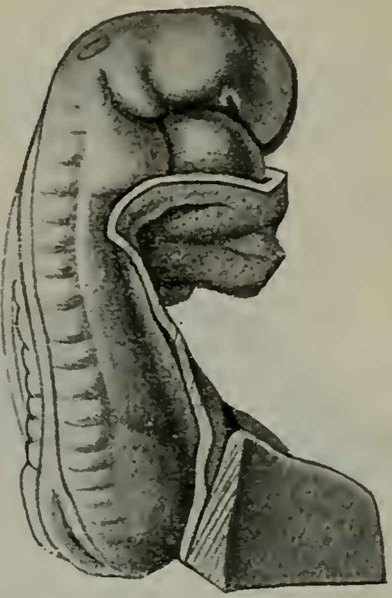

FIG. 58.—DORSAL LATERAL VIEW OF A HUMAN EMBRYO — 2·4 mm. long. The Wolffian ridge is seen at the lateral border of the mesodermal somites. (Keibel and Elze, *Normaltafeln.*)

The **nails** are later developments. They appear at the third month and reach the ends of the digits at the sixth month.

Each limb bud is essentially an extension from a definite number of segments of the body. It consists, at first, of a core of mesoderm covered by ectoderm. As it grows the anterior branches of the spinal nerves of the corresponding segments are prolonged into it, together with a number of blood-vessels. The nerves remain as the nerves of the fully developed limb, but the blood-vessels are reduced in number and are modified to form the permanent main trunks.

The greater part, if not the whole, of the mesodermal core of the primitive limb-rudiment is derived from somatic mesoderm of the lateral plate. As the development proceeds it is differentiated into the cartilaginous, muscular, and other connective tissue elements which are the rudiments of the skeletal framework and the muscles and fasciæ of the adult limb.

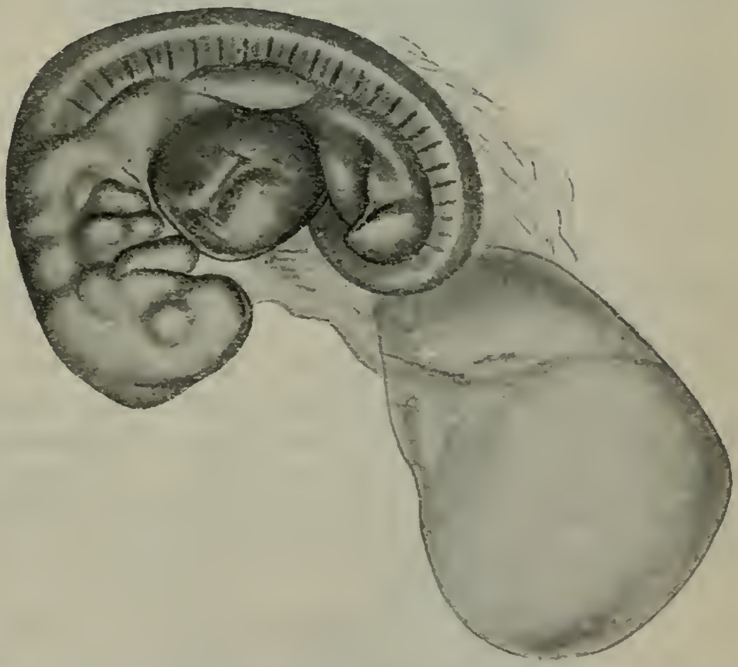

FIG. 59.—LATERAL VIEW OF A HUMAN EMBRYO—2·1 mm. greatest length, showing limb buds projecting from the Wolffian ridge. (Keibel and Elze, *Normaltafeln.*)

It is uncertain whether or not the muscle elements of the mesodermal core are derived from the lateral plate mesoderm, or from muscle cells which have migrated into the limb, from the muscle plates of the segments from which the limb is formed and from which muscles of the body wall are developed; and although it is generally believed that the bone which replaces the cartilaginous skeletal rudiments is produced by mesodermal cells, it has been asserted that the bone-producing cells originate in the ectoderm and migrate from the surface into the interior.

THE EARLIER MODIFICATIONS OF THE PRIMITIVE ENTODERMAL ALIMENTARY CANAL AND THE FORMATION OF THE STOMATODÆUM AND PROCTODÆUM.

The greater part of the permanent alimentary canal is derived from the entodermal sac and is therefore lined by entoderm cells. This part is enclosed in the embryo as the latter is folded off from the remainder of the zygote (Fig. 56), but the cephalic and caudal portions of the alimentary canal are formed by the enclosure of part of the external space and are, therefore, lined by ectoderm.

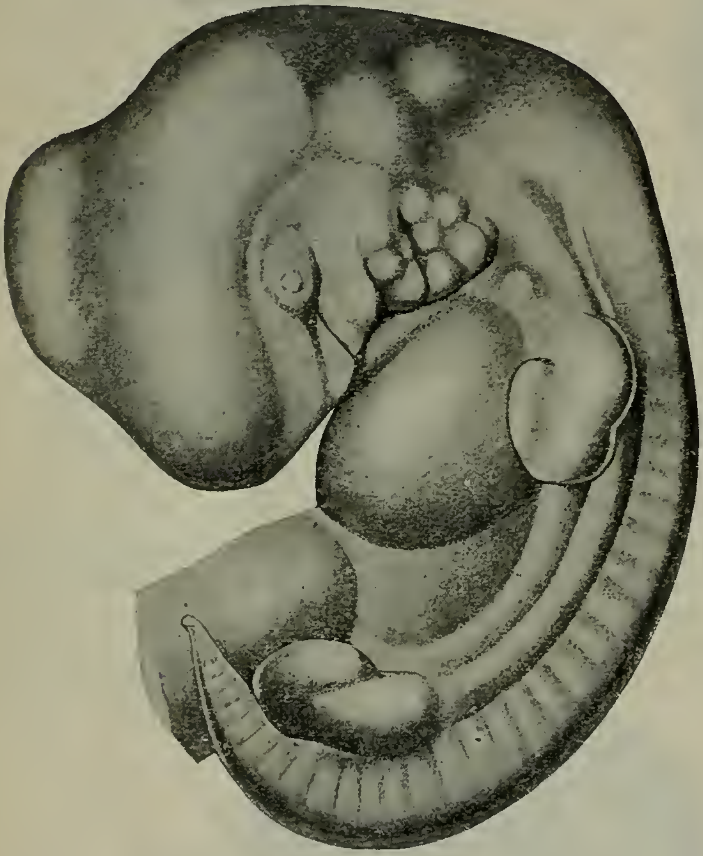

Fig. 60.—Lateral View of a Human Embryo—9·5 mm. long. (Keibel and Elze, *Normaltafeln.*)

Note that the limb rudiments no longer project at right angles from the side of the body but that they are bent ventrally.

The cephalic part is a portion of a space called the **stomatodæum** which lies, at first, between the ventrally bent extremity of the head and the bulging pericardial region (Fig. 56). At a later period it is enclosed laterally by the rudiments of the maxillæ or upper jaws, and caudally by the mandibular rudiments.

When it first appears the stomatodæum is separated from the cephalic end of the entodermal portion of the primitive canal by the bucco-pharyngeal membrane, but when that septum disappears, during the third week, the stomatodæum communicates with the fore-gut. Subsequently, it is separated into nasal and oral portions, and the oral portion forms that part of the mouth in which the gums and the teeth are developed.

The caudal part of the permanent canal is formed by the elevation of a surface fold round a pit-like hollow called the **proctodæum** (Fig. 66), which is separated from the caudal part of the entodermal portion of the alimentary canal, until about the fourth week, by a membrane called the **anal membrane**, a portion of the more extensive cloacal membrane mentioned on p. 44.

Differentiation of the Fore-gut.

Derivatives of the Lateral Wall.—Shortly after the fore-gut is enclosed, and whilst it is still separated from the stomatodæum by the bucco-pharyngeal membrane, its cephalic extremity dilates to form the primitive pharynx, and thereafter a series of thirteen pouches are formed in its walls, five in each lateral wall; the **pharyngeal** or **branchial pouches**; two in its ventral wall, one near the cephalic extremity, the rudiment of the **thyreoid gland**, and a second situated more caudally, which is the germ of the **respiratory system**, that is, the epithelial lining of the larynx, the trachea, the bronchi, and the lungs. The thirteenth pouch, **Seessel's pouch**, is formed in the dorsal wall, immediately caudal to the dorsal end of the bucco-pharyngeal membrane, and it projects into the floor of the primitive cranium.

Simultaneously with the formation of the pharyngeal pouches internally a series of clefts appear externally. They correspond in position with the first four pharyngeal pouches, and they are called the **pharyngeal** or **branchial clefts.**

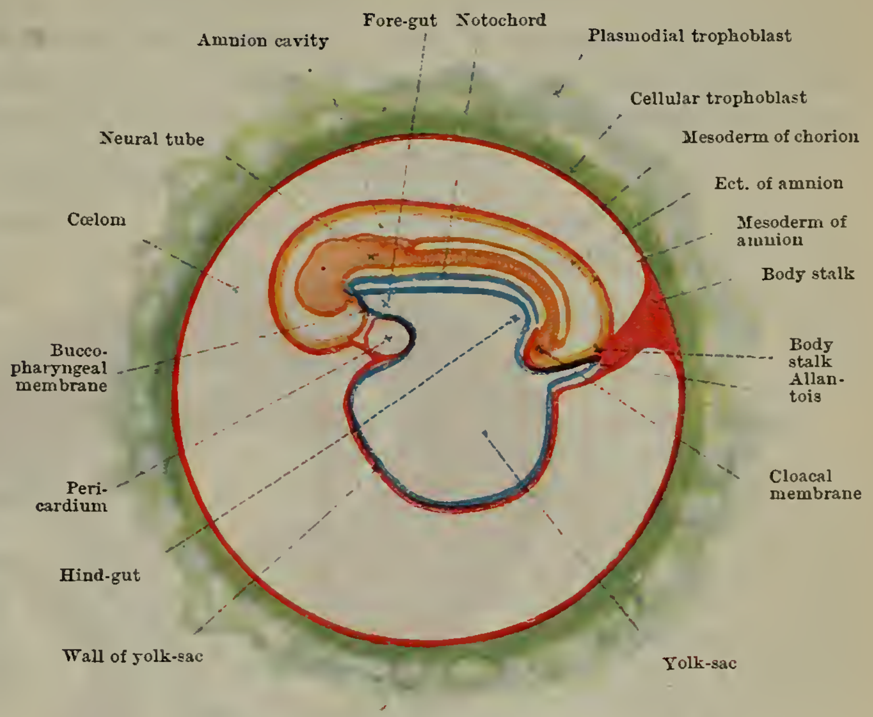

FIG. 61.—SAGITTAL SECTION OF ZYGOTE SHOWN IN FIG. 44.

By means of the pharyngeal pouches and clefts the lateral boundary of the cephalic part of the fore-gut, on each side, is divided into a series of bars, the **pharyngeal** or **branchial bars,** five in number, but the fifth is distinctly visible only in the inner aspect of the pharynx.

The first of the pharyngeal bars is the rudiment of the maxillary and mandibular regions. It is called the **mandibular arch.** The second is the **hyoid arch,** and the remainder are the branchial arches proper.

When they first appear, the arches extend from the level of the dorsal wall of the fore-gut to the pericardium but, as growth proceeds, and the neck is developed between the head and the pericardium, the ventral ends of the arches of opposite sides meet in the ventral wall of the primitive pharynx. The growth of the mandibular and the hyoid arches soon greatly exceeds that of the branchial arches proper, and the latter gradually recede from the surface until, on each side, they lie at the bottom of a depression, the **precervical sinus,** which is overlapped by the caudal border of the hyoid arch. As the overgrowth of the hyoid arch continues the opening of the precervical sinus to the surface is reduced to a narrow channel, the **precervical duct.** Afterwards this is obliterated, the sinus becomes the **precervical vesicle,**

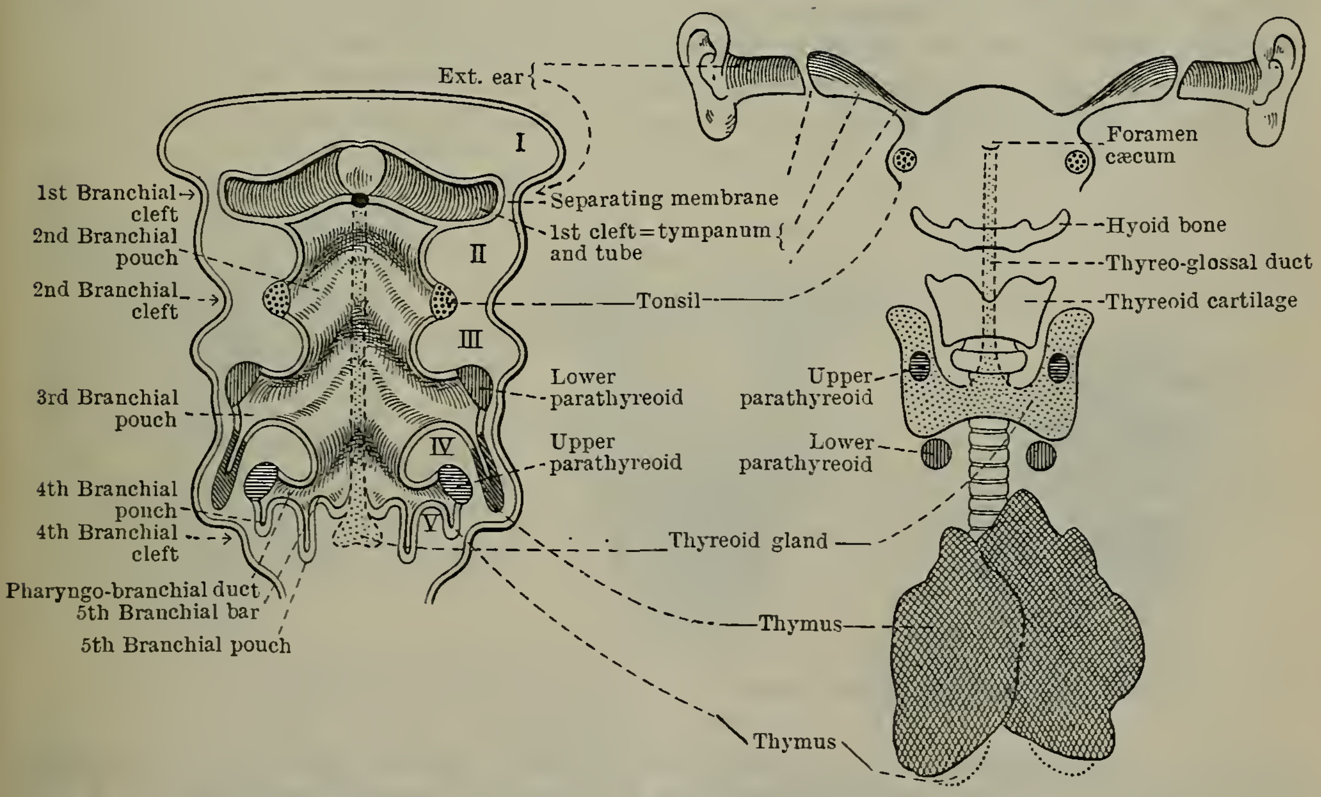

FIG. 62.—SCHEMA showing the branchial pouches, the branchial clefts, the branchial bars, and the thyreoglossal duct and some of their derivatives. I., II., III., IV., and V., the five branchial bars.

but the position of the original aperture of the precervical duct is temporarily indicated by a sulcus, the **precervical sulcus**, which soon disappears. The precervical vesicle lies at the side of the third pharyngeal cleft, and it is associated with the second and fourth clefts by narrow canals, the **branchial ducts**, which are the remains of the branchial clefts. Ultimately the precervical vesicle and the branchial ducts disappear, but it has been suggested that before the vesicle disappears a part of the lobe of the thymus of the same side is formed from its wall.

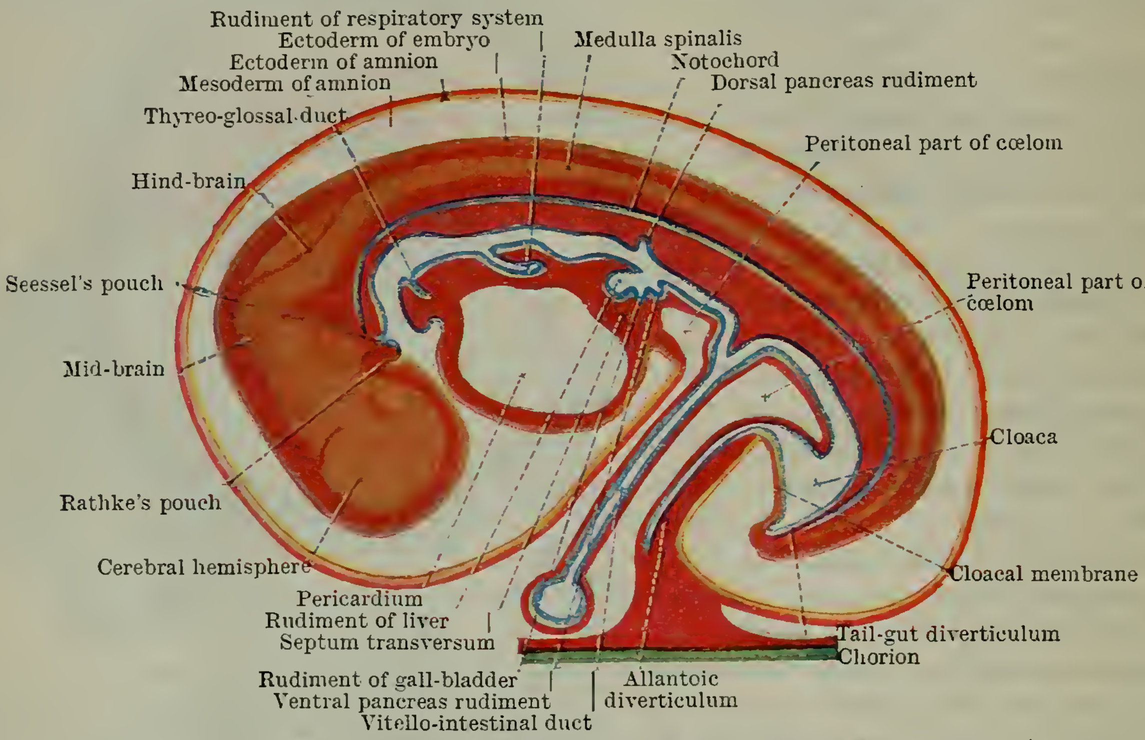

FIG. 63.—SCHEMA OF A LONGITUDINAL SECTION OF AN EMBRYO. (After Mall, modified.) Showing dorsal and ventral diverticula for alimentary canal. The heart is not shown.

The portion of the wall of the primitive pharynx which lies between each pair of visceral arches and separates the clefts externally from the pouches internally is called the **separating membrane**. In the earliest stages it consists of ectoderm, mesoderm, and entoderm; then, for a time, the mesoderm disappears to reappear again between the two epithelial strata at a still later period.

Round the margins of the dorsal part of the first pharyngeal or mandibular cleft are formed a series of tubercles which develop into the **auricle** of the external ear, and the cavity of the cleft becomes the **external acoustic meatus** (see p. 58). The first pharyngeal pouch and the adjacent part of the cavity of the primitive pharynx becomes the **tympanic cavity** and the **auditory** (O.T. **Eustachian**) **tube**. A part of the cavity of the second pharyngeal or hyoid pouch is represented in the adult by the supra-tonsillar recess, which lies in the side wall of the pharynx above the palatine tonsil (Fig. 62).

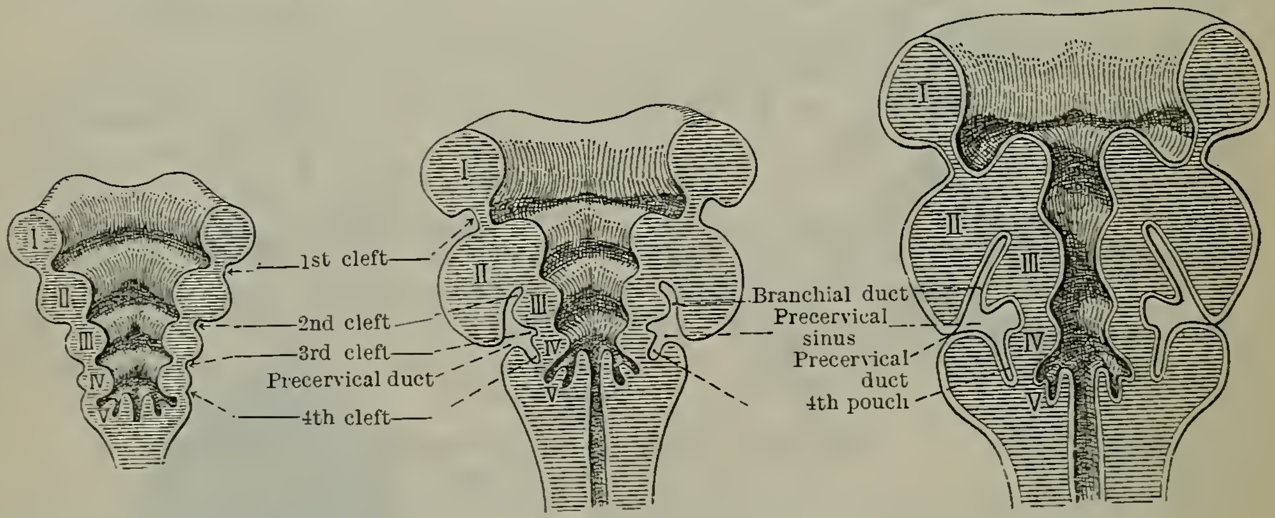

FIG. 64.—SCHEMA showing the formation of the precervical sinus, the branchial ducts, and the precervical sulcus.

The third pharyngeal pouch opens like the first and second directly into the cavity of the fore-gut, but the fourth and fifth pouches lie in the lateral wall of a common recess which opens by a single aperture, the **pharyngo-branchial duct**, into the cavity of the primitive pharynx (Fig. 62).

The cavities of the third, fourth, and fifth pouches ultimately disappear, but before the disappearance takes place diverticula which, at first, are hollow but, afterwards, become solid are given off from the ventro-lateral parts of each, and solid epithelial outgrowths, the epithelial bodies, are formed from the dorso-lateral walls of the third and fourth pouches (Fig. 62).

The ventral diverticulum from the third pouch, on each side, forms the main part of the corresponding lobe of the **thymus**, and the ventral diverticulum of the fourth pouch either takes part in the formation of the thymus or it entirely disappears. The rudiment of the thymus is formed in the neck, but as the gland differentiates it extends and it migrates caudally, until its cephalic end lies near the caudal end of the thyreoid gland, at the level of the sixth ring of the trachea, and its caudal end is in the thorax at the level of the fourth costal cartilage.

The epithelial bodies derived from the third and fourth pharyngeal pouches form the structures known in the adult as the **parathyreoid bodies.** That derived from the third pouch migrates caudally more rapidly than its fellow formed from the fourth pouch; consequently the parathyreoid derived from the fourth pharyngeal pouch lies at the middle of the dorsal border of the corresponding lobe of the adult thyreoid gland, and the parathyreoid formed from the third pharyngeal pouch is situated at the caudal end of the corresponding lobe of the thyreoid gland and close to the cephalic end of the thymus.

The diverticulum formed from the ventral part of the fifth pharyngeal pouch is the **ultimo-branchial body.** After it separates from the pouch it becomes solid and is associated with the corresponding lobe of the thyreoid gland, but, apparently, in the human subject, it takes no part in the formation of that gland.

Derivatives of the Ventral Wall.—The diverticulum from the ventral wall of the primitive fore-gut, which is situated nearest the cephalic or anterior end of the gut, is the rudiment of the thyreoid gland. It commences in the median plane, between the ventral ends of the mandibular and hyoid arches, and grows ventrally, into the substance of the neck, then turns caudally, ventral to the cartilages which form in the second, third, and fourth arches, from which the hyoid bone and the cartilages of the larynx are developed. When the caudal end of the diverticulum reaches the region where the cephalic or anterior portion of the trachea will be formed it becomes bilobed, and thus is differentiated into the isthmus and the two lobes of the permanent gland. The stalk of the diverticulum, which extends from what becomes the oral part of the primitive pharynx to the isthmus of the gland, is the **thyreoglossal duct.** Its cephalic end remains as the **foramen cæcum,** which is situated in the dorsum of the tongue, at the junction of the anterior two-thirds with the posterior third. The caudal end sometimes persists and is transformed into the third or pyramidal lobe of the thyreoid gland, which is attached to the dorsal border of the isthmus (Figs. 62, 67).

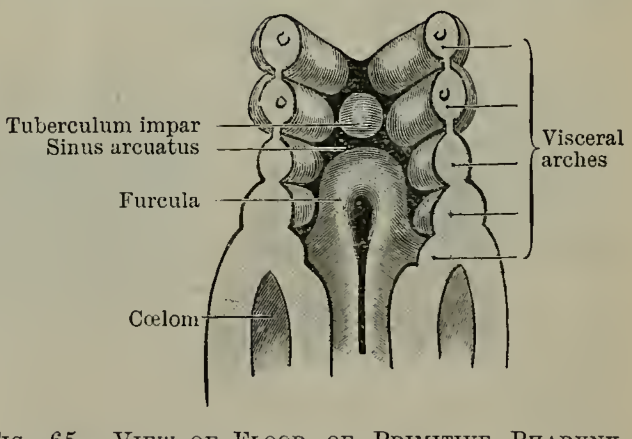

Fig. 65.—View of Floor of Primitive Pharynx, showing the furcula with the groove, from which arise the cavities of the larynx, the trachea, the bronchi, and the alveoli of the lungs.

The more caudally situated diverticulum from the ventral wall of the fore-gut is the **rudiment of the respiratory system** (Figs. 65, 66). When it first appears it has the form of a longitudinal groove bounded at its cranial end and laterally by an elevated ridge, named by His the **furcula** (Fig. 65). The caudal end of the groove soon dilates into a pouch, and then the pouch and groove are separated from the more dorsal part of the fore-gut, which becomes the **œsophagus,** by a constriction, which passes from the caudal towards the cranial end. The constricting process ceases before the separation reaches the cranial extremity of the respiratory rudiment, which remains, therefore, in communication with the pharynx and forms the permanent laryngeal aperture. The tube formed by the separation of the groove is differentiated into the larynx and the trachea, and the caudal terminal dilatation soon divides into two lateral lobes, each of which is the rudiment of the epithelium lining the bronchi and the lung of the corresponding side.

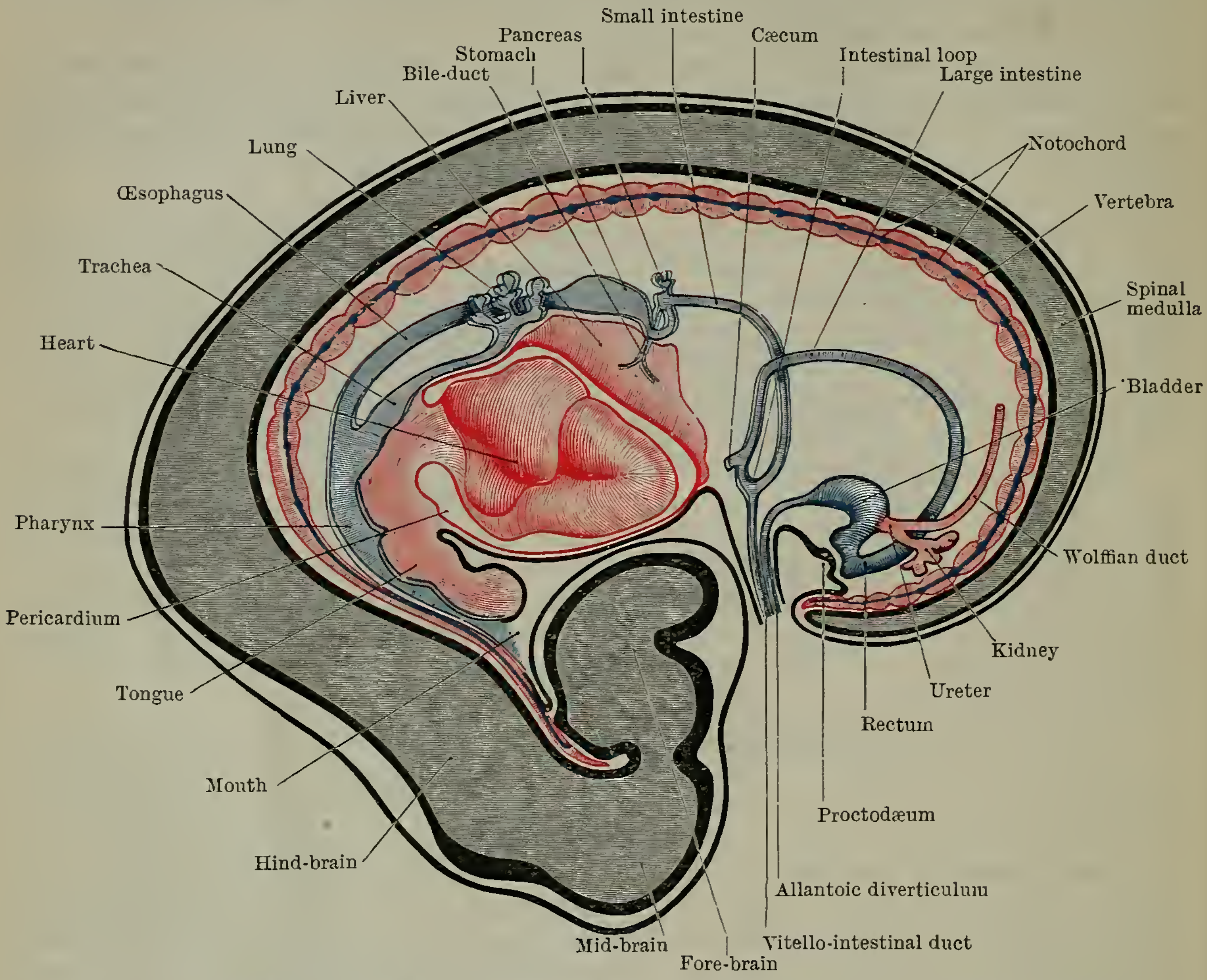

FIG. 66.—FURTHER DEVELOPMENT OF THE ALIMENTARY CANAL, AS SEEN IN A HUMAN EMBRYO ABOUT FIVE WEEKS OLD (Diagrammatic).

The tongue is well formed, the trachea and œsophagus are separated, the bronchi have commenced to branch; the duodenal curve is well formed, and the cæcum has appeared in the loop of the mid-gut. The cloaca is partially separated into genito-urinary and rectal portions.

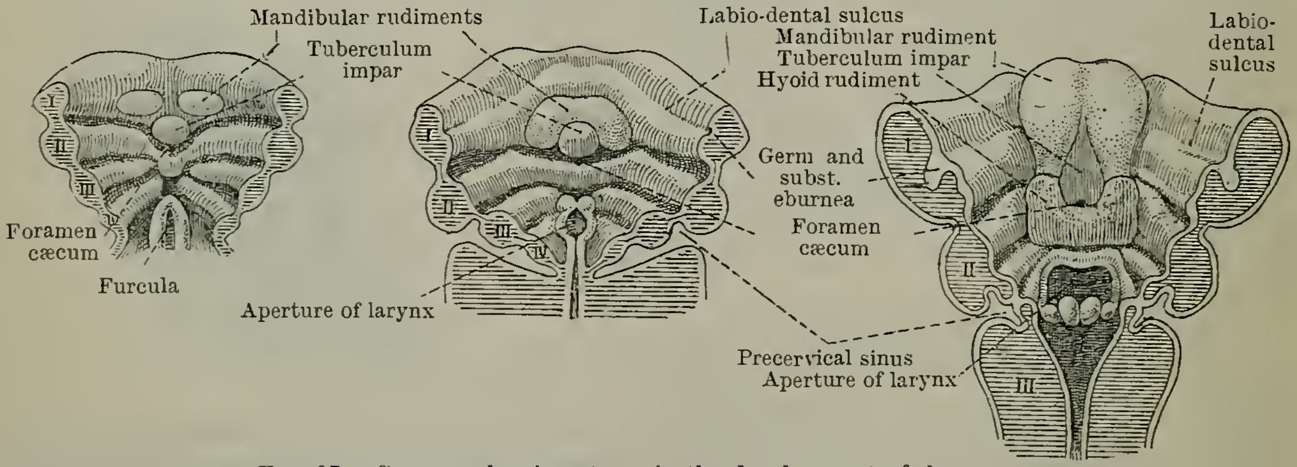

FIG. 67.—SCHEMA showing stages in the development of the tongue.

The Tongue.—The tongue is formed by *four separate rudiments* which lie in the ventral part of the cranial end of the primitive pharynx. Two of these are elevations formed on the caudal surfaces of the ventral ends of the mandibular arches, one on each side. The third is a median elevation, the **tuberculum impar**, which is situated immediately caudal to the conjoined ventral ends of the mandibular arches, and the fourth, called the **copula**, formed by the conjoined ventral ends of the second arches, is separated from the tuberculum impar by the orifice of the thyreoid rudiment (Fig. 67).

The two lateral elevations on the mandibular arches unite to form the greater part of the anterior two-thirds of the tongue, upon which all the papillæ are developed. The tuberculum impar either disappears or it forms the median part of the anterior two-thirds of the organ. The posterior third of the tongue, which lies in the ventral or anterior wall of the permanent pharynx, is formed from the copula of the second arches. It follows from what has been said that the commencement of the thyreoid rudiment, which persists in the adult as the foramen cæcum of the tongue, must lie at the junction of the posterior third with the anterior two-thirds. In many cases it appears to lie in the dorsal end of the anterior two-thirds, a position which may be associated with the fact that, in some cases, the rudiment of the thyreoid passes through the substance of the tuberculum impar and not from between the tuberculum impar and the ventral ends of the hyoid arches.

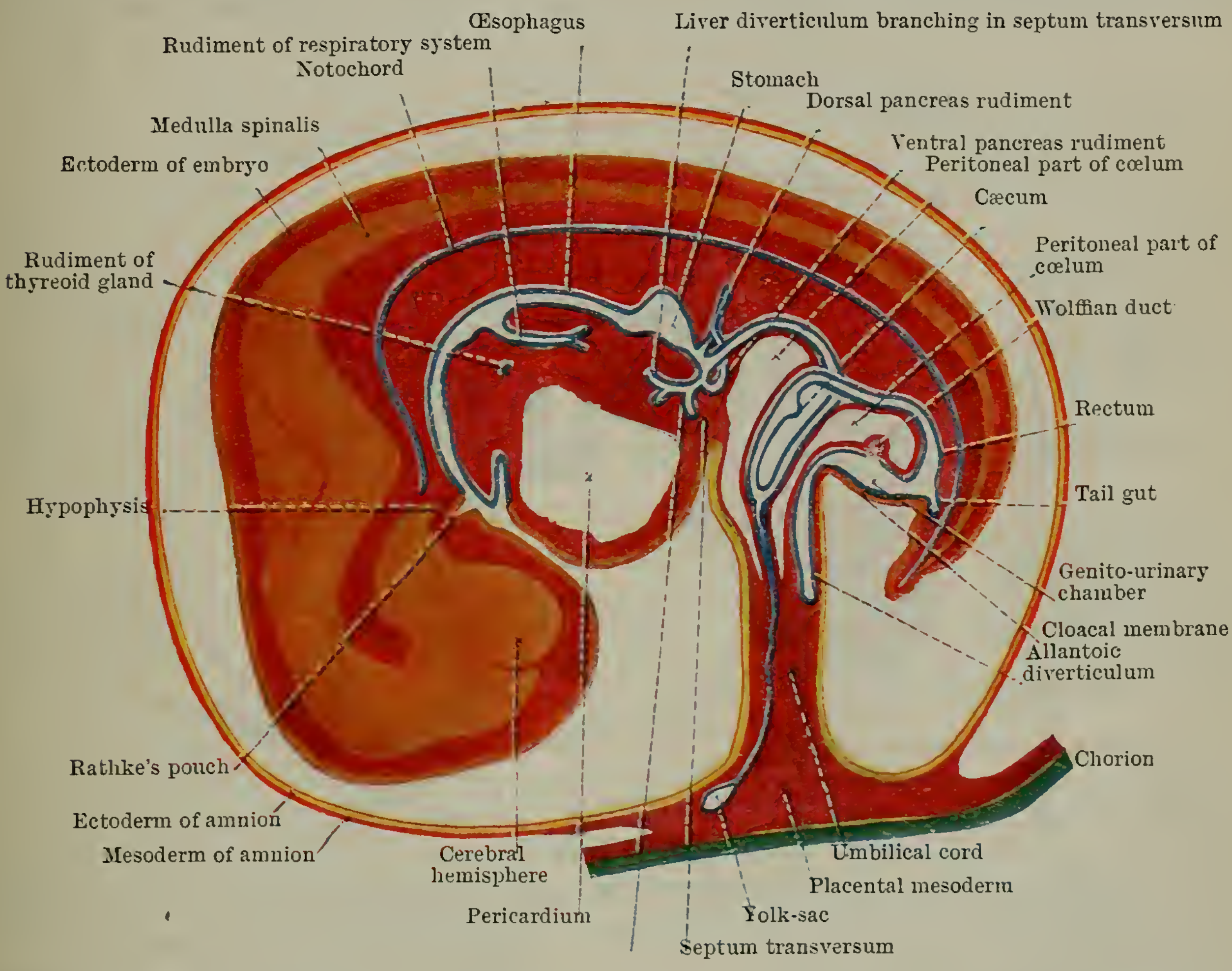

FIG. 68.—SCHEMA showing further stages in the development of the diverticula from the primitive gut and modifications of the mid-gut and the mid-gut regions. The heart is not shown. (After Mall, modified.)

Derivative of the Dorsal Wall (Seessel's Pouch).—The dorsal diverticulum from the cranial end of the fore-gut, to which the above term is applied, enters the base of the occipital region of the primitive head. The ultimate fate of the pouch is unknown in the human subject, but it has been suggested that it is represented by a depression in the mucous membrane of the cranial part of the pharynx, close to the pharyngeal tonsil, which is known as the pharyngeal bursa.

The reader who has followed this description will have noted that from the cranial portion of the fore-gut are formed the caudal or inferior part of the mouth (with the exception of the lips, teeth, and gums), the pharynx, the thyreoid gland, the thymus, the parathyreoids, the respiratory organs, and the œsophagus. The more caudally situated portion of the fore-gut is differentiated into the stomach and the first and second parts of the duodenum.

The stomach is formed from the part of the fore-gut immediately adjacent to the œsophagus, and the duodenum from the more caudally placed portion, which is directly continuous with the mid-gut.

The Liver and Pancreas.—When the embryo is about three weeks old and has attained a length of 2·5 mm. a ventral diverticulum appears in the ventral wall of the duodenal part of the fore-gut, and when the age of the embryo is about four weeks and its length increased to about 4 mm. a diverticulum is formed in the dorsal wall a little nearer the cranial end. The ventral pouch is the rudiment of the *liver*, the *gall bladder*, the *bile-ducts*, and a portion of the *pancreas*, and the remainder of the pancreas is formed from the dorsal diverticulum (Figs. 63, 68, 69).

The Derivatives of the Mid-Gut.—The mid-gut is that part of the primitive alimentary tract which lies between the more definitely enclosed fore-gut and hind-gut, and it is in free communication with the yolk-sac by the vitello-intestinal duct. It is transformed into the greater part of the small intestine.

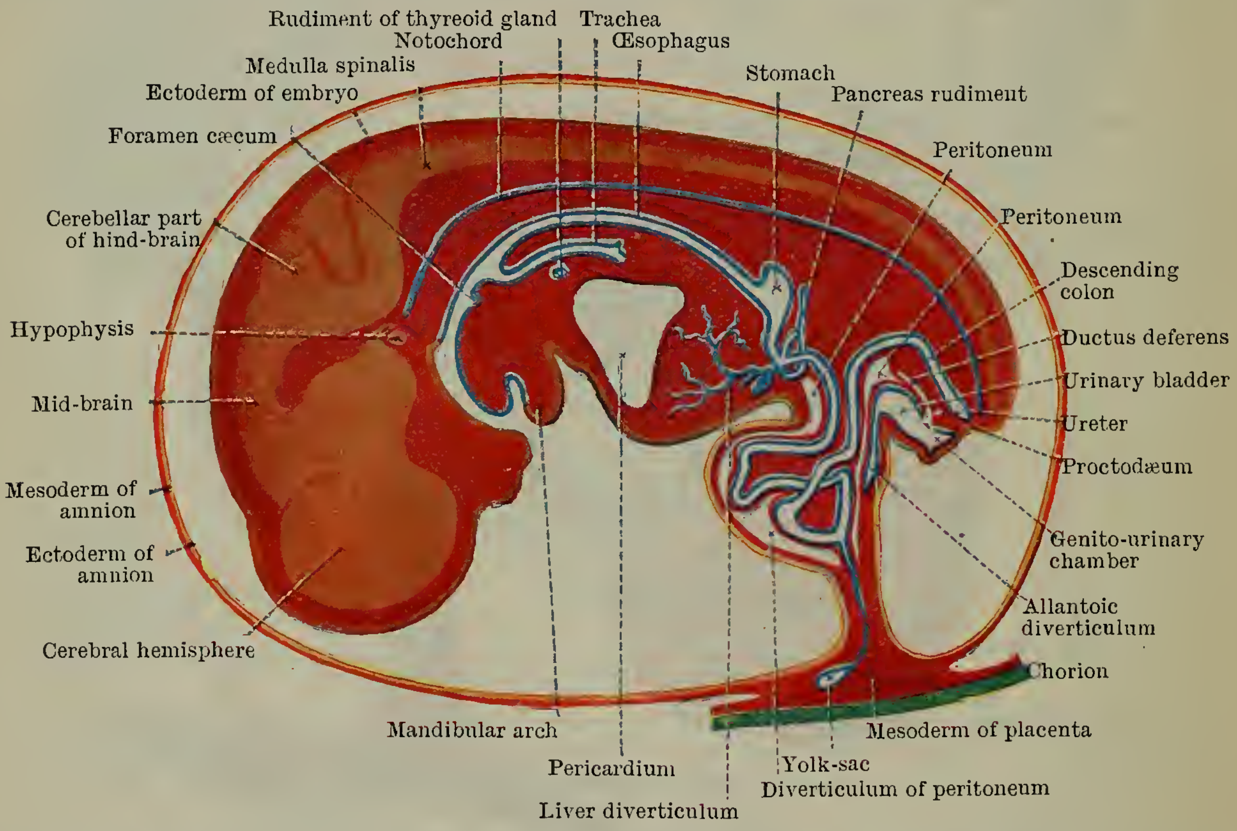

FIG. 69.—SCHEMA showing complete separation of cloaca into dorsal and ventral parts and the temporary ventral hernia of a portion of the gut through the umbilical orifice. The heart is not shown. (After Mall, modified.)

The Derivatives of the Hind-Gut.—The parts formed from the hind-gut are:—(1) The terminal part of the ileum; (2) the whole of the large intestine, except a small portion of the anal canal; (3) the urachus, the urinary bladder, the urethra in the female, and the greater part of the urethra in the male.[1]

As development proceeds the mid-gut and the cephalic part of the hind-gut form a U-shaped tube which possesses a cranial and a caudal limb, and a ventral extremity which is connected with the yolk-sac by a narrowed and elongated canal, **the vitello-intestinal duct** (Fig. 63).

Upon the caudal limb of the loop, about the middle of its dorso-ventral height, an enlargement appears which is the rudiment of the **cæcum** and **vermiform process** of the adult. After this rudiment has formed the caudal limb of the loop undergoes rotation, being carried first to the left, then cranially, and finally to the right. As it is carried to the right it crosses the cranial (later ventral) aspect of the cranial limb of the loop, and when the rotation is completed the regions of the jejunum and ileum, the cæcum, the ascending and the transverse colon are defined.

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[1] T. B. Johnston, *Journ. of Anat.*, Oct. 1913 ; H. v. Berenberg-Gossler, *Anat.*, Heft. 1913.

After the rotation has occurred the tubular intestine, formed from the mid-gut and the anterior part of the hind-gut, undergoes rapid elongation and is thrown into a number of coils.

When the embryo has attained the length of 10 mm., and is a little over a month old, the greater portion of the coiled gut passes through the umbilical orifice into an expansion of the cœlom formed in the proximal part of the umbilical cord (see p. 52) (Fig. 69), which has replaced the allantoic or body-stalk as the medium by which the embryo is attached to the chorion. The herniated coils remain in the root of the umbilical cord until the embryo is about 40 mm. long, and about ten weeks old, when they return to the abdomen, and the cœlomic space in the umbilical cord disappears.

The Derivatives of the Posterior Part of the Hind-Gut.—When the caudal portion of the hind-gut is first enclosed its terminal extremity and its ventral wall are bounded by the caudal portion of the primitive streak, which is bent ventrally during the folding-off of the embryo.

The terminal part of this portion of the gut becomes expanded, forming a chamber called the **entodermal cloaca**, into the ventral parts of which the ducts of the primitive kidneys, the pronephric or **Wolffian ducts**, open, one on each side.

The ventral part of the cephalic end of the cloaca is continuous with the allantoic diverticulum, and the dorsal part with a tubular portion of gut which forms the descending and probably also the iliac and pelvic portions of the colon.

As the temporary tail is formed and projected first caudally and then ventrally, by the growth energy of the nodal point situated at the caudal end of the neural tube, a diverticulum of the caudal end of the dorsal part of the cloaca is prolonged into it, forming the **tail gut**. This soon becomes shut off from the cloaca. It entirely disappears before the temporary tail is absorbed into the caudal end of the body (Figs. 63, 68, 69).

At a later period the cloaca itself is separated into a dorsal part, the rectum, and a ventral part, the uro-genital chamber, by the formation of a septum, which commences in the angle between the allantoic diverticulum and the ventral wall of the hind-gut, and is prolonged caudally till it reaches and fuses with the internal surface of the cloacal membrane, which thus becomes separated into uro-genital and anal portions, both of which disappear about the eighth week.

In both sexes the uro-genital section of the cloaca is separable into three parts: (1) a cranial part, which is converted into the urachus or middle umbilical ligament; (2) an intermediate part, which becomes the urinary bladder; and (3) a caudal part, which, in the female, is transformed into the urethra and the vestibule of the vagina, whilst in the male it is developed into the urethra.

Derivatives of the Stomatodæum.—When the stomatodæum is first definitely established, it is bounded cranially by the caudal surface of the ventrally bent terminal part of the head, caudally by the conjoined ventral ends of the mandibular arches, and laterally by the dorsal parts of the mandibular arches, and the maxillary processes, which grow ventrally from the dorsal parts of the mandibular arches. The space is open ventrally, and it is closed dorsally by the bucco-pharyngeal membrane, which separates it from the fore-gut (Fig. 61).

The bucco-pharyngeal membrane disappears about the third week, and about the twenty-first day a diverticulum from the stomatodæum is projected into the caudal surface of the head, from the point where that surface originally joined the dorsal end of the external surface of the bucco-pharyngeal membrane. The diverticulum is **Rathke's pouch**. The cranial extremity of the pouch comes into relation with the hypophyseal diverticulum from the floor of the third ventricle, and dilates. The stalk which connects the dilated terminal part of the diverticulum with the stomatodæum disappears, and the terminal vesicle becomes the anterior lobe of the hypophysis (O.T. pituitary body) (Figs. 63, 68, 69). (See Ductless Glands.)

The Separation of the Stomatodæum into Nose and Mouth.—In the cephalic boundary of the stomatodæal space lies the ventral end of the head, which is called the **fronto-nasal process**.

In the fronto-nasal process, on each side of the median plane, is situated a shallow pit, the **olfactory pit**, and by the pits the process is divided into a median part, the **median nasal process**, and two lateral parts, the **lateral nasal processes.** Further, the margin of the median process is divided by a median cleft into right and left **globular processes** (Fig. 70).

The orifices of the olfactory pits are directed laterally, therefore the lateral nasal processes lie dorsal to the median nasal process in the cranial boundary of the stomatodæal space, and as their margins increase in height the pits deepen.

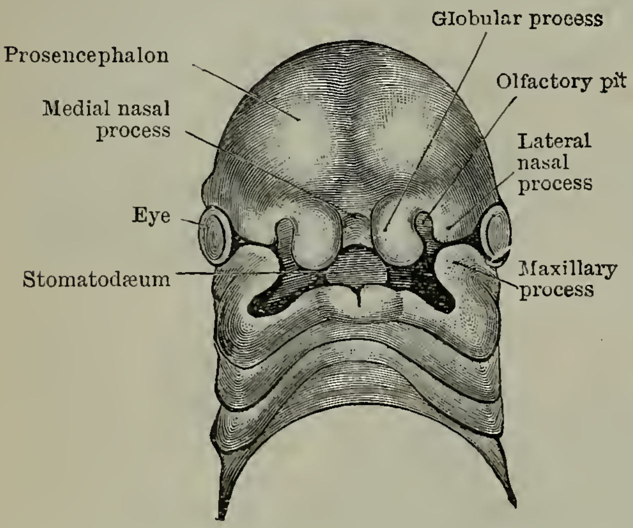

Fig. 70.—Anterior View of Boundaries of Stomatodæum before Completion of Primitive Upper Lip.

At this period the cranial boundary of the stomatodæum is divided by the median sulcus and the olfactory pits into four projections—the two globular processes, each of which lies between the median sulcus and an olfactory pit, and the two lateral nasal processes, which form the dorso-lateral borders of the olfactory pits. The lateral boundaries are formed by the maxillary processes and the dorsal parts of the mandibular bars, and the caudal boundary is formed by the medially turned and conjoined ventral parts of the mandibular bars. Immediately cranial to the maxillary process, on each side, is the projecting eye; and leading from it, between the maxillary process and the lateral nasal process, is the **naso-lacrimal sulcus.**

As growth proceeds and each maxillary process grows ventrally, its extremity fuses with the caudal or posterior border of the lateral nasal process, and then, carrying the lateral nasal process with it, it fuses with the globular process of the same side.

After the fusion of the maxillary processes, and the caudal borders of the lateral nasal processes, with the globular processes has occurred, the olfactory pits are completely separated, for a time, from the stomatodæum, and they lie in the ledge which now forms the cranial boundary of the stomatodæal opening. This ledge consists of the two globular processes, fused into a single mass, and the two maxillary processes, the caudal[1] edges of the lateral nasal processes being shut off from the margin of the ledge by the maxillary processes (Fig. 71).

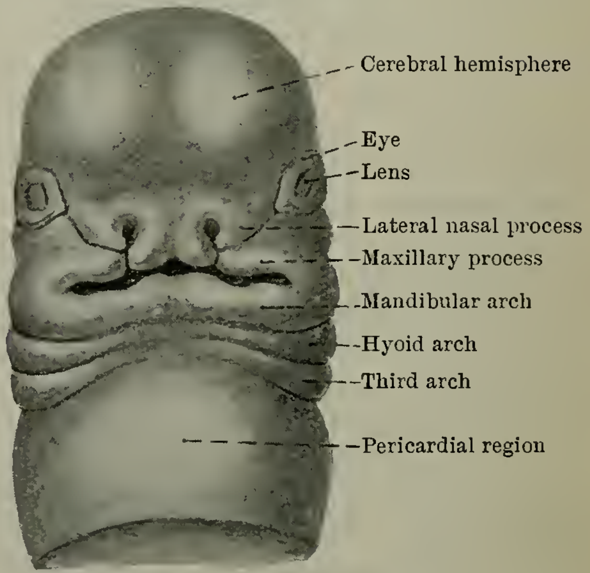

Fig. 71.—Schema of Anterior View of the Head of a Human Embryo showing the Completion of the Primitive Upper Lip.

After the ledge is completed the dorsal ends of the olfactory pits are separated from the stomatodæal cavity by a thin membrane, but this soon disappears, and the pits open again into the stomatodæal space, through apertures which are called the **primitive choanæ.**

After the formation of the primitive choanæ a ledge grows from the medial surface of each maxillary process towards the median plane, dorsal to the choanæ. These ledges, the **palatine processes**, meet and fuse during the third month of fœtal life, the fusion commencing ventrally and being completed dorsally in the region of the uvula. As the ledges meet and fuse, the stomatodæal cavity is separated into a cranial and a caudal portion. The cranial part is the **nasal cavity**; it is soon divided into two lateral halves by a septum which passes caudally from the base of the cranium. The caudal portion of the stomatodæum blends with the ventral part of the primitive pharynx. Its cavity forms the cavity of the vestibule of the mouth and from its walls the gums and teeth are developed.

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[1] Inferior in erect posture.

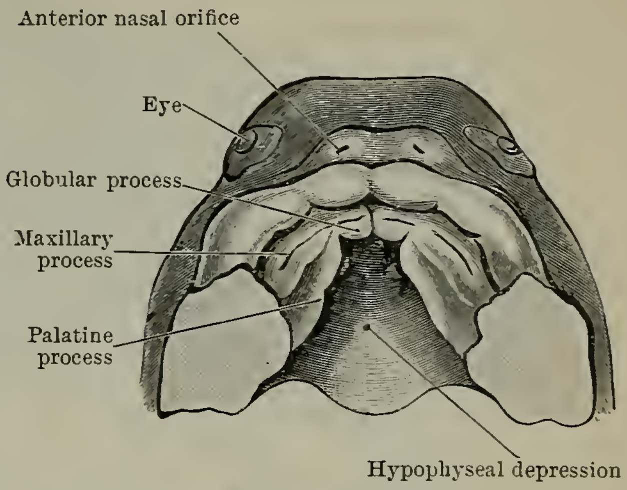

Fig. 72.—Portion of the Head of a Human Embryo about 2½ months old (His). The lips are separated from the gums, and the line of the common dental germ is visible in the latter. The palatine processes are growing inwards from the maxillary processes.

The details of the process by which the primitive lips, which form the boundaries of the primitive buccal aperture, are separated into the permanent lips, and the gums are defined, are described in the section dealing with the digestive system.

The Derivative of the Proctodæum.—The proctodæum is a surface depression which owes its origin to the elevation of the surface round the margin of the anal membrane. It forms the lowest portion of the pars analis recti of the adult.

Uro-genital System.—The formation of the internal parts of the uro-genital system from the intermediate cell tract, the uro-genital chamber, and the differentiation of the external genitals in the region of the cloacal membrane are described in the account of the uro-genital system.

The development of the auditory organ is so intimately associated with the development of the pharyngeal portion of the primitive gut that a short consideration of the chief phenomena may with advantage be introduced here; but for the details of the development of the internal, middle, and external portions of the ear the student must refer to the account of the development given in association with the description of the auditory organ.

THE INTERNAL EAR, THE TYMPANUM AND AUDITORY TUBE, AND THE EXTERNAL EAR.

In the human subject, as in other mammals, the auditory organ consists of the **internal ear** or labyrinth, the middle ear or **tympanum**, with which is associated the **auditory tube** (O.T. **Eustachian**); and the **external ear**, which consists of the **external acoustic meatus** with the **auricle** at its lateral end.

The **internal ear** itself consists of two parts—the **cochlea**, which is the true organ of hearing, and the **vestibule** and the **three semicircular canals** connected with it, which are associated with the recognition of alterations in the position of the head, and, therefore, with the recognition and maintenance of equilibrium.

The whole of the internal ear is lined with ectodermal epithelium, the **auditory epithelium**, which is derived from the surface of the head of the embryo. It is recognisable in embryos of about 2·6 mm. (Fig. 73) as a thickened and slightly depressed plate of ectodermal cells which lies on the surface of the head, in the region of the hind-brain, dorsal to the second branchial cleft. As development proceeds the plate is gradually invaginated into the substance of the head, and is transformed into a pear-shaped vesicle called the **otic vesicle**. For a time the otic vesicle remains in communication with the exterior by a short tubular canal. As the canal disappears a diverticulum is formed from the vesicle immediately to the medial side of the deep end of the canal. The diverticulum grows dorsally as a narrow tube called the *recessus labyrinthi*. It is ultimately transformed into the **ductus** and **saccus endolymphaticus** of the adult ear (see Auditory Organ).

After it is separated from the surface the otic vesicle alters its position, until its ventral end lies in close relation to the dorsal wall of the pharynx, and, at the same time, it undergoes alteration of shape. The ventral part of the vesicle grows towards the median plane, along the ventral wall of the hind-brain. It forms the cavity and the lining epithelium of the **cochlea**; but it remains in connexion with the dorsal part by means of a narrow tube, the **canalis reuniens**, and as it grows in length it becomes converted into a spiral tube.

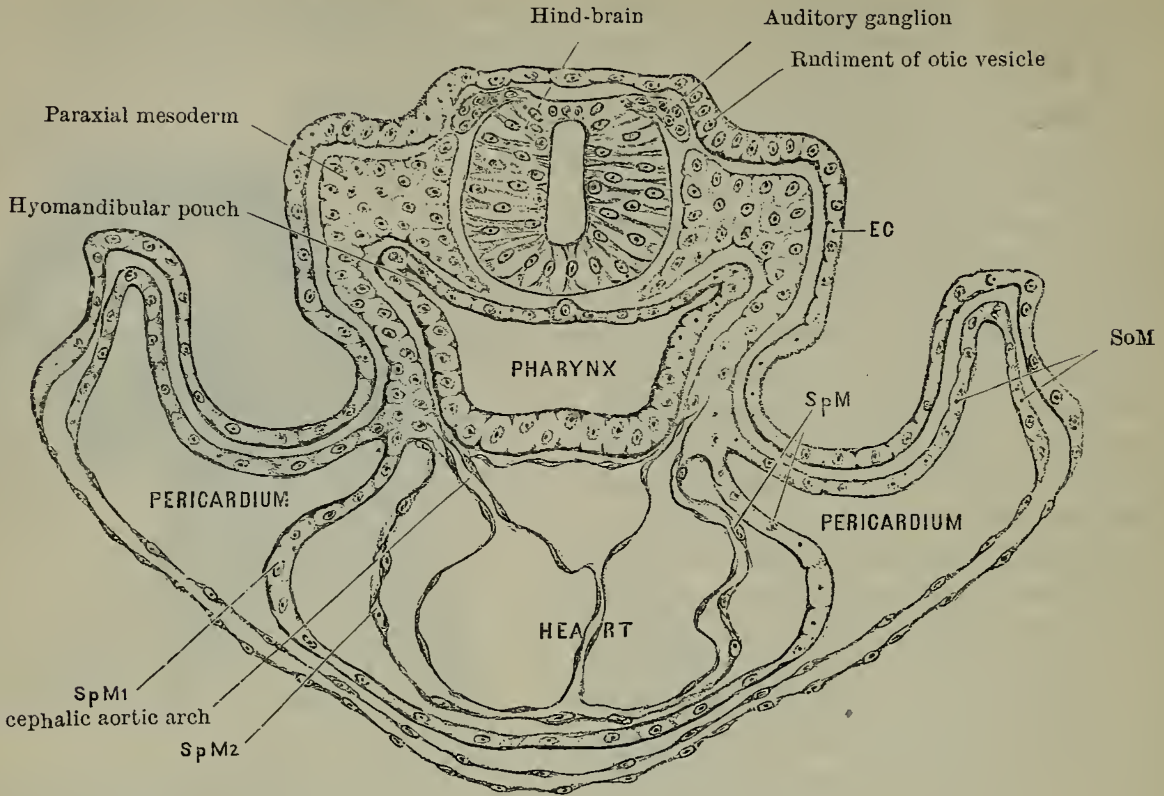

Fig. 73.—Transverse Section of a Rat Embryo.

Showing the relation of the paraxial mesoderm of the head to the lateral plates, the commencement of the formation of the otic vesicles and hyomandibular pouches and the relation of the primitive heart to the pericardium and fore-gut.

EC. Ectoderm. SoM. Somatic mesoderm. SpM. Splanchnic mesoderm.

The portion of the dorsal section of the primitive vesicle, which lies to the lateral side of the **recessus labyrinthi**, first expands and then becomes compressed and constricted into the form of three flat, purse-like diverticula which, by the partial obliteration of their cavities, become converted into the three **semicircular ducts** (see Sense Organs). The more ventral part of the dorsal section of the vesicle is divided, by a constriction of its lateral wall, into a dorsal part, the **utricle**, which remains in connexion with the semicircular ducts, and a ventral part, the **saccule**, which is united to the cochlea by the canalis reuniens. The apex of the constriction which separates the utricle from the saccule passes into the mouth of the ductus endolymphaticus, which is thus transformed into the Y-shaped canal which connects

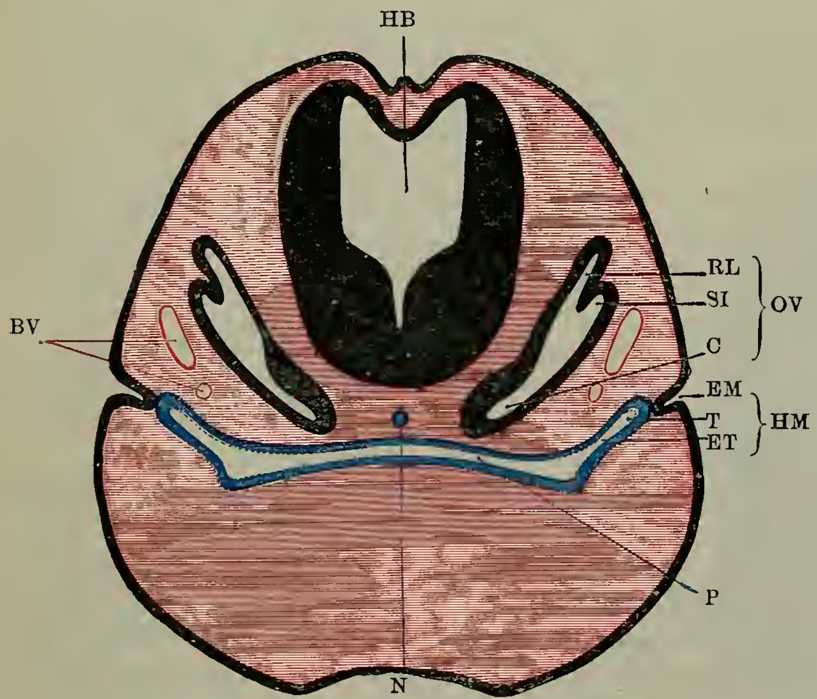

Fig. 74.—Transverse Section through the Head of an Embryo.

Showing the rudiments of the three parts of the ear and their relation to the hyomandibular cleft.

BV.	Blood-vessels.	N.	Notochord.
C.	Cochlea.	OV.	Otic vesicle.
EM.	Ext. acoustic meatus.	P.	Pharynx.
ET.	Auditory tube.	RL.	Recessus labyrinthi.
HB.	Hind-brain.	SI.	Stalk of invagination.
HM.	Hyomandibular cleft.	T.	Tympanum.

the utricle with the saccule. At a later period the closed extremity of the ductus endolymphaticus dilates and forms a small saccule, the **saccus endolymphaticus.** In the adult the saccus endolymphaticus lies in the posterior fossa of the skull, in relation with the posterior surface of the petrous part of the temporal bone and external to the dura mater.

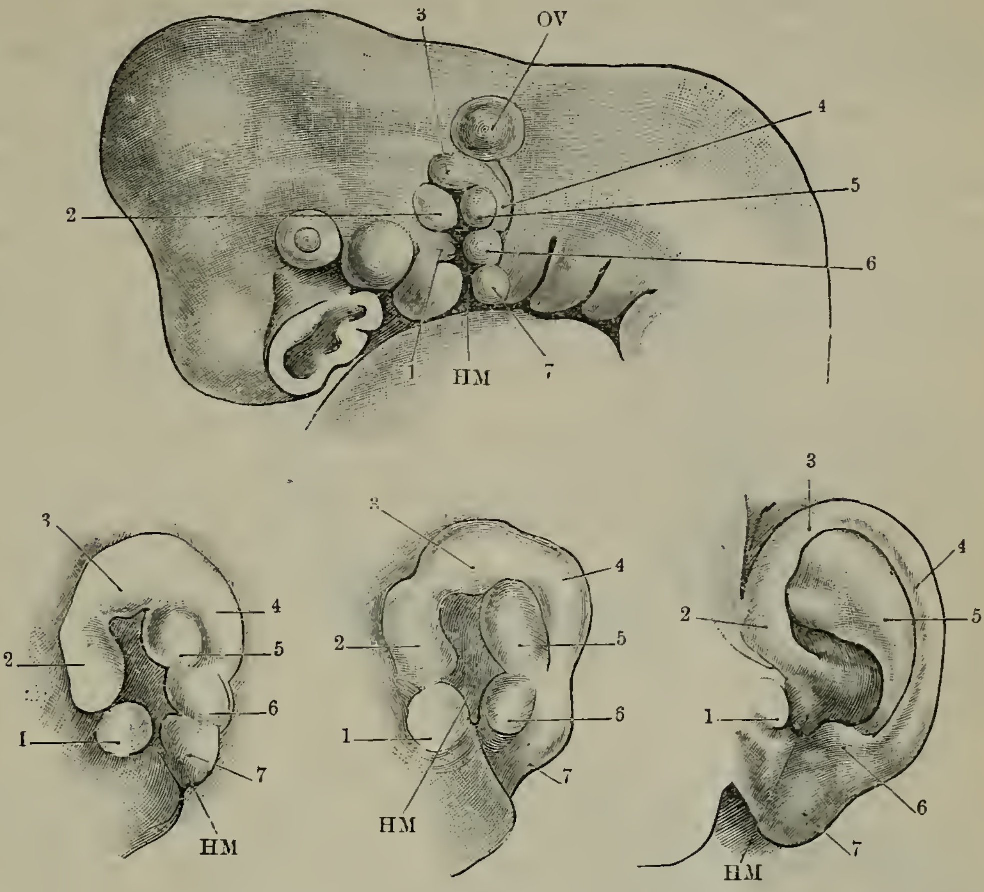

FIG. 75.—FIGURES, MODIFIED FROM HIS, ILLUSTRATING THE FORMATION OF THE PINNA.

1. Tuberculum tragicum = Tragus.
2. ,, anterius helicis } Helix.
3. ,, intermedium helicis } Helix.
4. Cauda helicis } Helix.
5. Tuberculum anthelicis = Antihelix.
6. Tuberculum antitragicum = Antitragus.
7. Tuberculum lobulare = Lobule.

HM. Hyomandibular cleft.
OV. Otic vesicle.

When the changes which have been mentioned are completed the primitive otic vesicle is transformed into the epithelial labyrinth.

At a later stage lymph spaces appear in the neighbourhood of the various parts of the epithelial labyrinth, and they become, in the adult temporal bone, the cavities of the semicircular canals which enclose the semicircular ducts, the vestibule, in which lie the utricle and saccule and the adjacent parts of the ductus endolymphaticus, and the scala vestibuli and the scala tympani of the bony cochlea, which lie immediately adjacent to the epithelial ductus cochlearis or scala media (see Auditory Organ).

As the lymph spaces appear around the epithelial parts of the labyrinth the mesoderm itself becomes first converted into cartilage and then into the petrous part of the temporal bone, except around the saccus endolymphaticus, which, therefore, in the adult, lies between the dura mater and the posterior surface of the petrous part of the temporal bone.

The **tympanum** and the **auditory tube** (O.T. **Eustachian**) are developed from the first branchial pouch.

The ventral part of the pouch disappears at an early stage. The dorsal extremity expands and is converted into the cavity of the tympanum, whilst the stalk of connexion with the pharynx is gradually constricted off from its lateral towards its medial end, and is converted into the auditory tube. The constriction commences when the embryo has attained a length of about 20 mm., that is about the beginning of the eighth week, and is completed about the end of that week when the embryo is about 25 mm. long.

After the auditory tube is defined it grows rapidly in length, and cartilage appears in its walls during the fourth month.

As the tympanic cavity increases in size the auditory ossicles—*stapes, incus,* and *malleus,* which are differentiated from the dorsal ends of the cartilages of the first and second branchial arches, are invaginated into it.

The **membrana tympani,** which separates the tympanum from the external acoustic meatus, is formed from the separating membrane which intervenes between the first branchial pouch and the first cleft. It consists, therefore, of an external covering of ectoderm, an internal lining of entoderm, and an intervening layer, of fibrous tissue, derived from the mesoderm.

The **external ear** is developed from the cavity and the boundaries of the first branchial cleft. The cavity of the cleft is transformed into the cavity of the external acoustic meatus, and on the mandibular and on the hyoid margins of the cleft three eminences appear. From the eminences on the two arches, and the skin immediately posterior to the eminences on the hyoid arch, are formed the various parts of the auricle, but the exact part played by the individual eminences, in the human subject, is as yet a matter of some doubt.

THE PROTECTION AND NUTRITION OF THE EMBRYO DURING ITS INTRA-UTERINE EXISTENCE.

Whilst it is passing down the uterine tube, and for a brief period after it enters the uterus, the zygote, or impregnated ovum, depends for its nutrition upon the yolk granules (deutoplasm) embedded in its cytoplasm.

As the human ovum is small, and as it contains but little deutoplasm, there is urgent necessity for the formation of adequate arrangements whereby external sources of nutritive supply may be acquired and maintained; that necessity leads to the early establishment of an intimate connexion between the zygote and the mother, which is one of the characteristic features of the development of the human embryo.

During the third week after fertilisation, as the embryo is beginning to be moulded from the embryonic region, and before the paraxial mesoderm commences to separate into mesodermal somites, a primitive heart and the rudiments of some well-defined blood-vessels are distinguishable in the embryo; but the details of the development of the vascular system and the establishment of the embryonic circulation cannot be well understood until the formation and structure of a group of closely associated extra-embryonic organs or appendages, derived from the zygote, and adapted for the nutrition and protection of the embryo, has been considered.

This group includes the chorion, the placenta, the amnion, the umbilical cord, and the yolk-sac.

THE MEMBRANES AND APPENDAGES.

The Chorion.—It has already been noted that when the zygote becomes a blastula it consists of three vesicles, a large vesicle enclosing two smaller vesicles and a mass of primary mesoderm (Fig. 35).

The wall of the large vesicle is composed of trophoblast (trophoblastic ectoderm), and its inner surface is in direct contact with the primary mesoderm.

A little later a cavity, the **extra-embryonic cœlom**, appears in the primary mesoderm, separating it into two layers, one lining the inner surface of the trophoblast and the other covering the outer surfaces of the two inner vesicles (Figs. 76, 77).

As soon as the extra-embryonic cœlom is established the **chorion** is formed; it consists of the trophoblast and its inner covering of mesoderm.

In the meantime the trophoblast has differentiated into two layers, an inner cellular layer, and an outer plasmodial layer. In the plasmodial layer cell territories are not defined, and it consists, therefore, of nucleated protoplasm.

The differentiation of the trophoblast into two layers occurs after the zygote is embedded in the mucous membrane of the uterus which is modified for its reception and which, after the modification has occurred, is called the **decidua**.

As development proceeds the trophoblast increases in thickness and it invades the decidua. As this invasion occurs the plasmodial layer of the trophoblast becomes permeated with spaces which are continuous with the lumina of the maternal blood-vessels in the decidua, and are, therefore, filled with maternal blood.

By means of the spaces the plasmodial trophoblast is separated into branching processes which intervene between the blood-filled spaces. The processes are the **primary chorionic villi**, and they soon develop cellular interiors (Fig. 78).

After a time the primary villi are invaded by the chorionic mesoderm, and are thus converted into the **secondary chorionic villi**, which become vascularised by the growth of fœtal vessels into the fœtal mesodermal cores. The secondary villi, therefore, consist of a mesodermal core covered by a layer of cellular trophoblast and a layer of plasmodium, the latter lying outside the former. Still later the secondary villi send out numerous branches into the blood spaces, and thus increase greatly in complexity (Figs. 81, 82, 83).

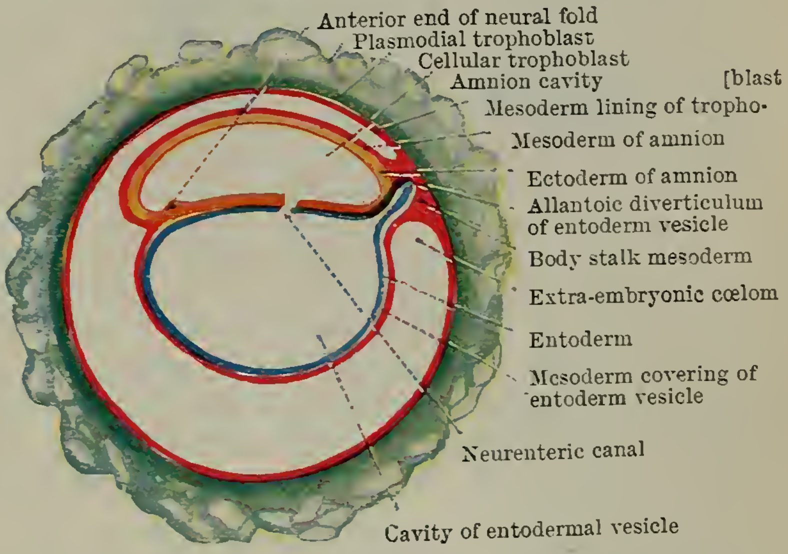
Anterior end of neural fold
Plasmodial trophoblast
Cellular trophoblast
Amnion cavity
Mesoderm lining of trophoblast
Mesoderm of amnion
Ectoderm of amnion
Allantoic diverticulum of entoderm vesicle
Body stalk mesoderm
Extra-embryonic cœlom
Entoderm
Mesoderm covering of entoderm vesicle
Neurenteric canal
Cavity of entodermal vesicle

FIG. 76.—SCHEMA OF SAGITTAL SECTION OF ZYGOTE ALONG LINE A.

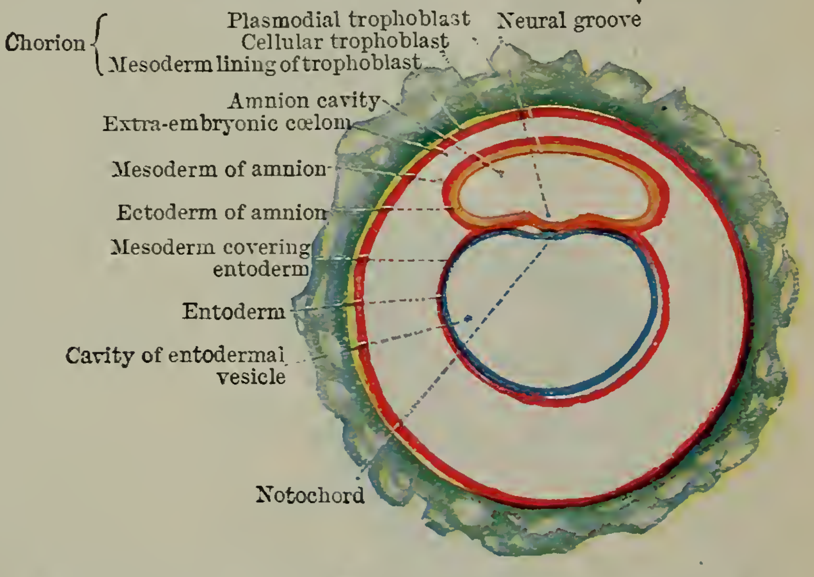

FIG. 77.—SCHEMA OF TRANSVERSE SECTION OF ZYGOTE ALONG LINE B (Fig. 37).

As development progresses still further a part of the chorion is converted into the fœtal portion of an organ called the **placenta**, and thus the chorion is divided into placental and non-placental regions. Upon the placental part the villi continue to increase, but they disappear entirely from the non-placental part, which is then called the **chorion læve** (Fig. 83).

The Amnion, the Body-Stalk (Allantoic Stalk), and the Umbilical Cord.—The amnion is formed from that portion of the wall of the more peripheral of the two inner vesicles of the zygote—the ecto-mesodermal vesicle—(p. 26), which does not take part in the formation of the embryo. It consists of ectoderm cells covered externally by a layer of extra-embryonic mesoderm, and it is continuous with the margin of the embryonic area (Figs. 76, 77).

The cavity of the ecto-mesodermal vesicle, enclosed between the amnion and the embryonic area, is the **cavity of the amnion**; it is filled with fluid, which raises the amnion in the form of a cupola over the embryonic region (Fig. 76).

The Body-Stalk (Allantoic Stalk).—It has been noted already that the mesoderm of the median part of the posterior or caudal portion of the amnion becomes thickened. In the thickened strand lies the allantoic diverticulum of the entodermal vesicle (Fig. 76), whilst through it, on either side of the allantoic diverticulum, pass the umbilical arteries and veins, by means of which blood is conveyed between the embryo and the chorion.

This segment of the wall of the amnion vesicle was termed by His the **body-stalk**. It takes no direct part in the formation of the embryo, and as it contains the rudimentary allantoic diverticulum and represents the much more highly developed allantois of other forms, it would, perhaps, be better to term it the **allantoic stalk**. For the present purpose it is important to note that the blood-vessels which pass through the body-stalk enter or leave the body through the umbilical orifice, which is, at first, a relatively large aperture (Fig. 56).

As the embryonic area is folded into the form of the embryo the amnion increases in extent, filling more and more of the extra-embryonic cœlom, and the embryo rises into the interior of its cavity. In other words, the walls of the amnion bulge ventrally round the cranial and caudal extremities and the lateral borders of the embryo (Figs. 81, 82, 83). As the distension of the amnion still continues, the ventral bulging, round the margin of the umbilical orifice, becomes more pronounced, the yolk-sac is forced farther and farther away from the embryo, the vitello-intestinal duct is elongated, and it is surrounded by a hollow tube. The cavity of the tube is an elongated part of the extra-embryonic cœlom, and its walls are formed by the amnion (Figs. 63, 68, 69).

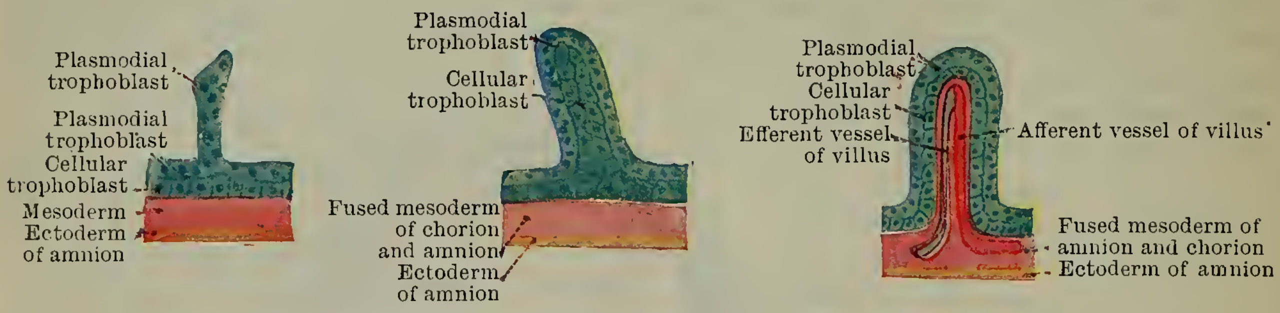

Fig. 78.—Schema of Three Stages in the formation of a Chorionic Villus.

The caudal wall of the tube necessarily consists of the elongated body-stalk (allantoic stalk).

As the distension of the amnion still continues, the walls of the tube are forced against the vitello-intestinal duct, and the amniotic mesoderm fuses with the mesoderm of the vitello-intestinal duct. When the fusion is completed, a solid cord, the **umbilical cord**, is formed (Figs. 83, 84, 86). It consists of an external covering of amniotic ectoderm, and a core of mesoderm in which lie the two umbilical arteries of the body-stalk, a single umbilical vein formed by the fusion of the two primitive veins, and the remains of the vitello-intestinal duct and the vitelline vessels. The proximal end of the umbilical cord is connected with the embryo; the distal end is attached to the chorion, and in its neighbourhood lies the now relatively small vesicular yolk-sac (Fig. 68).

As the amnion grows still larger, all that part of its outer surface which does not take part in the formation of the umbilical cord is ultimately pressed into contact with the inner surface of the chorion, with which it fuses, and the cavity of the extra-embryonic part of the cœlom is obliterated (Fig. 84).

The outer wall of the zygote now consists of the fused chorion and amnion, and it contains in its interior the amniotic cavity and the embryo, which is attached to the chorion by the umbilical cord.

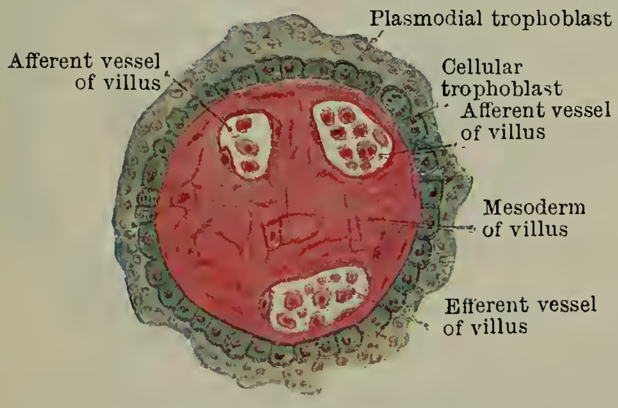
Plasmodial trophoblast
Afferent vessel of villus
Cellular trophoblast
Afferent vessel of villus
Mesoderm of villus
Efferent vessel of villus

Fig. 79.—Schema of a Transverse Section of a Secondary Chorionic Villus. A loop of the afferent vessel has been cut at two points.

When it is first formed the umbilical cord is comparatively short, but, as the amniotic cavity increases, the cord elongates, until it attains a length of from 45 to 50 cm. (18 to 20 inches), a condition which allows the embryo to float freely in the fluid in the amniotic cavity, whilst its nutrition is provided for by the flow and return of blood, through the umbilical cord, to and from the placenta, where interchanges take place between the maternal and the fœtal blood.

The Yolk-Sac or Umbilical Vesicle.—When the embryonic area is folded into the form of the embryo, the entodermal vesicle is differentiated into three parts: (1) a part enclosed in the embryo, where it forms the **primitive entodermal alimentary canal**; (2) a part which lies external to the embryo in the extra-embryonic cœlom—this is the **yolk-sac** or **umbilical vesicle**; (3) the third portion is the **vitello-intestinal duct**, which connects the primitive alimentary canal and the yolk-sac together (Figs. 46, 68).

The walls and the cavity of the yolk-sac are, therefore, continuous with the walls of the primitive alimentary canal, and the structural features of the two are identical, each consisting of an internal layer of entodermal cells and an external layer of mesoderm.

Free communication between the yolk-sac and the primitive alimentary canal appears to exist in the human subject till the embryo is three weeks old and about 2·5 mm. long. During the fourth week the vitello-intestinal duct is elongated into a relatively long narrow tube, which is lodged in the umbilical cord, and the yolk-sac, which has become a relatively small vesicle, is placed between the outer surface of the amnion and the inner surface of the chorion, in the region of the placenta (Fig. 68). During the latter part of the fourth or the early part of the fifth week, when the embryo has attained a length of about 5 mm., the vitello-intestinal duct separates from the intestine and commences to undergo atrophy, but remnants of it may be found in the umbilical cord up to the third month.

The yolk-sac itself persists until birth, when it is, relatively, a very minute object which lies either between the amnion and the placenta or between the amnion and the chorion læve.

At a very early period, before the paraxial mesoderm has commenced to divide into mesodermal somites, a number of arteries, the **primitive vitelline arteries**, are distributed to the yolk-sac from the primitive arterial trunks of the embryo, the primitive aortæ, and the blood is returned from the yolk-sac to the embryo by a pair of **vitelline veins** (Fig. 87).

After a time the arteries are reduced to a single pair, and after the two primitive dorsal aortæ have fused into a single trunk, the pair of vitelline arteries also becomes converted into a single trunk, which passes through the umbilical orifice along the vitello-intestinal duct to the yolk-sac (Fig. 89).

The vitelline veins also pass through the umbilical orifice on their way to the heart of the embryo, and they become connected together, in the interior of the body of the embryo, by transverse anastomoses, which are described in the account of the development of the vascular system (see Vascular System).

After the umbilical cord is formed, the extra-embryonic parts of the vitelline veins disappear, and can no longer be traced in the cord. The same fate overtakes the extra-embryonic and a portion of the intra-embryonic part of the vitelline artery, and the remainder of the artery persists as the superior mesenteric.

THE PLACENTA.

The placenta is an organ developed for the purpose of providing first the embryo and later the fœtus with food and oxygen, and for removing the effete products produced by the metabolic processes which take place in the growing organism. It is formed partly from the zygote and partly from the mucous membrane of the uterus of the mother.

In the placenta the blood-vessels of the embryo of the earlier stages, and the fœtus of the later stages, and the blood of the mother are brought into close relationship with one another, so that free interchanges may readily take place between the two blood streams, but the blood of the embryo and fœtus and the blood of the mother are always separated from one another by two or more layers of fœtal cells. The modifications and transformations of the uterine mucous membrane and the chorion of the zygote, by which this intimate relationship is attained, constitute the phenomena of the development of the placenta.

The details of the development of the human zygote for the first ten or twelve days after the fertilisation of the ovum are not known, but the knowledge of what happens in other mammals justifies the belief that during that time the zygote is formed, in the ovarian, or the middle part of the uterine tube, by the union of a spermatozoon with the mature ovum. During the first ten to fourteen days after its formation it passes along the uterine tube, towards the uterus, whilst, at the same time, it undergoes the divisions which convert it into a morula.[1]

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[1] This is an estimate, for there is no certain knowledge, and it is possible that the passage through the uterine tube is completed in seven or eight days or less.

The Formation of the Placenta.—Before the zygote reaches the uterus the mucous membrane which lines the cavity of that organ undergoes changes, in preparation for the reception and retention of the zygote, and when the changes are completed the modified mucous membrane is known as the **uterine decidua.**

The changes which take place are, for the most part, hypertrophic in character; the vascularity of the mucous membrane is increased, mainly by the dilatation of its capillaries; the tubular glands of the membrane are elongated, they become tortuous, and dilatations form in their walls a short distance from their outer closed extremities. At the same time the interglandular tissue increases in amount, and as a result of the various processes the decidua is thicker, softer, more spongy, and more vascular than the mucous membrane from which it was evolved.

Partly on account of the dilatation of the deep part of the glands and partly on account of differences in texture of the internal as contrasted with the external part of the decidua, the membrane may be looked upon as consisting of three layers. (1) An internal layer, next the cavity, the **stratum compactum.** (2) An intermediate layer, the **stratum spongiosum,** formed largely by the dilated parts of the glands. (3) An external layer, the **unchanged layer,** in which lie the comparatively unaltered outer ends of the glands.

When the zygote, in the morula stage, reaches the uterus, it acts as a parasite, it eats its way through the epithelium on the surface of the decidua, and implants itself in the stratum compactum.

The zygote may penetrate the decidua at any point of the wall of the uterine cavity, but it usually enters at some point of the dorsal or the ventral wall. The entrance generally takes place between the mouths of adjacent glands, which are pushed aside, and the zygote becomes at once surrounded by the interglandular tissue of the stratum compactum of the decidua. The aperture through which it passes may be closed by a fibrinous plug or its margins may converge rapidly and fuse together.

The portion of the decidua in which the zygote is embedded is thicker than the other parts of the membrane, and it is separated by the zygote into an internal part, the **decidua capsularis,** and an external part, the **decidua basalis.** The junction of the decidua capsularis with the decidua basalis is the **decidua marginalis,** and the remainder of the decidua, by far the larger portion, is the **decidua vera.**

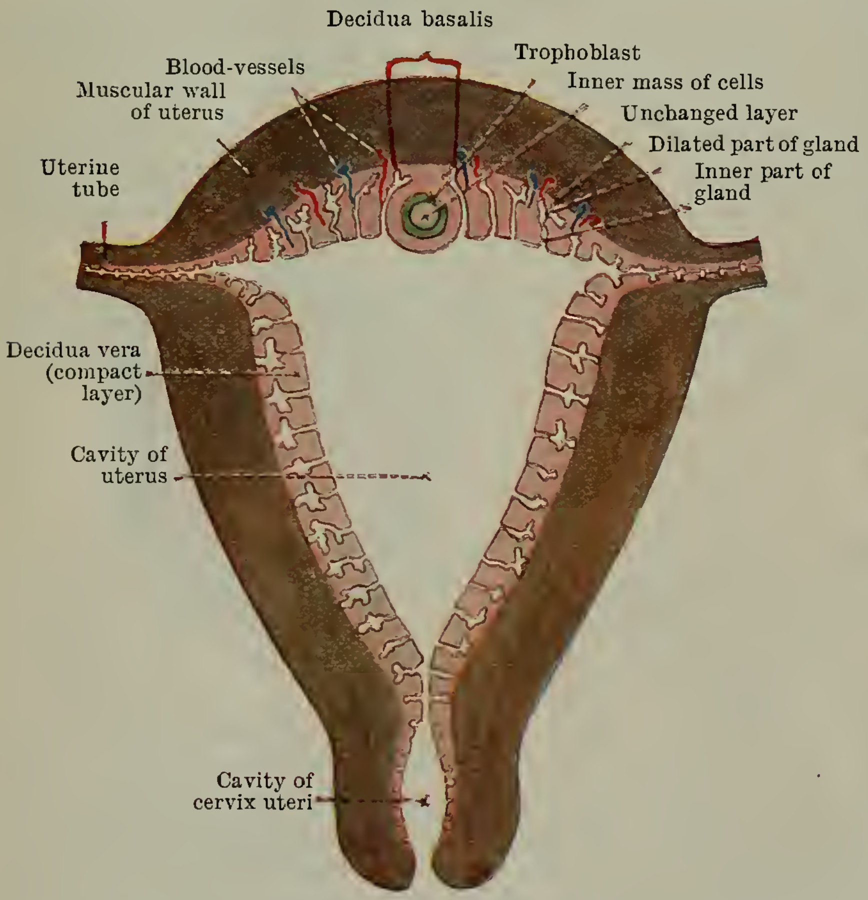


Fig. 80.—Schema of a Frontal Section of the Uterus, showing the various parts of the decidua and a zygote embedded in the decidua.

As soon as the zygote becomes embedded in the decidua its trophoblast undergoes rapid proliferation. The superficial part of the growing trophoblast becomes converted into a mass of nucleated protoplasm, the plasmodial or syncytial layer, but the inner part remains more or less distinctly cellular.

The plasmodial portion of the trophoblast invades and destroys the surrounding maternal tissue, and at the same time spaces appear in its substance. As the plasmodium destroys the walls of the dilated maternal blood-vessels, channels are made through which the maternal blood flows into the spaces in the plasmodium, and thus maternal blood begins to circulate in the trophoblast of the zygote.

In the meantime the extra-embryonic cœlom has appeared in the primary mesoderm of the zygote, and the outer layer of the mesoderm has associated itself with the trophoblast to form the chorion (see p. 58).

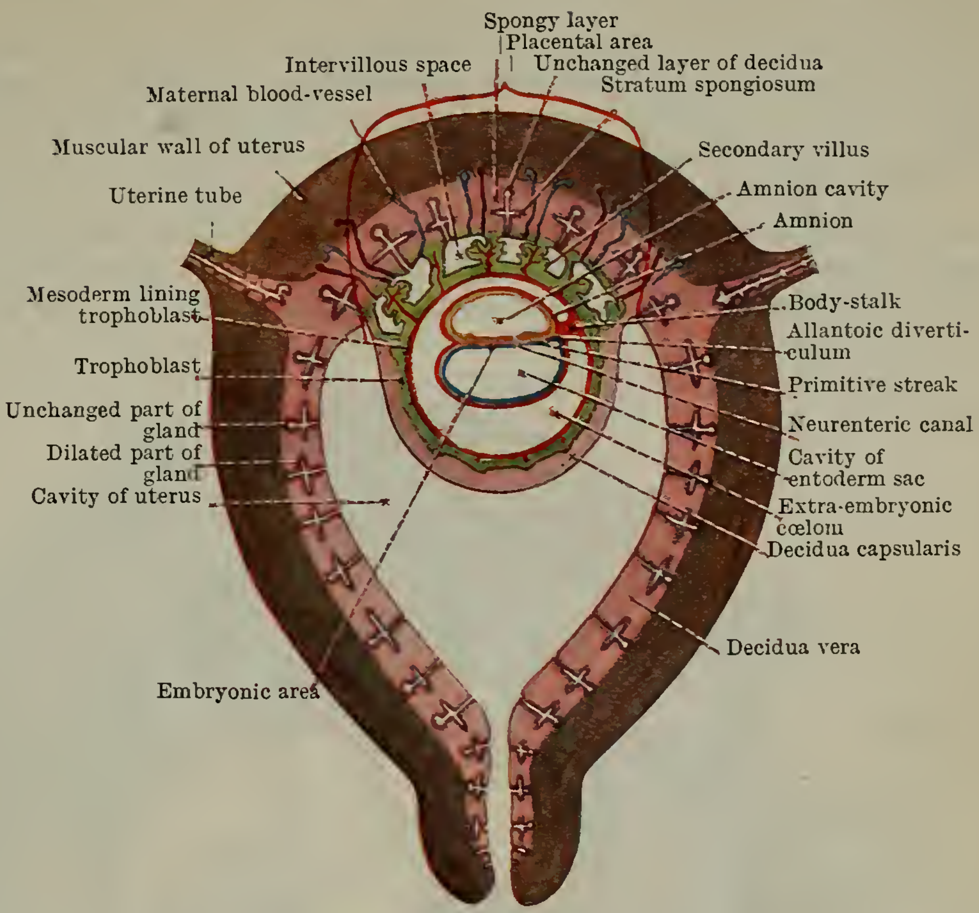


FIG. 81.—SCHEMA OF A SECTION OF A PREGNANT UTERUS AFTER THE FORMATION OF THE INTERVILLOUS SPACES.

The spaces in the plasmodium enlarge rapidly after the maternal blood begins to circulate within them, and the plasmodium becomes divided into three series of parts. (1) The parts which lie between adjacent blood spaces, the **primary chorionic villi.** (2) The parts which lie in contact with the mesoderm of the chorion, and which form with the mesoderm the **chorion plate.** (3) The parts which cover the maternal tissues and form the outer boundaries of the blood spaces, the **basal layer.** The blood spaces themselves are called the **intervillous spaces** (Figs. 82, 85).

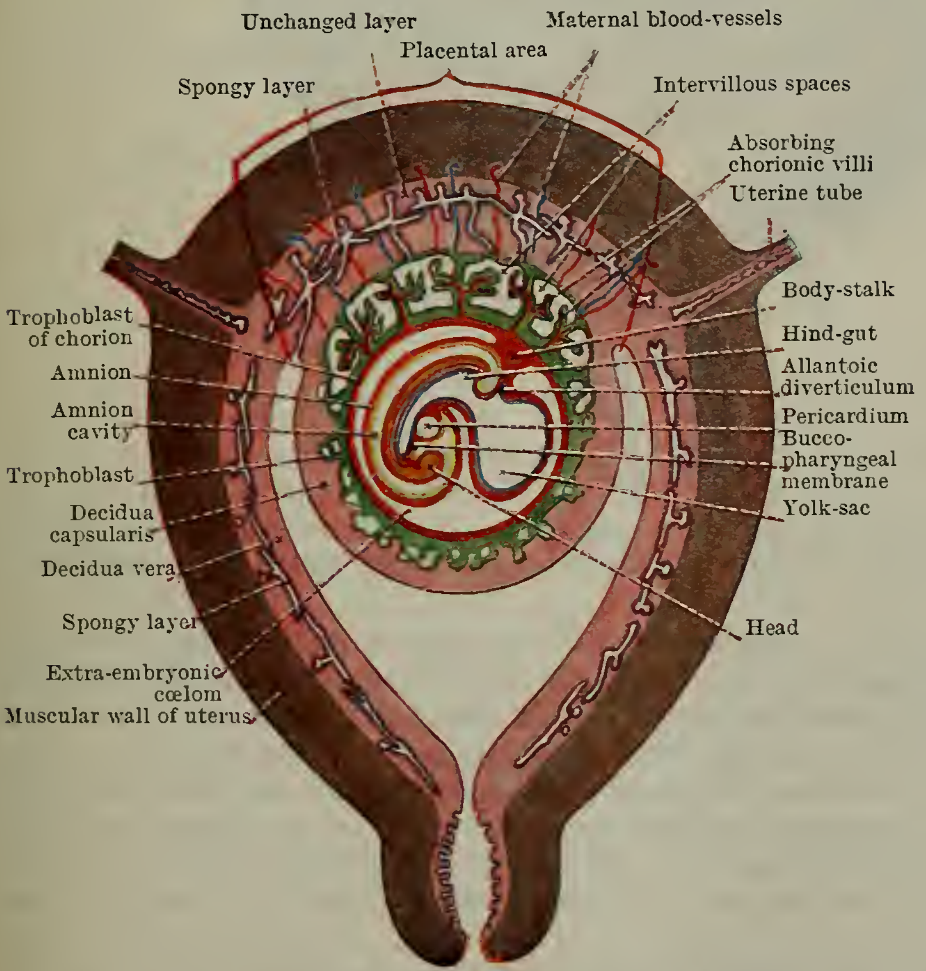


FIG. 82.—SCHEMA OF A FRONTAL SECTION OF A PREGNANT UTERUS AT THE PERIOD OF THE FORMATION OF THE EMBRYO. Note extension of amnion as contrasted with stage shown in Fig. 81.

After a time each primary villus differentiates into a cellular core and plasmodial periphery, and thereafter the villi are invaded by the mesoderm of the chorion and are thus converted into **secondary villi** (Fig. 82).

The first-formed villi are non-vascular, but by the time the secondary villi have developed the umbilical arteries have grown through the body-stalk (allantoic stalk) into the mesoderm of the chorion, and branches from them enter the mesodermal cores of the villi, which thus become vascular.

When the secondary villi are fully developed each consists of a vascular mesodermal core continuous with the mesoderm of the chorion. The mesodermal core is covered by a layer of cellular trophoblast, *Langhan's layer*, which lies next the mesoderm, and a layer of plasmodium external to the cellular layer. The proximal end of each villus is continuous with the chorion plate of the intervillous spaces, formed by the chorion, and the distal extremity is connected with the plasmodial basal layer of the trophoblast, which forms the outer boundary of the intervillous spaces and which is fused with the maternal decidual tissue.

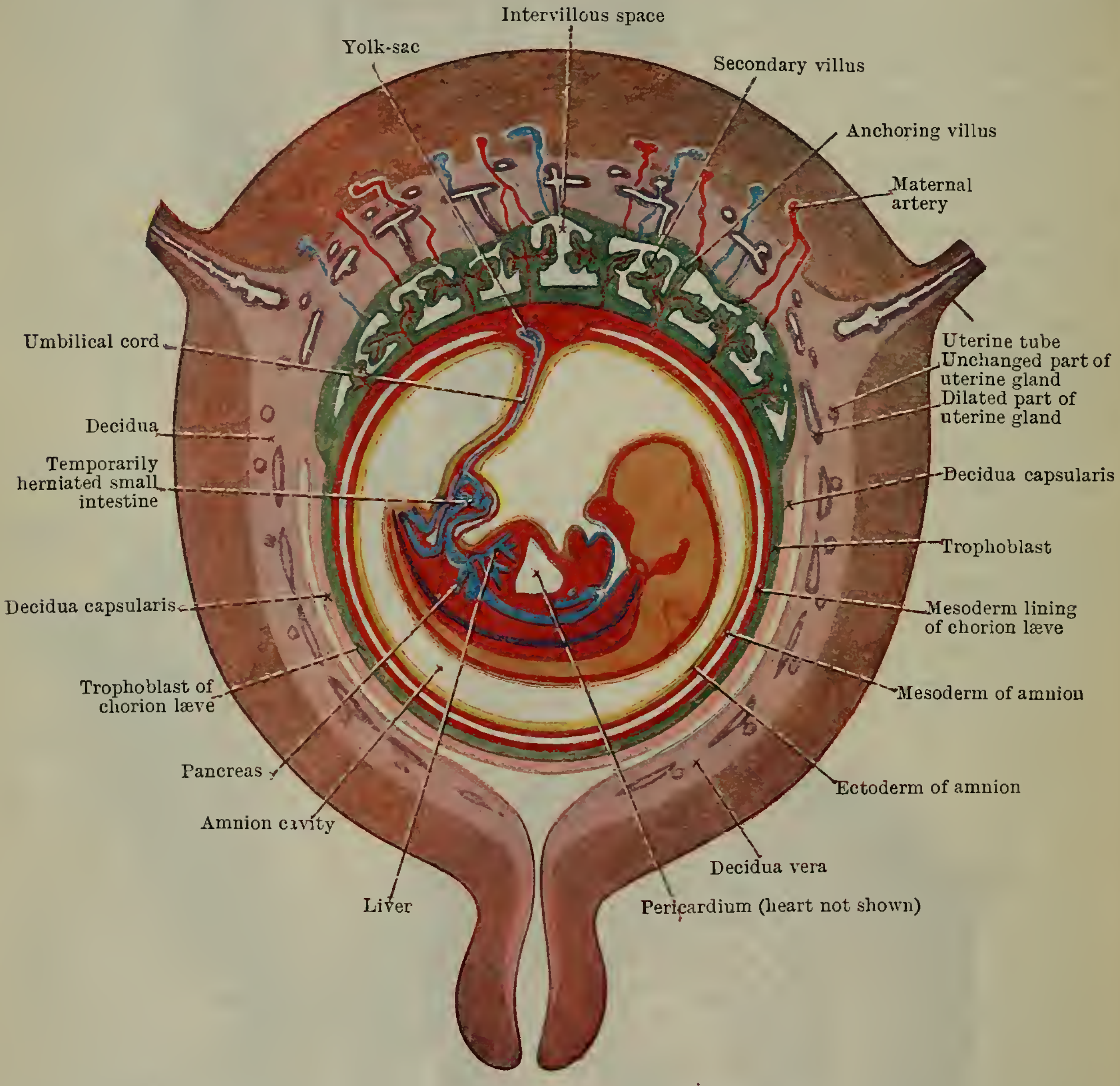


Fig. 83.—Schema of a Section of a Pregnant Uterus after the Formation of the Umbilical Cord. Note that the expanding amnion has almost obliterated the extra-embryonic cœlom which lies between it and the chorion.

After a time branches are projected from the sides of the secondary villi into the intervillous spaces. In this way two sets of secondary villi are differentiated, (1) the **anchoring villi** (Fig. 85), which cross from the chorion to the basal layer of trophoblast and are attached to the latter by cell columns, which are the remains of the primary villi which have not been penetrated by the fœtal mesoderm, and (2) **free or absorbing villi** (Fig. 82), which extend from the sides of the original secondary villi into the blood, in the intervillous spaces.

Whilst the trophoblastic invasion of the compact layer of the decidua is proceeding, not only are the interglandular elements of the decidua destroyed, but the walls of the glands also, and, as a consequence, some of the glands in the decidua basalis open for a time into the intervillous spaces, and become filled with blood which passes from the spaces into the gland cavities. In many cases, however, before the glands are destroyed their walls are converted into solid strands of cells, and thus the cavities of their more external undestroyed portions are converted into closed spaces.

In the early stages the trophoblast is differentiated in a similar manner over the whole of the surface of the zygote, and thus, for a time, the whole of the surface of the chorion is covered with villi. As the embryo grows, and the amnion and the extra-embryonic cœlom are distended, the zygote increases in size, and the capsular portion of the decidua is stretched till its vascular supply is interfered with and the villi associated with it undergo atrophy and disappear.

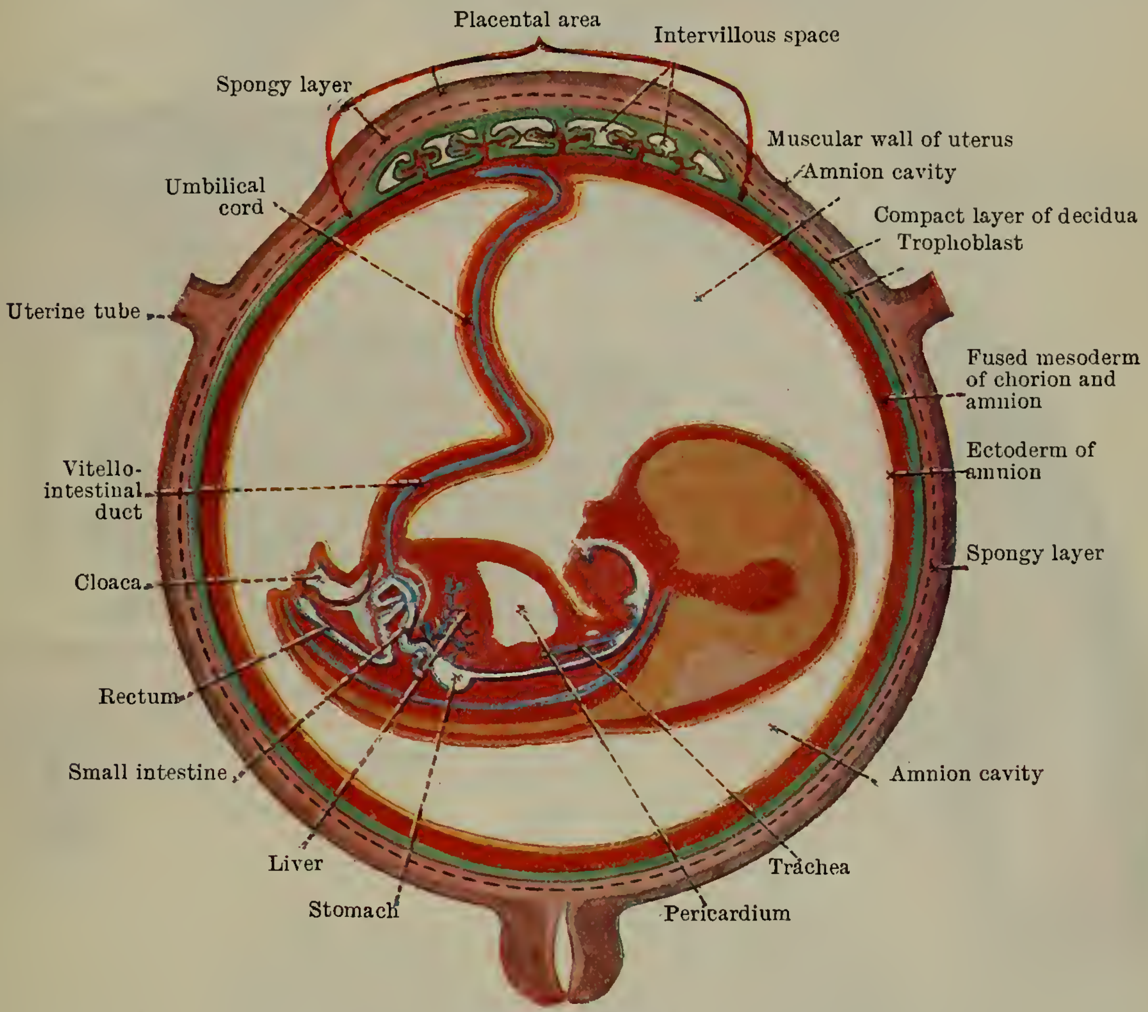


Fig. 84.—Schema of a Section of a Pregnant Uterus after Fusion of Amnion and Chorion.

When these degenerative changes have occurred, the portion of the chorion in association with the thinned decidua capsularis presents a relatively smooth surface, and is known as the **chorion læve**. Whilst the decidua capsularis is being stretched and thinned, and the associated portion of the chorion is being reduced to the condition of a non-villous region, the decidua basalis increases in thickness; at the same time the villi associated with it increase in size and in the complexity of their branches. The portion of the chorion from which these large villi spring is termed the **chorion frondosum**. It is this portion of the chorion which takes part in the formation of the so-called **fœtal portion** of the placenta, the **maternal part** of that organ being formed by the decidua basalis.

The placenta, therefore, is formed partly by the zygote and partly by maternal tissues, but the interchanges between the fœtal and the maternal blood take place in the substance of the zygote through the trophoblast which covers the surfaces of the villi.

As the growth of the embryo and the distension of the amnion continue, the outer surface of the amnion is gradually forced against the inner surface of the chorion, with which it fuses. When this fusion is completed the extra-embryonic cœlom is obliterated and the zygote contains only one extra-embryonic cavity, the amniotic cavity, in which the fœtus floats in the amnion fluid (Fig. 84).

At this period the amnion cavity is bounded by a wall formed by the fused amnion chorion and decidua. In the meantime the chorion has differentiated into the chorion læve, fused with the decidua capsularis, and the chorion frondosum, fused with the decidua basalis. As the distension of the amnion proceeds to a still greater extent, the part of the wall of the cavity formed by the fused amnion chorion læve and the decidua capsularis projects more and more into the cavity of the uterus, until it is forced against the surrounding wall of the uterine cavity, where it fuses with the decidua vera, and thus the cavity of the uterus is obliterated. This fusion takes place towards the end of the second month, and as soon as it has occurred the discoid mass of placental tissue is continuous at its margin with the fused amnion, chorion, and decidua vera (Fig. 84).

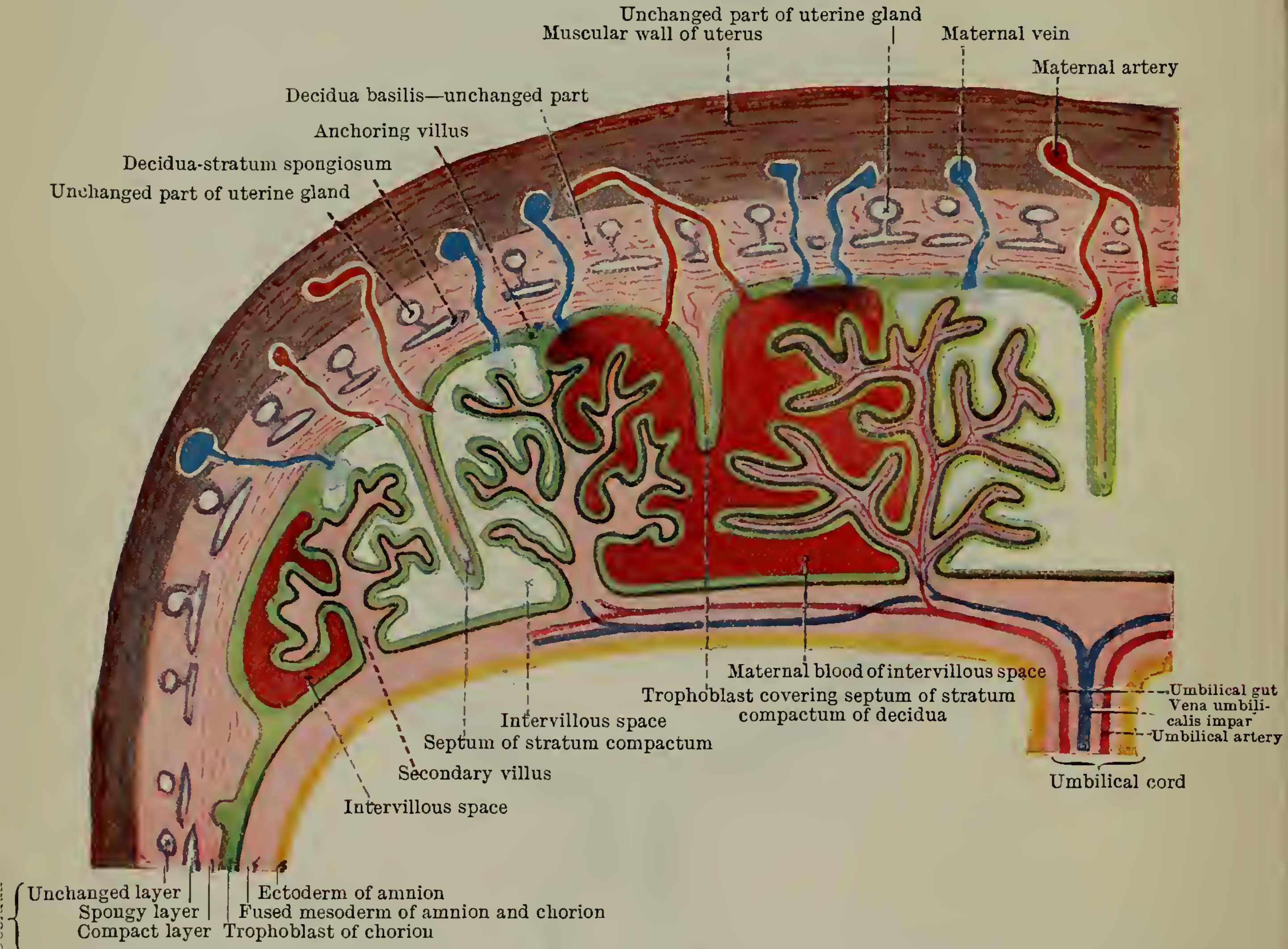

Unchanged part of uterine gland
Muscular wall of uterus
Maternal vein
Maternal artery
Decidua basilis—unchanged part
Anchoring villus
Decidua-stratum spongiosum
Unchanged part of uterine gland
Maternal blood of intervillous space
Trophoblast covering septum of stratum compactum of decidua
Intervillous space
Septum of stratum compactum
Secondary villus
Intervillous space
Umbilical gut
Vena umbilicalis impar
Umbilical artery
Umbilical cord
Unchanged layer
Spongy layer
Compact layer
Ectoderm of amnion
Fused mesoderm of amnion and chorion
Trophoblast of chorion

FIG. 85.—SCHEMA OF STRUCTURE OF COMPLETED PLACENTA.

After the second month the fœtus lies in the amnion cavity, which is bounded by the fused chorion and uterine wall, except at the lower end of the uterus, over the orificium internum, where the cavity of the body of the uterus communicates with the cavity of the neck of the uterus; there the amniotic cavity is bounded by a membrane formed by the fused amnion chorion læve and the decidua capsularis only.

And at the end of pregnancy that portion of the membrane is ruptured by the increased pressure of the amnion fluid produced by the contraction of the muscular wall of the uterus (Fig. 86).

Completion of the Placenta.—It has already been stated that each absorbing villus consists of a vascular mesodermal core covered by a cellular and a plasmodial layer of trophoblast, the latter lying next the maternal blood in the intervillous spaces. As development proceeds and the intervillous spaces become larger, the villi become longer and more complicated, and at the same time the cellular layer of the trophoblast largely disappears, until in the majority of the villi the plasmodial layer alone covers the vascular mesodermal core.

In still later stages, degenerative changes occur not only in the villi, but also in the chorionic plate of the intervillous spaces and in the basal trophoblast which closes the spaces externally. One of the results of the degenerative processes is the deposit of fibrinoid material in the place originally occupied by the trophoblast—the object of this process is still unknown; another is the adhesion of the fibrinous layers on the surfaces of adjacent villi, and the fusion of the villi thus connected into masses of intermingled fibrinous and vascular tissue.

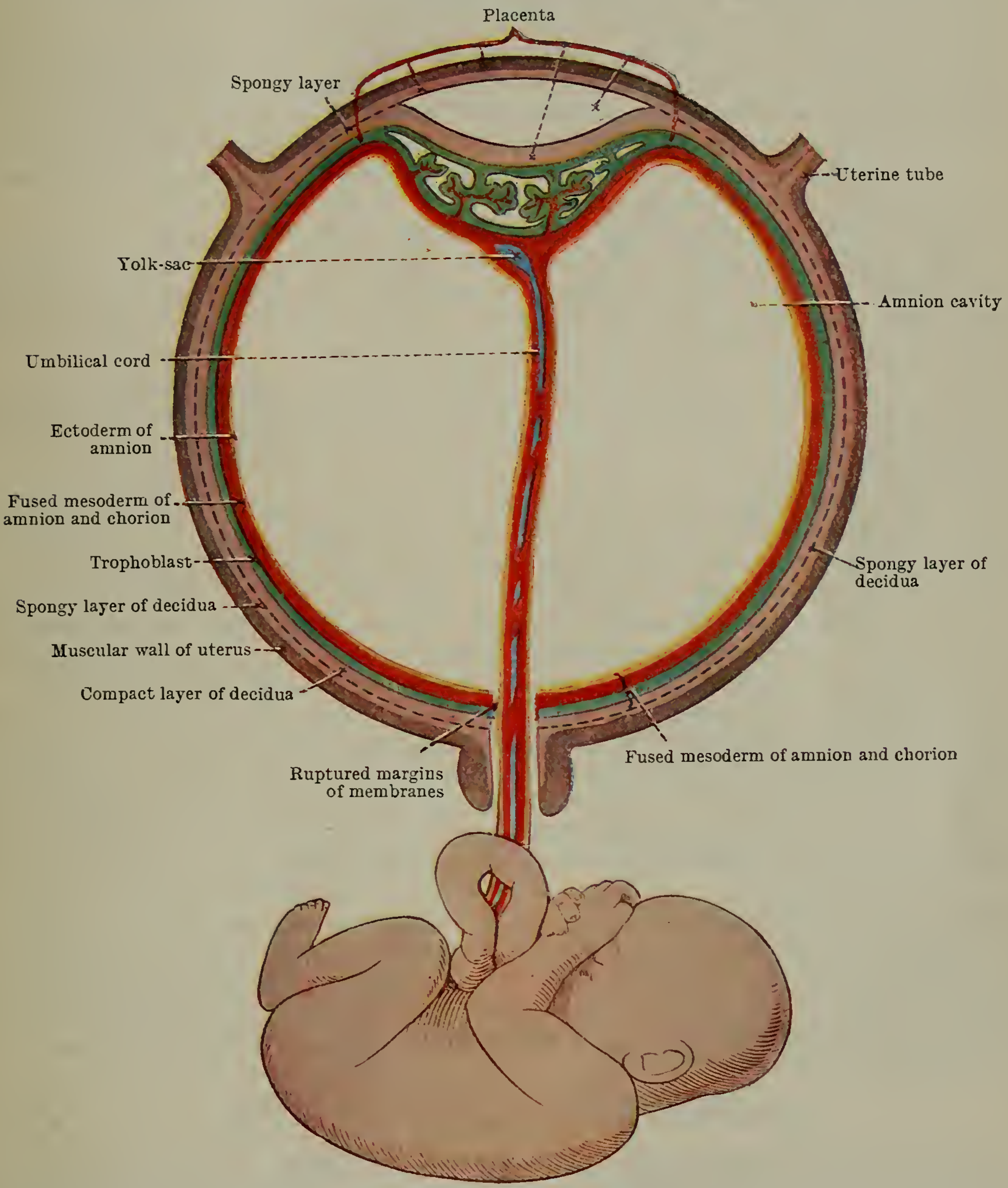


FIG. 86.—SCHEMA OF PREGNANT UTERUS IMMEDIATELY AFTER BIRTH OF THE CHILD, showing commencing separation of the placenta. Part of the umbilical cord is shown in section and part in surface view. The blue streaks in the former part indicate the position occupied by the vitello-intestinal duct in earlier stages.

When the chorionic part of the placenta is completed it consists of (1) the chorion plate closing the intervillous spaces internally; (2) the villi; (3) the intervillous spaces; and (4) the basal layer of the trophoblast, which closes the intervillous spaces externally, and is perforated by the maternal vessels passing to and from the spaces.

The maternal portion of the completed placenta consists from within outwards of (1) the basal layer of the decidua; (2) the remains of the spongy layer of the decidua; and (3) the unchanged layer.

The basal layer of the decidua is the remains of the compact part of the decidua basalis of earlier stages. It is fused internally with the basal plate of the trophoblast, and is continuous externally with the spongy layer. The spongy layer consists of a series of cleft-like spaces. These spaces are the compressed remains of the earlier dilated portions of the glands of the stratum spongiosum, from which the epithelial lining has, to a great extent, disappeared. The spongy layer is continuous externally with the unchanged layer, in which lie the unaltered outer parts of the glands and the intervening interglandular tissue.

The maternal blood-vessels pass from the muscular wall of the uterus into the submucous tissue, and thence into the placenta, where they traverse the maternal portion and the basal plate of the trophoblast and open into the intervillous spaces. The arteries usually open on or near the septa and the veins in the intermediate areas.

In addition, however, to the constituent parts already described, the chorionic part of the placenta contains some strands of maternal tissue, and in the maternal part there are portions of trophoblast.

The parts of the decidua found in the chorionic part of the placenta are a series of fibrous strands, the remains of parts of the stratum compactum which were not destroyed by the trophoblastic invasion. They are continuous externally with fibrous strands of the maternal part of the placenta, and serve to separate the placenta into a series of lobes, from 15 to 20 in number.

The portions of trophoblast met with in the maternal part of the placenta are variable pieces of plasmodium which appear to have wandered from the general mass. They may be found in any of the strata of the maternal part, and even in the submucous tissue.

At the end of pregnancy, when intra-uterine life terminates, the fused amnion chorion and decidua capsularis are ruptured, in the region of the internal orifice of the uterus, and the amniotic fluid is expelled through the vagina. Next the fœtus is extruded, and as soon as it is born it becomes a child. After the child is born it remains attached to the placenta by the umbilical cord (Fig. 86), which is usually ligatured in two places and then divided, between the ligatures, by a medical man or an attendant. Afterwards the placenta is expelled from the uterus.

Detachment of the placenta is probably caused by contraction of the muscular substance of the uterus, and it takes place by rupture of the strands of the spongy layer of the decidua (Fig. 86). As the detached placenta is expelled the decidua vera is torn through along the line of the spongy layer, and the fused amnion and chorion læve and the inner part of the decidua vera, which are attached to the margin of the placenta and which constitute the membranes, are expelled with it.

At birth the placenta weighs about 500 grm., it has a diameter of about 16 to 20 cm., and is about 3 cm. thick. Its inner surface is covered with the amnion which fused with the chorion towards the end of the second month of pregnancy. Its outer surface is rough, it is formed by the remains of the spongy layer of the decidua, and is divided into a number of areas by a series of fissures which correspond in position with the septa by which the organ is divided into lobes.

THE PRIMITIVE VASCULAR SYSTEM.

As the zygote travels along the uterine tube, from the ovarian towards the uterine end, it exists upon the yolk granules derived from the oocyte. After it enters the uterus it must depend, for a time, upon the same source of nutriment, but as it penetrates the decidua it is probable that the cells of the trophoblast actually devour the cells of the decidua which they invade. This source of food is only sufficient for a short period, whilst the zygote remains relatively small, and substances absorbed by its surface cells can be transmitted easily to all parts.

Whilst the period exists, however, not only are the decidual tissues utilised as a food-supply, but fluids are absorbed from them and transmitted into the interior of the zygote to fill the expanding cavities of the amnion and the cœlom.

In all probability the fluids passed into the zygote contain nutritive materials which suffice for the requirements of the embryonic and non-embryonic parts of the zygote so long as both consist of comparatively thin layers of cells, but when the embryonic area increases in thickness, and begins to be moulded into the embryo, its association with adjacent fluids becomes less intimate, and as the development of its various parts progresses, a supply of food and oxygen is required which is greater than can be provided by osmosis from the adjacent fluid media. Thus an imperative necessity arises for a method of food-supply adequate to the increasing requirements upon which the continued development and growth depend.

To meet this necessity the **blood vascular system** is formed. The system is essentially an irrigation system. In its earliest stages it consists of a series of vessels, the blood-vessels, all of which contain a corpuscle-laden fluid, called blood. The blood is kept circulating, in the early stages, by the rhythmical contraction of the walls of the vessels, but, after a short time, parts of the vessels are developed into a muscular organ called the heart. After the heart is established the continuance of the circulation of the blood depends upon the regular contractions of the muscular substance of its walls.

The corpuscular portions of the blood and the walls of the blood-vessels are formed from the cells of the zygote, but it is obvious, in the early stages at all events, that the fluid portion of the blood must be obtained from the mother. It is necessary, therefore, both for this purpose and for the facilitation of interchanges between the fœtal and maternal blood streams, that the fœtal blood-vessels should be brought into close association with the maternal blood at an early period. It is for this purpose, among others, that large spaces appear in the trophoblast (p. 25); that the spaces become filled with blood from maternal vessels which have been opened up by the destructive action of the trophoblast cells; and that the spaces are afterwards invaded by the chorionic villi, which carry in their interiors branches of the blood-vessels of the embryo (Fig. 82). As soon as the intimate relationship between the chorionic villi and the maternal blood is established fluids can readily pass from the maternal to the fœtal vessels, and there can be no doubt that both food and oxygen pass from the maternal to the fœtal blood through and by the agency of the trophoblastic epithelium, whilst, at the same time, waste products of fœtal metabolism are passed from the fœtal to the maternal blood.

The Germs of the Vascular System.—In addition to the mesoderm cells which form the paraxial mesoderm and the mesodermal somites into which it divides, the intermediate cell tracts, and the somatic and splanchnic layers of the lateral plates of the embryo, there are certain other cells, of mesodermal nature, called **mesenchyme cells.**

Whether the mesenchyme cells are derived from the primitive streak, like the majority of the embryonic mesoderm cells, or whether they are derivatives of the entoderm cells is uncertain.

The mesenchyme cells are characterised by their irregular and stellate outlines, and by the fact that, speaking generally, they do not form regular layers or masses, but are scattered irregularly between the mesoderm proper on the one hand and the entoderm and ectoderm on the other.

It is from some of the mesenchyme cells that the walls of the primitive blood-vessels and their cellular contents are derived, and the changes by which the transformation is produced become first visible in the walls of the yolk-sac, but they occur later in the embryonic region also.

The mesenchyme cells which are the rudiments of the blood vascular system become definitely spherical and their nuclei become relatively large; at the same time they are aggregated together into more or less round patches which are called **blood islands.** As soon as the cells have attained their distinctive appearance they are known as *hæmohistoblasts* or *angioblasts,* and from them are derived both the endothelial walls of the blood-vessels and the blood corpuscles.

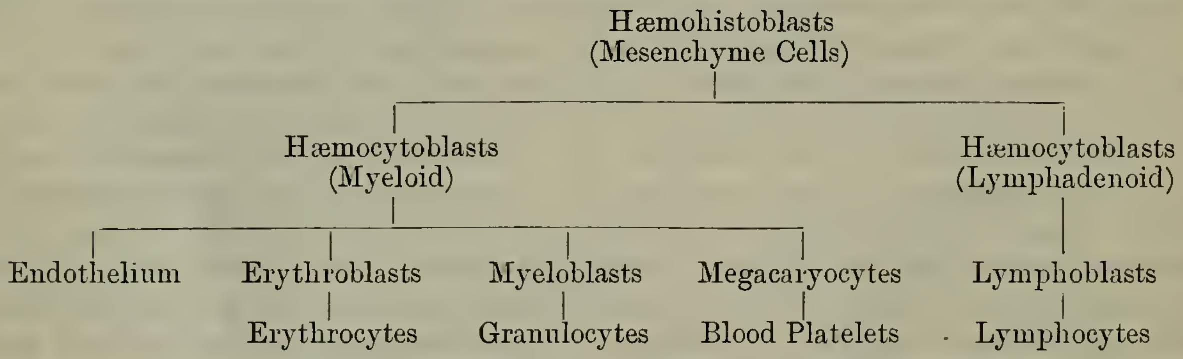
The peripheral hæmohistoblasts become endothelial cells and those more centrally situated become the blood corpuscles.

When they first become distinct in the walls of the yolk-sac the blood islands are isolated from one another, but the peripheral hæmohistoblasts soon throw out processes which anastomose with similar processes from other islands and the anastomosing processes develop into endothelial tubes, into which fluid, derived from the maternal blood, is secreted; there is thus established a plexus of anastomosing tubes filled with blood plasma in which float nucleated cells which are the primitive blood corpuscles.

By similar methods blood-vessels are formed in the embryonic area or they extend into it from the yolk-sac.

In adult animals, however, most of the blood corpuscles are red and non-nucleated, whilst some are white and nucleated. The latter are separable into several groups having distinctive characteristics. The blood-vessels also are different, for the original plexuses are transformed into distinct stems and branches of varying sizes and importance, therefore two groups of events associated with the development of the vascular system still remain to be considered; they are the evolution of the blood corpuscles from the hæmohistoblasts and the development of the main embryonic blood-vessels.

The Development of the Blood Corpuscles.—Numerous researches have been made with the object of discovering the mode of origin of the various groups of blood cells, but there is as yet no general agreement either with regard to the exact genesis or to the terminology to be used in describing the various types of cells which are found at different periods, therefore the schema below, which is modified from Ferrata,[1] must be looked upon merely as a provisional expression of opinion:



As the schema indicates, the general progenitors of the vascular endothelium and the blood cells are certain mesenchyme cells called hæmohistoblasts, and it is those cells which form the blood islands previously mentioned. The descendants of the hæmohistoblasts form two groups, one called *myeloid hæmocytoblasts* and the other *lymphadenoid hæmocytoblasts.*

Some of the descendants of the myeloid hæmocytoblasts form endothelium. Others known as *erythroblasts* become laden with hæmoglobin and after the extrusion of their nuclei they become *erythrocytes* or red blood corpuscles.

The hæmocytoblasts which produce erythroblasts and the erythroblasts themselves increase by mitotic division as they float in the blood stream of the young embryo, so the number of erythrocytes is increased for a time; but, after the liver is differentiated, the number is further increased, for hæmocytoblast cells which have been carried into the liver from the yolk-sac by the blood stream, or which have been developed in it, *in situ,* from hæmohistoblastic mesenchyme cells, produce erythrocytes which pass through the vessel walls and enter the blood stream.

When ossification of bone commences hæmohistoblasts pass into the bones, where their descendants become *erythroblasts, myeloblasts,* and *megacaryocytes.* From the erythroblasts red blood corpuscles are formed, from the myeloblasts granular white blood corpuscles are developed, and the megacaryocytes are the progenitors of blood platelets.

The *lymphocytes* are relatively late in appearing. They are not discoverable until the spleen and other foci of adenoid tissue have been formed, and they are derived from hæmohistoblastic cells which are included in the adenoid masses as they are developed, or which are carried into the adenoid tissue by the blood stream.

In very young embryos both immature and mature blood cells are present in the blood stream, the mature being developed from the immature in the stream, but after bone marrow and lymphoid tissue have been formed it is probable that only mature blood cells pass into the blood stream, entering the stream by piercing the endothelial walls of the capillaries.

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[1] *Le Emopatie*, by A. Ferrata, Soc. Editrice Libraria, Rome, 1918.

The Formation of the Primitive Blood-Vessels.—It has been pointed out that in the yolk-sac area of the entodermal vesicle a plexiform system of tubes, filled with fluid and corpuscular elements, is formed from hæmohistoblastic cells which are called hæmocytoblasts as soon as their destiny becomes evident.

Similar but less easily demonstrated plexuses are formed in the chorionic mesoderm and also in the embryonic area.

It is probable that the various plexuses are directly connected with one another from the period of their initiation, but if that is not the case they soon become connected, and from them are evolved what may be called the primitive stem vessels of the embryo, through which the blood circulates from one area to another.

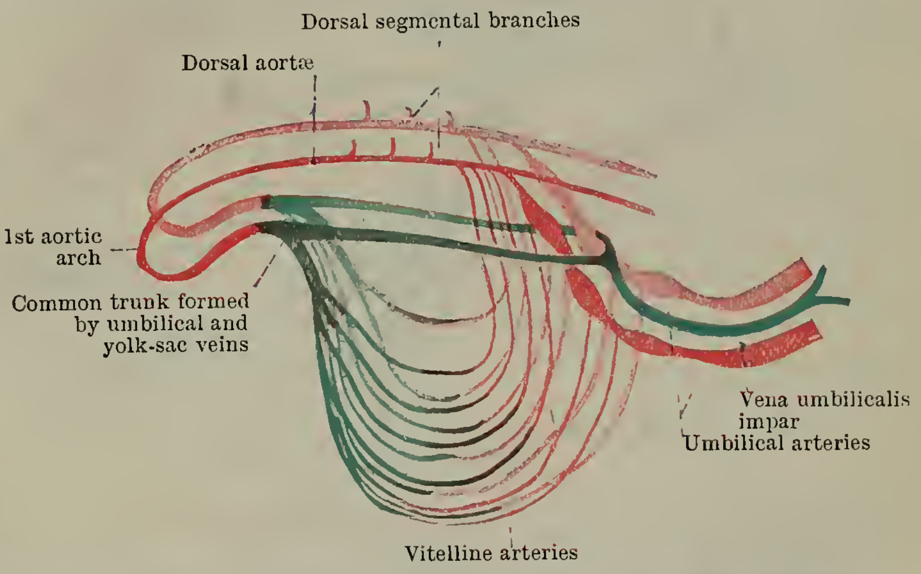

FIG. 87.—SCHEMA OF CIRCULATION OF AN EMBRYO, 1·35 MM. LONG, WITH SIX SOMITES. (After Felix, modified.)

In the embryonic area two main stem vessels are first differentiated; they are the **primitive aortæ.**

The primitive aortæ appear in the splanchnic mesoderm of the pericardial or anterior region of the embryonic area, whence they extend to the caudal or posterior end of the area.

At their anterior ends they are continuous with two stem vessels, right and left, called the **vitelline veins**, which emerge from the vascular plexus in the wall of the yolk-sac.

As the primitive aortæ pass caudalwards in the embryonic area, ventral to the paraxial bars of mesoderm (see p. 32), they give off from their ventral aspects a series of paired branches called **vitelline arteries**, which terminate in the vascular plexus in the yolk-sac wall; and from the caudal and dorsal part of that plexus, represented in Fig. 87 by a series of dilatations, a pair of vessels—the **umbilical arteries**—passes along the body-stalk to the vascular plexus in the chorion, whilst another stem vessel, the **vena umbilicalis impar**, commences in the vascular plexus in the chorion and passes along the body-stalk to the caudal margin of the embryonic area, where it divides into right and left umbilical veins. The latter run along the corresponding margins of the embryonic area and fuse with the corresponding

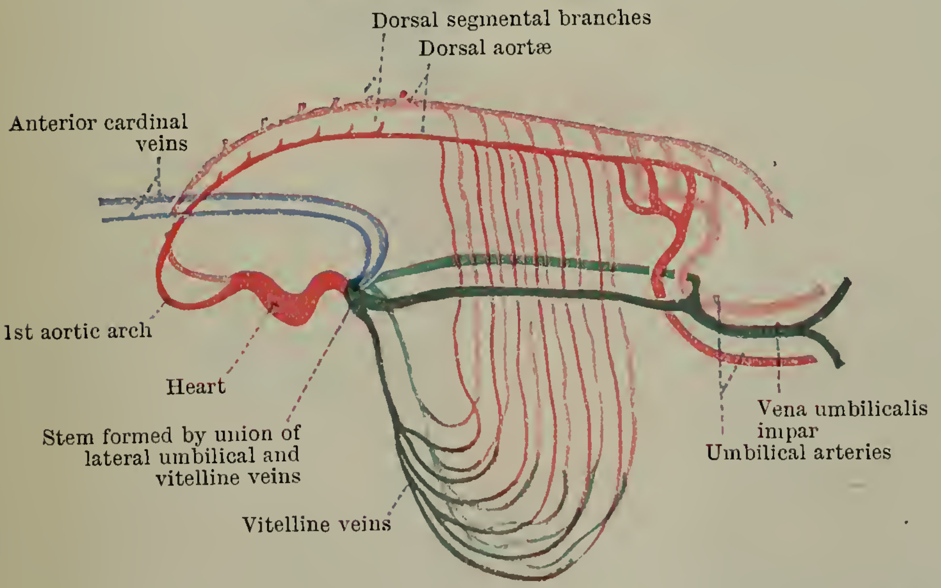

FIG. 88.—SCHEMA OF VASCULAR SYSTEM OF AN EMBRYO, 2·6 MM. LONG, WITH FOURTEEN SOMITES. (Arteries after Felix, modified.)

vitelline veins at the points where the latter join the primitive aortæ, forming with them vitello-umbilical trunks. Therefore, when the rhythmic contractions commence in the pericardial portions of the primitive aortæ, and pass from the anterior towards the caudal end of the embryonic area, the blood is driven caudalwards, through the primitive aortæ, and passes through their vitelline branches to the yolk-sac and the chorion, whence it is returned to the aortæ by the vitelline and umbilical veins.

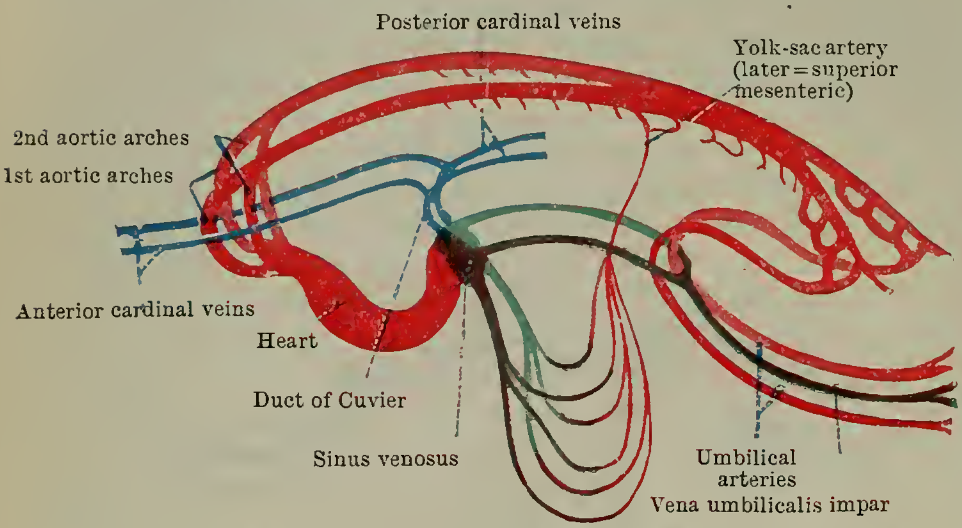

Fig. 89.—Schema of Vascular System of an Embryo with twenty-three Somites. (Arteries after Felix, modified.)

In the meantime branches have been given off from the lateral aspects of the primitive aortæ, which in later stages, as the mesodermal somites are defined, become the presegmental and intersegmental arteries, but for a time no purely intra-embryonic veins are distinguishable.

As the head fold is formed and the pericardial region is transposed into the ventral wall of the fore-gut (see pp. 42, 43), the anterior parts of the primitive aortæ are carried ventrally in the fold, and so are bent into the shape of hooks. That condition is well seen in embryos of 1·35 mm. length which possess six mesodermal somites (Fig. 87).

Three parts of each primitive aorta are now defined; the short ventral limb of the hook is the *primitive ventral aorta*, the long dorsal limb is the *primitive dorsal aorta*, and the bend, which connects the two limbs, is the *first aortic arch*. It runs along the side of the buccopharyngeal membrane, in the substance of the mandibular or first branchial arch. What were previously the anterior ends of the primitive aortæ have now become the caudal ends of the primitive ventral aortæ; they lie in the substance of the septum transversum, which is the bar of mesoderm which separates the pericardial cavity from the extra-embryonic cœlom at the cranial margin of the umbilical orifice, and in that situation the common vitello-intestinal venous trunks terminate in them.

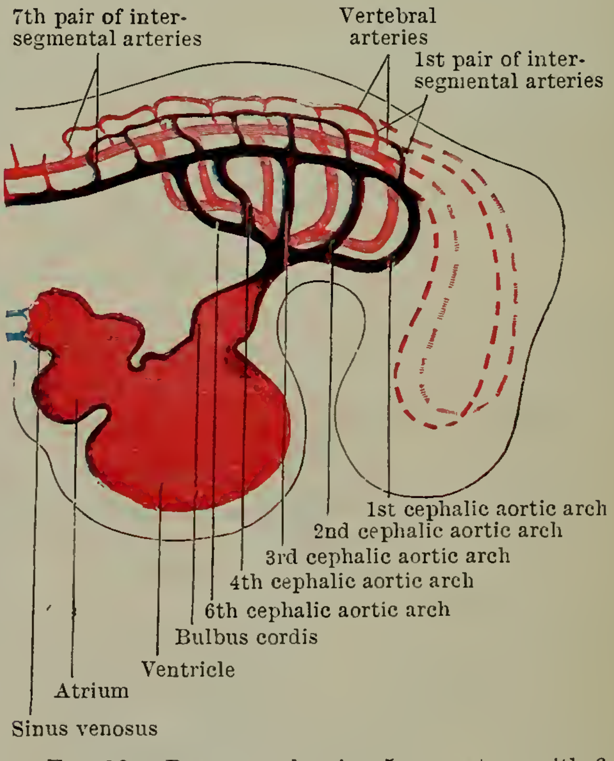

Fig. 90.—Diagram showing 5 mm. stage with five aortic arches.

During the time in which the embryo grows a little more than another millimetre in length, and the tail and lateral folds are formed and the number of its mesodermal somites increases to fourteen pairs, three important changes take place in the vascular system.

(1) The caudal parts of the primitive ventral aortæ fuse together to form a single median tubular heart, which is divided, by dilatations and constrictions, into five parts, named, from the caudal towards the cranial end, the **sinus venosus**, the **atrium**, the **ventricle**, the **bulbus cordis**, and the **arterial trunk**. At the same time the heart increases in length more rapidly than the region in which it lies,

therefore it becomes bent, both in the longitudinal and the transverse direction, and its caudal and cranial ends are relatively approximated (Fig. 88).

(2) The origins of the umbilical arteries are transferred from the vitelline plexus to the primitive dorsal aortæ from which they arise by three roots for each (Fig. 88).

(3) The **precardinal veins**, which are the first pair of purely intra-embryonic veins, are defined. They return blood, which has been distributed to the head, neck, and anterior part of the trunk regions of the embryo by the pre- and intersegmental arteries, to the sinus venosus of the heart, which they enter, in the septum transversum, close to the terminations of the common vitello-umbilical trunk veins.

As the embryo increases from 2·6 mm. to about 5 mm. in length, by which time it is about five weeks old, its mesodermal somites increase to 38 pairs, and numerous changes take place in the cardiac, the arterial, and the venous parts of the vascular system, and the rudiments of all the main blood-vessels of the adult are defined.

In the case of the heart its various chambers become more definitely demarcated, and the rudiments of the septa which divide its atrial and ventricular portions into right and left parts are formed. (For the further development of the heart see Vascular System.)

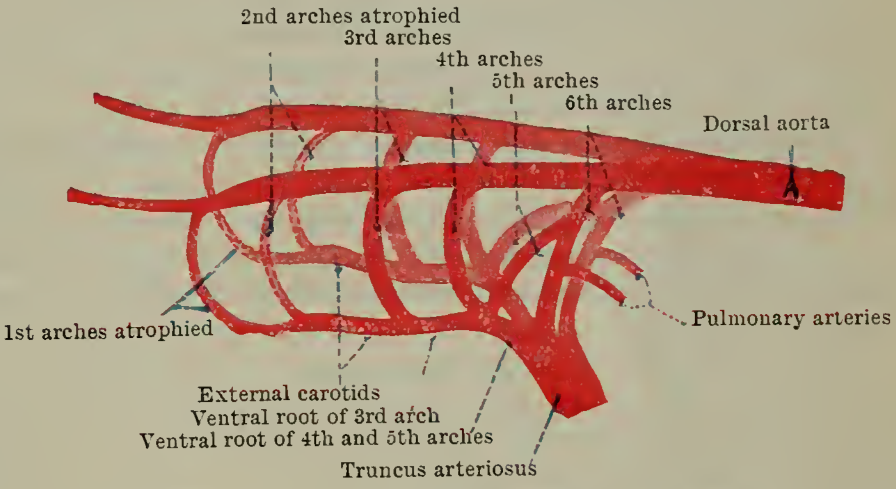

FIG. 91.—SCHEMA OF AORTIC ARCHES OF AN EMBRYO, 9 MM. LONG. (After Tandler, modified.) The second and third arches have atrophied and the transitory fifth has appeared.

The changes in the arterial system consist of fusions, reductions, transpositions, and additions.

Fusions.—The primitive dorsal aortæ fuse, from the region of the tenth mesodermal somite (seventh cervical) caudalwards, to form the permanent descending aorta (Fig. 89) and its caudal continuation the middle sacral artery.

At the same time the pairs of ventral branches of the fused portions of the primitive dorsal aortæ fuse to form single trunks, which divide, on the dorsal aspect of the alimentary tube, into right and left branches which reunite on the ventral wall of the tube.

Reductions.—Not only do the paired ventral or vitelline branches of the primitive dorsal fuse to form single trunks, which anastomose with those cranial and caudal to them on the walls of the primitive gut, but they also become reduced in number.

A few remain in the thoracic region and become the bronchial and œsophageal branches of the descending aorta of the adult. In the abdominal region they are reduced to three main vessels, the cœliac artery, the superior mesenteric artery, which for a time passes to the yolk-sac as the vitelline artery (Fig. 89), and the inferior mesenteric artery.

Additions.—Four additional aortic arches, connecting the unfused portions of the primitive ventral and dorsal aortæ. appear in the following sequence, the second, the third, the fourth, and the sixth.

The second pair of arches is found in embryos possessing 23 mesodermal somites (Fig. 89). They spring from the aortic trunk close to the commencements of the primitive ventral aortæ.

Branches are given off from the ventro-lateral aspects of the descending aorta to the rudiments of the nephric or urinary system, which are, in the meantime, developed from the intermediate cell tract, and to the rudiments of the genital glands.

By the time the embryo has fully attained a length of 5 mm. (Fig. 90) all five pairs of aortic arches are present, but in the meantime, coincidently with the elongation of the neck, the primitive ventral aortæ have also been elongated and the second aortic arches have been transferred to them from the aortic trunk. The remaining three pairs of aortic arches originate from common stems, one on each side, which spring from the aortic trunk close to the origins of the primitive ventral aortæ.

Thus during the period of increase from 2·6 mm. to 5 mm., and by the time the embryo is about five weeks old, the rudiments of all the important arteries of the adult are evolved, and during the same period two additional pairs of intra-embryonic venous trunks are formed. They are called the **postcardinal** and the **subcardinal veins.**

The postcardinal veins (Fig. 89) appear in the thoracic and abdominal regions of the embryo, dorso-lateral to the nephric rudiments.

They drain blood from the body walls and from the nephric rudiments, and their cranial ends join the precardinals, in the thoracic region, at the point where the latter turn ventrally to enter the septum transversum (Fig. 89).

As soon as the union of the pre- and postcardinals is completed the parts of the precardinals ventral to the points of union become the **Ducts of Cuvier.**

In the meantime the common vitello-umbilical venous trunks have been absorbed into the sinus venosus; therefore, at the 5 mm. stage, six veins, three on each side, open into the sinus venosus of the heart. They are the Ducts of Cuvier, the vitelline veins, and the umbilical veins.

The subcardinal veins appear in the abdominal region ventro-medial to the mesonephros, which has been formed from part of the nephric rudiment. They communicate both at their cranial and caudal ends with the postcardinals.

In addition anastomoses are developed, across the median plane, between the pre-, the post-, and the subcardinal veins of opposite sides respectively. Anastomoses also develop between the post- and subcardinal veins of the same side.

At a later period still another pair of intra-embryonic veins is established in the abdominal and thoracic regions. They are called the **supracardinal veins** and they appear dorso-lateral to the descending aorta. They communicate with one another across the median plane, and with the post- and subcardinal veins, and when their formation and anastomoses are completed the rudiments of the main stems of the venous system of the adult are established.

As the changes which have been noted occur in the venous system the third and fourth pairs of aortic arches are transposed from their original positions (Fig. 90) to the primitive ventral aortæ, and the right and left fifth arches which, for a time, connect the ventral aortæ with the dorsal ends of the sixth arches are formed; pulmonary branches are projected from the sixth arches to the rudiments of the lungs, and the first two aortic arches have undergone or have begun to undergo atrophy (Fig. 91).

In order to facilitate the description of the further changes which take place in association with the aortic arches it is customary to speak of the parts of the ventral aortæ which lie caudal to the respective arches as the *ventral roots* of these arches and the corresponding parts of the dorsal aortæ as the *dorsal roots.* (For the further history of the vascular system and the fœtal circulation see Vascular System.)

THE CŒLOM.

It has already been pointed out that there are two parts of the cœlom, the extra-embryonic and the intra-embryonic. Both are clefts separating an outer from an inner layer of mesoderm.

The Extra-embryonic Cœlom.—The extra-embryonic cœlom appears in the primary mesoderm and separates it into a parietal and a visceral layer. The parietal layer covers the inner surface of the trophoblast and forms with it the chorion. It covers also the outer surface of the amnion. The visceral layer covers the outer surface of the extra-embryonic portion of the wall of the entodermal cavity.

The extra-embryonic and intra-embryonic parts of the cœlom are at first separate from one another (Fig. 42), then they become continuous, for a time, in the region of the umbilical orifice (Fig. 43), but are separated from one another again when the umbilical orifice closes. The extra-embryonic portion is entirely obliterated when the outer surface of the expanding amnion fuses with the inner surface of the chorion (compare Figs. 83 and 84).

The Intra-embryonic Cœlom.—The intra-embryonic cœlom appears as a series of cleft-like spaces in the margin of the embryonic mesoderm. The spaces fuse together to form a ∩-shaped cavity (Fig. 92) which separates the peripheral part of the embryonic mesoderm into a parietal or somatic, and a visceral or splanchnic, layer. The bend of the ∩-shaped cavity lies in the margin of the cephalic part of the embryonic region, and it has no direct communication with the extra-embryonic cœlom, but the greater part of each stem of the cavity, on account of the disappearance of its lateral wall, soon opens, laterally, into the extra-embryonic cœlom.

The transverse portion of the ∩-shaped cavity, which extends across the cephalic end of the embryonic area and connects the two limbs together, is the **pericardial cavity**. The adjacent part of each lateral limb of the cavity is the **pleuro-pericardial canal**, it becomes a *pleural cavity*, and the remaining portions of the two limbs unite ventrally, as the umbilical orifice closes, to form the single **peritoneal cavity**.

As the head fold forms, the pericardial part of the cavity is carried ventrally and caudally into the ventral wall of the fore-gut (Fig. 93). The mesoderm which originally formed its peripheral boundary, but which now lies in the cephalic boundary of the umbilical orifice, becomes thickened, and forms the *septum transversum* (Figs. 93, 94, 95).

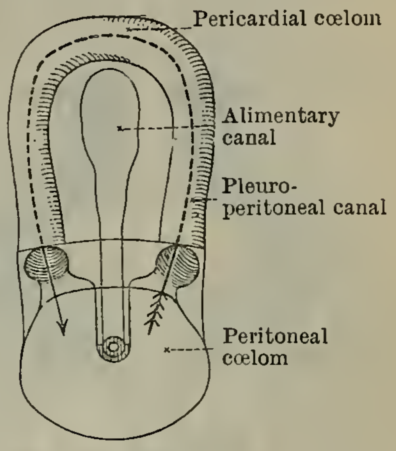

Fig. 92.—Schema of Intra-Embryonic Cœlom seen from above before the Folding of the Embryonic Area.

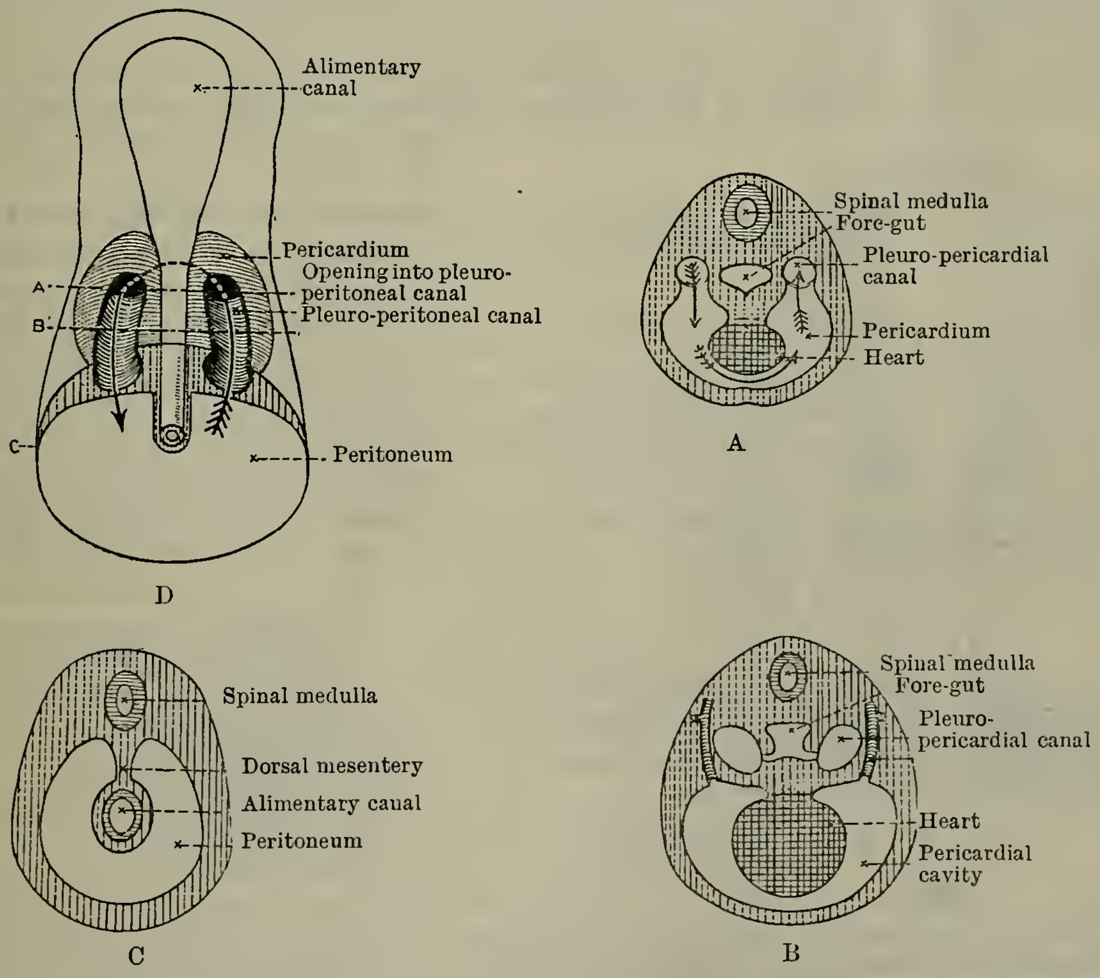

Fig. 93.—Schemata of Embryonic Cœlom after folding of Embryonic Area but before the Separation of the Various Parts. D from above ; A, B, and C at levels of line A, B, and C in Fig. D.

At the cephalic end of its dorsal wall, on each side, the pericardial cavity is still continuous with the two lateral parts of the cœlom; and each lateral part, which lies dorsal to the pericardium, and between the fore-gut medially and the body wall laterally, is still a pleuro-pericardial canal.

The Separation of the Pericardial, Pleural, and Peritoneal Parts of the Cœlom.—In the lateral wall of each pleuro-pericardial canal, near its cephalic end, lies the duct of Cuvier, passing towards the heart; and a lung bud containing a primitive bronchial tube grows, from the medial wall, into the cavity of each pleuro-pericardial canal (Fig. 94). As the lung buds grow the cavities of the pleuro-pericardial canals increase in size, and each passes ventrally, round the side of the pericardium towards the ventral wall of the body, until it is separated from its fellow of the opposite side only by a median mesoderm-filled interval, which becomes the anterior mediastinum and the anterior part of the superior mediastinum (Fig. 97). At the same time the cavity of each pleuro-pericardial canal, and the growing lung bud in its interior, grow towards the cephalic end of the embryo (Fig. 96).

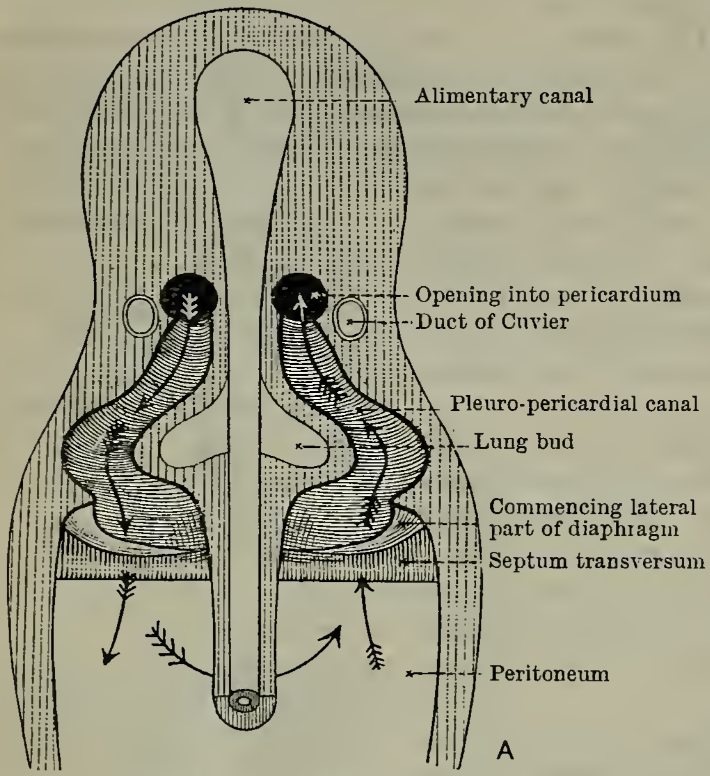

Fig. 94.—Schema of Later Stage of Differentiation of Cœlom. A, from above. B, transverse section cut at the level of lung bud in A.

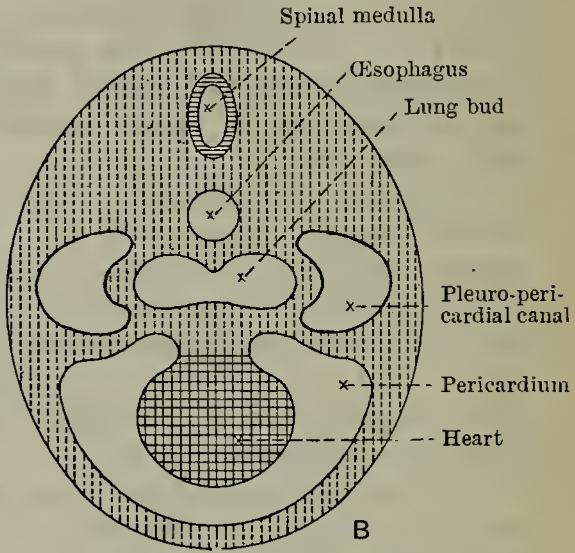

Fig. 95.—Schema of a Transverse Section at the level of the Lung Bud in Fig. 94.

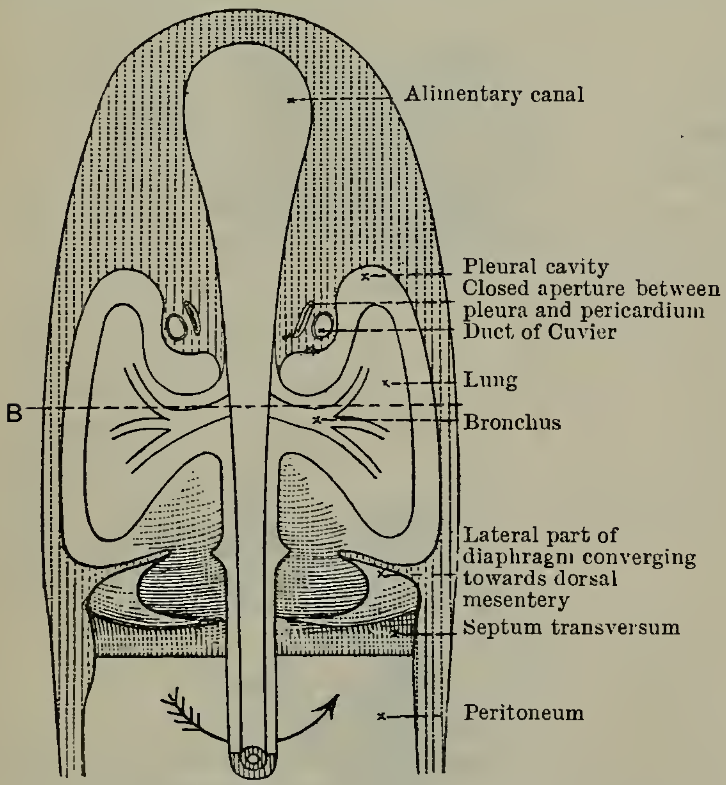
Alimentary canal
Pleural cavity
Closed aperture between pleura and pericardium
Duct of Cuvier
Lung
B
Bronchus
Lateral part of diaphragm converging towards dorsal mesentery
Septum transversum
Peritoneum

Fig. 96.—Schema of still later Stage of Cœlom Differentiation. The pleuræ are separated from the pericardia, but still communicate with the peritoneum.

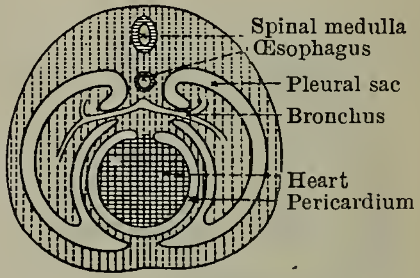

Fig. 97.—Schema of Transverse Section of Embryo at Level of Line B, Fig. 96, showing ventral extension of the pleuræ.

As it passes cephalwards the growing lung lies to the lateral side of the duct of Cuvier, which is thus forced against the cephalic end of the pleuro-pericardial canal, compressing it towards the median plane, against the sides of the trachea and the œsophagus, until its cavity is obliterated. When this occurs the pericardial cavity is entirely shut off from the remainder of the cœlom and it becomes a completely closed space (Fig. 96).[1]

As the closure of the pericardial cavity is taking place two wing-like folds of mesoderm, connected ventrally with the septum transversum and laterally with the body walls, appear, caudal to the lungs (Figs. 94, 96). These folds are the rudiments of the lateral parts of the diaphragm, and each passes medially until it fuses with the mesoderm of the side wall of the fore-gut and with the dorsal mesentery. When this fusion is completed the cavity of the portion of the cœlom surrounding the lung, the original pleuro-pericardial canal, is separated from the more caudal part of the cœlom, which now becomes the peritoneal cavity.

Only the broad outlines of the processes by which the pleuro-pericardial canals are separated from the pericardium and the peritoneum and so become the pleural sacs are mentioned in the preceding paragraphs. The details of the processes are too complicated for description in an ordinary text-book of anatomy.

The Formation of the Diaphragm.—There are four main parts of the diaphragm, a ventral, a dorsal, and a right and a left lateral.

The ventral part is formed from the septum transversum, which is gradually differentiated into a caudal, an intermediate, and a cephalic part. The caudal part is transformed into (1) the mesodermal tissue of the liver, which grows towards the abdomen, (2) the falciform and coronary ligaments, and (3) the lesser omentum. The cephalic part becomes the caudal or diaphragmatic wall of the pericardium. The intermediate part is transformed into the ventral portion of the diaphragm.

The dorsal part of the diaphragm is developed from the mesoderm of the dorsal mesentery of the fore-gut. Each lateral part is derived from a lateral ingrowth, which springs ventrally from the septum transversum and laterally from the body wall. The two lateral portions grow towards the median plane till they fuse with the dorsal portion; but in some cases, especially on the left side, the fusion is not completed. In such cases an aperture of communication remains, between the pleural and the peritoneal cavities, through which a portion of the abdominal contents may pass into the pleural sac, constituting a diaphragmatic hernia.

SUMMARY OF THE EXTERNAL FEATURES OF THE HUMAN EMBRYO AND FŒTUS AT DIFFERENT PERIODS OF DEVELOPMENT.

During the first **fourteen** days after the impregnation of the oocyte the human zygote descends through the uterine tube, assumes the morula condition, enters the uterus (see p. 25), penetrates into the decidua compacta, and differentiates into three vesicles and a mass of primitive mesoderm; but, probably, it is not until the beginning of the third week, if Bryce's calculations are correct, that a definite embryonic area is present. By that time the zygote is an ovoid vesicle measuring 2·4 by 1·8 mm. Its wall is formed by the trophoblast, and it contains two inner vesicles, the ecto-mesodermal and the entodermal vesicles. The inner vesicles are surrounded by a mass of primary mesoderm in which the extra-embryonic portion of the cœlom is beginning to appear. At that period the embryonic area is the region where the walls of the two inner vesicles lie in relation with one another, and it is ·19 mm. long (Fig. 36).

By the **eighteenth** or **nineteenth** day the area has attained a length of 1·17 mm. and it is ·6 mm. broad. It is pierced, about the centre of its length, by the neurenteric canal; the primitive streak has appeared on the dorsal surface of the area; the primitive groove is distinct, and the neural groove is indicated. The body-stalk is bent dorsally, at right angles with the area, and it contains the allantoic diverticulum, which has already been projected from the wall of the entodermal vesicle (Fig. 98).

During the next twenty-four hours the length of the embryonic area increases to 1·54 mm.; the neurenteric canal is moved caudally, to a point well behind the middle of the length of the area, and the posterior part of the area is bent ventrally, forming the posterior boundary of the hind-gut region and indicating the position of the future cloacal membrane. The head fold has begun to form, and the pericardial region lies in the ventral wall of the rudimentary fore-gut (Fig. 99).

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[1] Very rarely, as an abnormal condition the pericardial cavity of the adult communicates on one or other side with a pleural cavity.

By the middle of the **third week** the head and tail folds are distinctly formed and the length of the embryo is 1·9 mm., the neural folds are well developed, the neural groove is still completely open, and six pairs of mesodermal somites are visible (Fig. 100).

In the next few days the length increases to 2·5 mm., the neural groove closes except in the cranial and caudal regions, the number of mesodermal somites is increased to fourteen pairs, and the cranial region begins to bend ventrally as the cervical flexure forms (Fig. 101).

By the end of the **first month** the greatest length of the embryo is about 2·6 mm., the head is bent at right angles to the body, the Wolffian ridges have appeared along the ventral margins of the mesodermal somites and indications of the limb rudiments are present. The rudiments of the otic vesicles have appeared as slight depressions in the region of the hind-brain. The anterior and posterior neuropores are still open (Fig. 102).

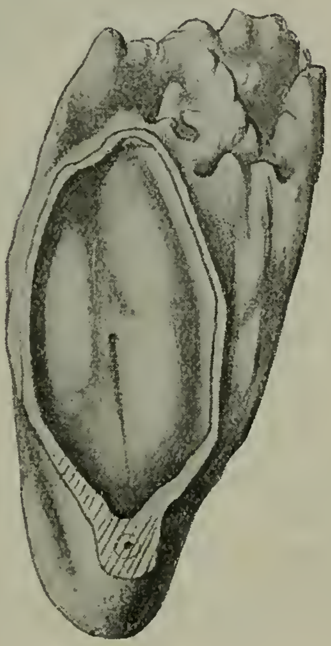

Fig. 98.—Frassi's Zygote. Estimated to be 18-19 days old (Bryce). The embryonic area is 1·17 mm. long and ·6 mm. broad. Copied from *Normaltafeln*, Keibel and Elze, representing a reconstruction. The chorion is not shown. The upper part of the amnion is cut away, and the dorsal aspect of the embryonic area is seen from above. In the centre of the area is the neurenteric canal and caudal (inferior in the Fig.) to it is the primitive groove. Cephalwards of the neurenteric canal is the neural groove, in the middle of the neural plate. At the lower (caudal) end of the Fig. is seen a section of the body-stalk containing the allantoic diverticulum, and the nodulated area seen at the upper and right lateral part of the Fig. is a portion of the yolk-sac.

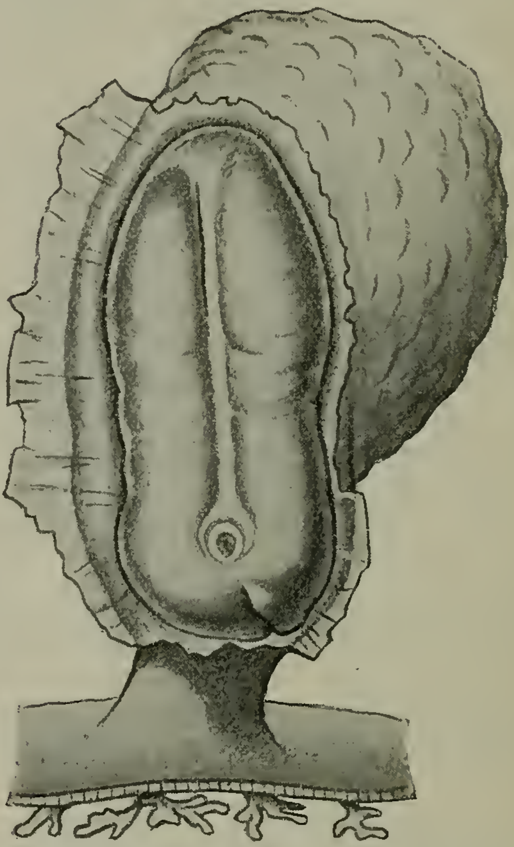

Fig. 99.—Spee's Zygote. (From Keibel and Elze's *Normaltafeln.*) Length of embryonic area 1·54 mm. Estimated age 19-20 days (Bryce). At the lower end of the Fig. (caudal end of the embryo) is seen a portion of the chorion attached to the embryo by the body-stalk. A portion of the amnion is still attached to the margin of the embryonic area, and the dorsal surface of the embryonic area is exposed. In the median plane of the area is the neural groove, and at the caudal end of the groove is the neurenteric canal. The caudal part of the area is bent ventrally, and upon it is the remains of the primitive groove. The yolk-sac is seen at the upper and right part of the Fig.

In the latter part of the fourth or the beginning of the fifth week the embryo attains a length of about 5 mm., when measured from the vertex of the head to the base of the tail, the mesodermal somites increase to thirty-five; the rudiments of the fore- and hind-limbs become quite distinct; the otic vesicles sink into the interior of the head but remain connected with the surface by a narrow canal, the tail becomes a very definite appendage, and the bulgings caused by the otic vesicles are quite obvious on the surface of the head. The cervical flexure remains acute, and the head bends at right angles upon itself in the region of the mid-brain, forming the cephalic flexure, with the result that the frontal extremity of the head is turned caudally (Fig. 103).

By the end of the **fifth week** the length of the embryo has increased to 11 mm. (CR)[1]

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[1] CR indicates the crown-rump or crown-breech measurement which corresponds with the sitting height (Mall).

(Mall). Forty-three mesodermal somites are present, but only about twenty-one are visible on the surface. During the fifth week the lens of the eye appears as a thickening of the surface ectoderm; sinks into the interior of the eyeball; becomes a vesicle and separates from the surface. The three segments of the fore-limb become visible, and the rudiments of the fingers appear. The hind-limb is less advanced; the thigh segment is not distinct, and the rudiments of the toes are not yet visible. The third and fourth visceral arches disappear from the surface and lie in the depths of the **precervical sinus**, a depression between the neck and the anterior part of the body; this is overlapped, superficially, by the caudal margin of the second arch, which grows tailwards and forms the operculum of the sinus (see p. 47) (Figs. 104, 105). During the fifth week the head grows rapidly, and becomes relatively very large as contrasted with the body.

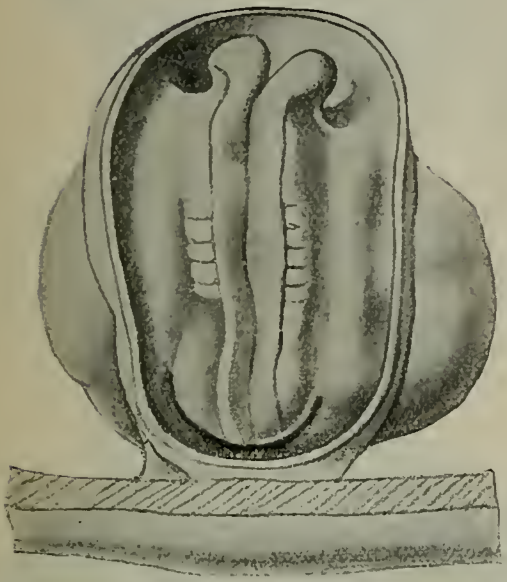

FIG. 100.—KRŒMER-PFANNENSTIEL ZYGOTE. (From Keibel and Elze's *Normaltafeln.*) The embryonic region is folded into the form of an embryo, which is 1·9 mm. long, and it is possibly about three weeks old. At the lower end of the Fig. (the caudal end of the embryo) are seen portions of the chorion and body-stalk. The cerebral portion of the neural rudiment is defined. Six pairs of mesodermal somites are present, but there are no signs of limbs.

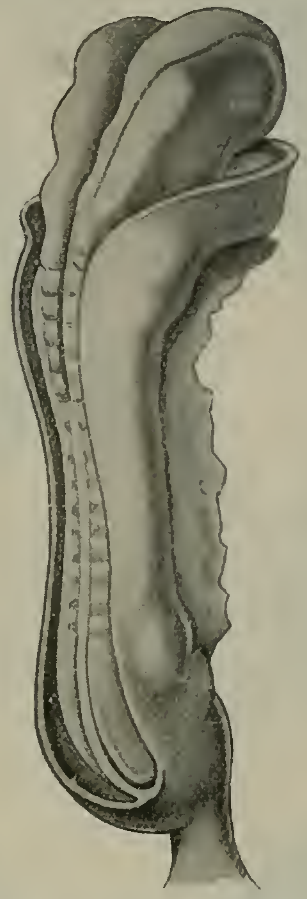

FIG. 101.—BALLE'S EMBRYO. (From Keibel and Elze's *Normaltafeln.*) Length after hardening in alcohol 2·5 mm. The neural groove is closed from the sixth somite to within a short distance of the caudal end, but it is open anteriorly. The hind-, mid-, and fore-brain regions and the optic vesicle can be distinguished At the lower end of the Fig. is the body-stalk, and at the right side a part of the yolk-sac.

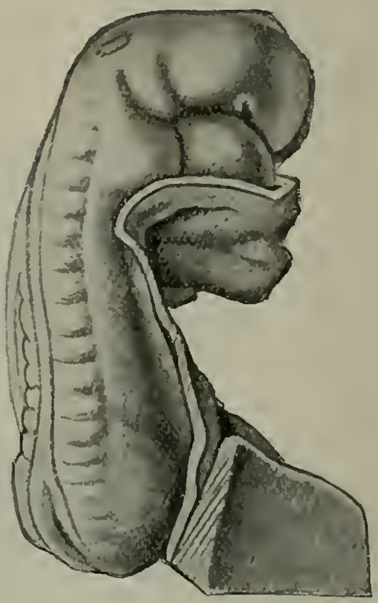

FIG. 102.—PFANNENSTIEL'S EMBRYO. (From Keibel and Elze's *Normaltafeln.*) Length of embryo about 2·6 mm. The rudiment of the otic vesicle is seen in the Fig. above the second branchial cleft. The heart and pericardium form the bulging eminence below the head, and the Wolffian ridge is seen at the lateral border of the mesodermal somites.

During this week also the olfactory pits appear, and grow dorsally in the roof of the stomatodæum, separating the median from the lateral nasal processes; the median process is divided into the two globular processes; and the maxillary processes of the mandibular arches, growing towards the median plane, fuse with the lateral nasal and the globular processes, so completing the lateral parts of the primitive cranial lip (Figs. 70, 71, 72).

The nodular outgrowths which form the rudiments of the auricles appear on the margins of the hyo-mandibular cleft and fuse together, and by the end of the week traces of the tragus, the helix, and the antitragus are visible (Fig. 106).

By the **seventh week** the embryo has attained a length of 17 mm. (CR). The cervical flexure has begun to unfold. The rudiments of the eyelids have appeared. The globular processes have fused together, but there is still a distinct notch in the middle of the upper lip. The margins of the auricles are now well defined; the hands are folded

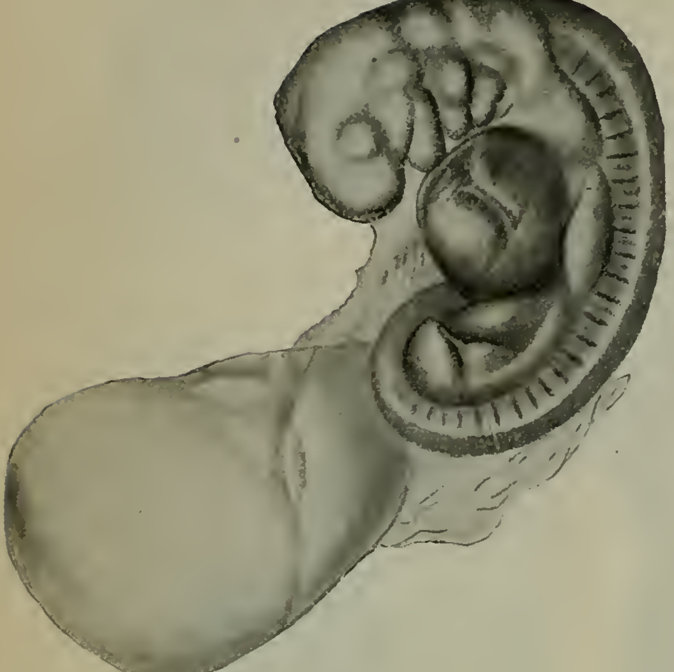

FIG. 103.—SIDE VIEW OF AN EMBRYO, measuring about 5 mm. from the root of the neck to the base of the tail, and about 47 mm. from the crown or mid-brain region to the base of the tail, that is to the breech or rump. (From Keibel and Elze's *Normaltafeln.*) The neural tube is closed. The limb buds are quite distinct, and the maxillary process of the mandibular bar has grown forward below the eye (dorsal to the eye in the Fig.).

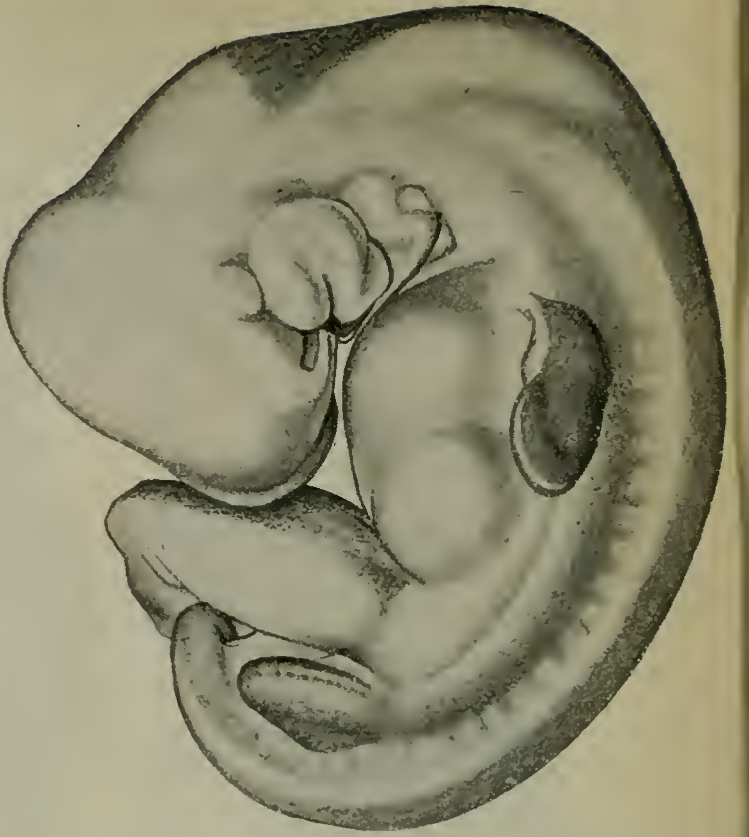

FIG. 104.—EMBRYO OF 7·2 MM., CR MEASUREMENT. 8·5 mm. greatest length. (From Keibel and Elze's *Normaltafeln.*) The fore-limb is distinctly in advance of the hind-limb. The second branchial arch has begun to overlap the third and fourth and to enclose the precervical sinus. The tip of the maxillary process is in contact with the lateral and medial nasal processes at the margins of the olfactory pit.

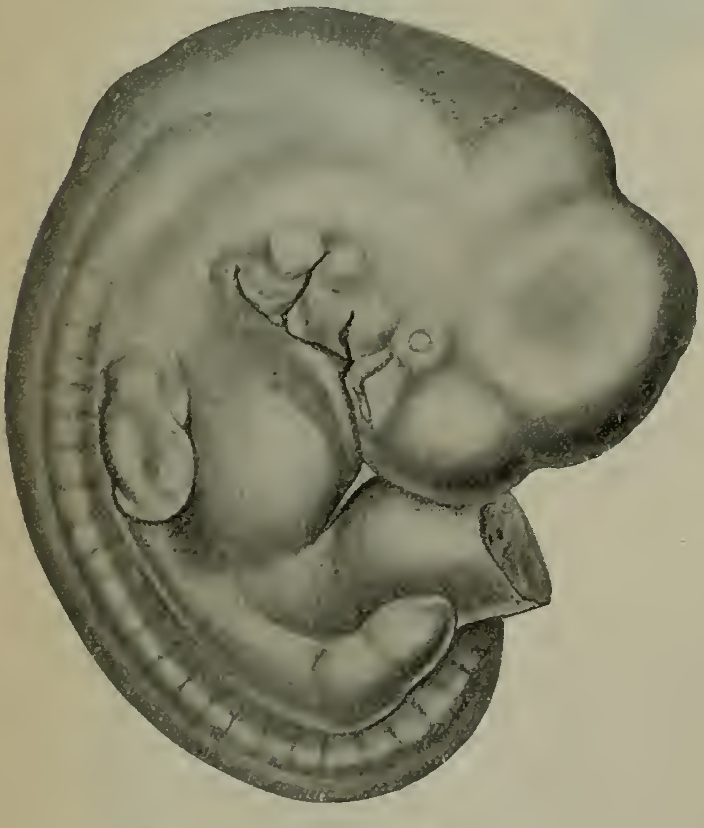

FIG. 105.—EMBRYO, 7·2 mm. (CR), and 8 mm. greatest length. (From Keibel and Elze's *Normaltafeln.*) The limbs have begun to fold ventrally. The second arch has completely overlapped the third and fourth, which now lie in the precervical sinus, and the sinus still opens on the surface at the posterior border of the second arch. The lens of the eyeball is very evident, and rudiments of the auricle of the external ear have appeared on the mandibular or first, and the hyoid or second arch.

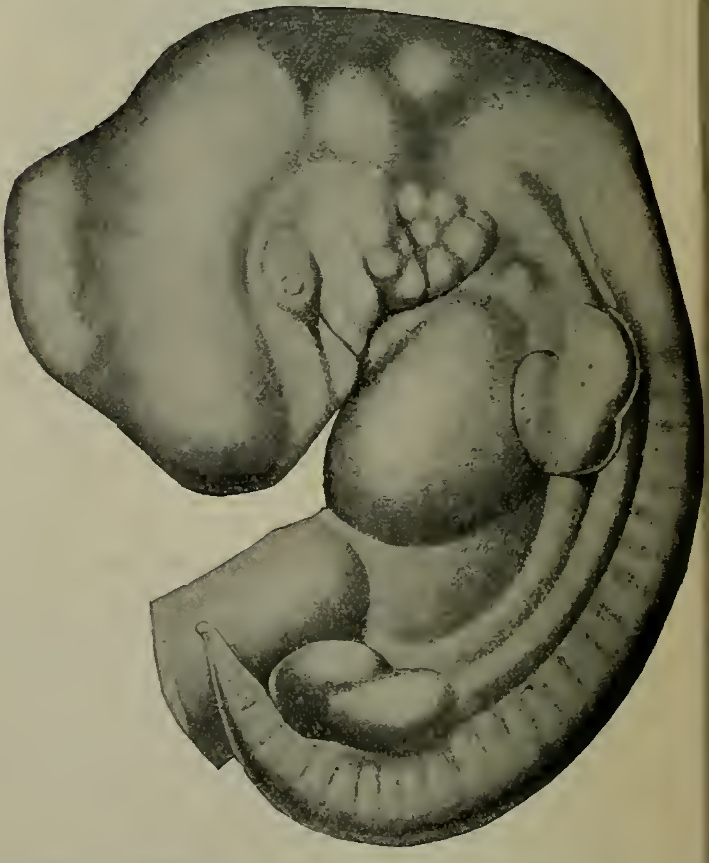

FIG. 106.—EMBRYO, 10·9 mm. (CR), and 11·5 mm. greatest length. (From Keibel and Elze's *Normaltafeln.*) The precervical sinus is closed and additional rudiments of the auricle of the external ear are present on the first and second arches. The anterior nares are no longer visible from the side.

medially; the tips of the fingers are free, and the palms rest on the cranial part of the distended abdomen. The thighs and the toes have appeared, and the tail has begun to fuse with the caudal end of the body (Fig. 107).

At the end of the **eighth week**, when the embryo becomes a fœtus, it has attained a length of about 25 mm. (CR). The auricles project from the sides of the head, the tail has almost disappeared from the surface, and the toes are free from one another. The cervical flexure is now very slight, and although the head is still relatively large, the disproportion between it and the body has begun to decrease (Fig. 108).

Third Month.—The head grows less rapidly, and, though it is still large, it is relatively smaller in proportion to the whole body. The eyelids close, and their margins fuse together. The neck increases in length. The various parts of the limbs assume their definite proportions, and nails appear on the fingers and toes. The proctodæum is formed and the external generative organs are differentiated, so that the sex can be distinguished on external examination. The skin is a rosy colour, thin and delicate, but more consistent than in the preceding stages. By the end of the third month the CR length of the fœtus is 87 mm. ($3\frac{1}{2}$ in.), and it weighs about 45 grams ($1\frac{1}{2}$ oz.).

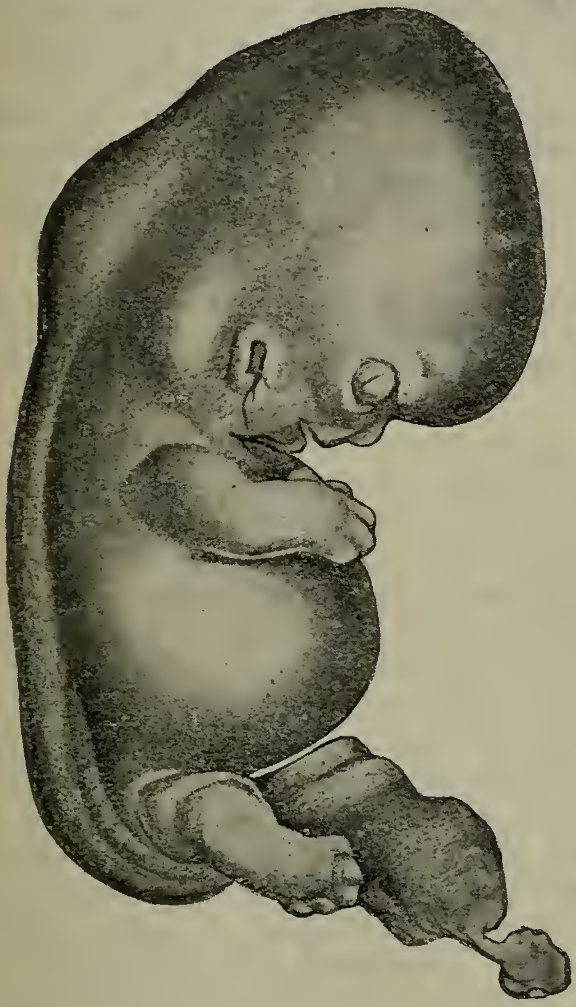

Fig. 107.—Embryo (CR), greatest length 18·5 mm. Probably between seven and eight weeks old. (From Keibel and Elze's *Normaltafeln.*) The abdomen is very prominent on account of the rapid increase of the liver. The digits of the hand and foot are distinct but not separated from one another. The margin auricle of the external ear is completed. The eyelids have begun to form.

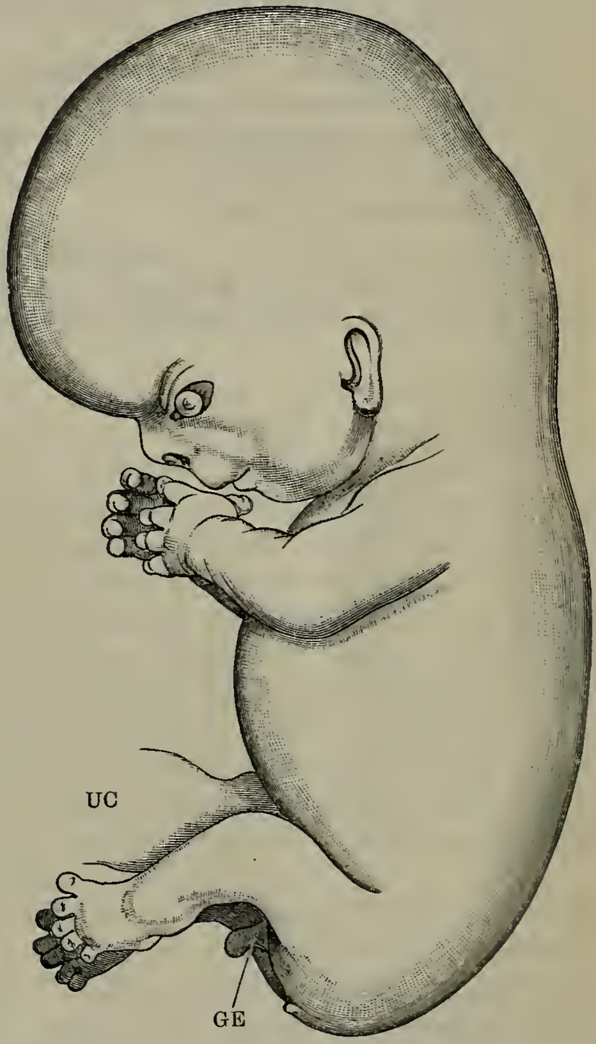

Fig. 108.—Human Fœtus eight and a half weeks old. (After His.)

GE, Genital eminence; UC, Umbilical cord.

Fourth Month.—In the fourth month the skin becomes firmer, and fine hairs are developed. The disproportion between the fore- and hind-limbs disappears. If the fœtus is born at this period it may live for a few hours. Its CR length is 142 mm. ($5\frac{3}{5}$ in.), and it weighs 198 grams (7 oz.).

Fifth Month.—The skin becomes firmer, the hairs are more developed, and sebaceous matter appears on the surface of the body. The legs are longer than the arms, and the umbilicus is farther from the pubis. At the end of the month the CR length of the fœtus is 186 mm. ($7\frac{1}{2}$ in.), and its average weight is 460 grams ($1\frac{1}{4}$ lbs.).

Sixth Month.—The skin is wrinkled and of a dirty reddish colour. The hairs are stronger and darker. The deposit of sebaceous matter is greater, especially in the axillæ and groins. The eyelashes and eyebrows appear. At the end of the month the CR total length of the fœtus is 228 mm. ($9\frac{1}{8}$ in.), and its average weight is about 930 grams ($2\frac{1}{16}$ lbs.).

Seventh Month.—The skin is still a dirty red colour, but it is lighter than in the previous month. The body is more plump on account of a greater deposit of subcutaneous fat. The eyelids reopen, and the fœtus is capable of living if born at this period. Its CR length at the end of the month is 265 mm. ($10\frac{3}{5}$ in.), and its weight is about 1·323 kilograms ($2\frac{3}{4}$ lbs.).

Eighth Month.—The skin is completely covered with sebaceous deposit, which is thickest on the head and in the axillæ and groins, and its colour changes to a bright flesh tint. The umbilicus is farther from the pubis, but it is not yet at the centre of the body. The CR length of the fœtus is 302 mm. (12 in.), and its weight about 2·074 kilograms ($4\frac{1}{2}$ lbs.).

Ninth Month.—The hair begins to disappear from the body, but it remains long and abundant on the head. The skin becomes paler, the plumpness increases, and the umbilicus reaches the centre of the body. At the end of the ninth month, when the fœtus is born, its CR length is about 360 mm. ($14\frac{1}{3}$ in.), and it weighs from 3·150 to 3·405 kilograms ($6\frac{1}{2}$-7 lbs.).

The age of a fœtus may be estimated, approximately, by Hasse's rule, viz., Up to the fifth month the length in centimetres, the lower limbs being included, equals the square of the age in months, and after the fifth month the length in centimetres equals the age multiplied by five.

OSTEOLOGY.

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INTRODUCTION.

BONES AND CARTILAGES.

The body is built around and supported by a framework of **bones** called the *skeleton* [σκελετός (skeletos) = dried]; and the bones are supplemented in many places by gristle or **cartilage**, more so in a growing person than in an adult.

Uses of Bones.—Bones make up the framework on which the form of the body is moulded. They give support to the softer tissues which are situated around them. They provide surfaces and projections for the attachments of certain of the softer structures, such as the muscles, tendons, and ligaments. Some of the bones are connected together in such a way that they form the walls of cages and boxes for the lodgment of internal organs, for example, the heart and the lungs in the chest, the brain in the skull, and the spinal marrow in the backbone.

In addition, the bones throughout the body are the chief factory, in the adult, for the production of the cells of the blood, for they contain a special tissue, called *bone marrow,* in which the blood corpuscles are made; and, further, many of the bones are used as passive levers in the movements of the body.

Articulation of Bones (see Figs. in Chapter on Joints).—Bones are held together indirectly by all the tissues which surround them and are attached to them, but bones which lie close to one another are connected together directly in a special way. The connexion or union between two or more adjacent bones is called a **joint** or articulation. The union is effected in most cases by special sheets and bands of fibrous tissue, called *ligaments,* which are fixed to adjoining parts of the two bones. The movements of the body take place at joints, and the bones are the levers in the movements at those joints at which free movements are possible. [*Articulus,* diminutive of *artus* = a joint; cf. "articulation" in speech, meaning the junction of words or syllables. *Ligamentum* = a band or bandage, from *ligare* = to bind.]

Bones which are united together at a joint are said to *articulate* with each other at that joint, and the part of the one bone that comes into relation with the other bone is called its **articular** surface or margin or end, as the case may be. At most of the joints of the *skull* there is a ribbon of fibrous tissue interposed between the two articular parts and firmly attached to both of them; and the articular parts are rough. At the joints between the *bodies* of the *vertebræ* (*i.e.* the segments of the backbone), and at the joint between the *two hip bones,* the articular parts are coated over with an adherent layer of **articular cartilage,** and interposed between them and firmly attached to them there is a plate or disc of a kind of cartilage called *fibro-cartilage;* at those joints also the articular parts of the bones are rough. But in the majority of joints the bones can either glide or rotate upon each other; the articular parts are covered with an adherent layer of articular cartilage which is smooth and polished, and the underlying bone also is smooth, so that the articular part of a dried bone is easily identified, even though the articular cartilage has come off during the preparation of the bone.

Constituents of Bone.—Bone, or bony tissue, consists of equal parts of solids and water, but it is the hardest and most enduring tissue in the body, excepting only the enamel or adamantine of the teeth. Bones are not only hard but are also exceedingly tough and elastic. They are composed of *white fibrous tissue* with which various *mineral salts* are incorporated. The chief salt is phosphate of lime; on account of the large proportion of that salt in bones they are one of the sources of phosphorus; there are also small quantities of calcium carbonate and fluoride, magnesium phosphate, and sodium chloride. About 30 per cent. of the solids of a bone is the *organic* matter of its component fibrous tissue; the remaining 70 per cent. is mineral salts (*inorganic* matter), and six-sevenths of that is phosphate of lime.[1] The mineral salts are so perfectly distributed through the fibrous tissue that a bone retains its form both when the salts are dissolved out of it by immersion in acid, and when the fibrous tissue is burnt out of it. Bones owe their toughness and elasticity to the fibrous tissue, and their hardness to the salts. In old age bones become more brittle owing, not to an increase of salts, but to diminution of the elasticity of the fibrous tissue.

Structure of Bone.—There are two kinds of bone, called compact bone and spongy bone. (See Fig. 223, p. 266.) **Compact bone** is hard and dense; it is seen and appreciated best in a bone such as the thigh bone when it is sawn across the middle. **Spongy bone** also is hard, but it is full of little cavities like a sponge; it is well seen in the end of a bone like the thigh bone, for the end consists of a mass of spongy bone covered with a thin surface shell of compact bone. When a bone is fresh, the cavities of spongy bone are filled with a soft, reddish material known as *red marrow*. The cavities and their walls appear very irregular to a casual glance, but with careful examination it becomes apparent that the bony substance around the cavities in any bone is arranged so as best to withstand the strain and stress that will normally be put upon that bone.

The **microscopical structure** of bony tissue is essentially the same in spongy and compact bone. The bony tissue is arranged in thin, closely applied sheets or layers called **bone lamellæ** [*lamella* or *lamina* = a leaf, blade, layer]. Here and there, between the lamellæ, there are minute cavities called **lacunæ** [*lacuna* = a pit, hole, or cavity], and in each lacuna, when the bone is fresh, there is a little cell or body called a **bone corpuscle**. Several slender tubes or canals, called **canaliculi**, pass from a lacuna through the lamellæ and connect it with neighbouring lacunæ. Where compact bone is thick, as in the shaft of a long bone, most of the lamellæ are tubular, and are arranged in groups called **Haversian systems** (after Clopton Havers, who first described them in detail). In each group there are from three to ten tubes, called **Haversian lamellæ**, arranged concentrically one outside the other. The cavity of the central tube is called a **Haversian canal**, and contains blood-vessels, a lymph channel, a nerve, and some loose connective tissue. The Haversian canals are continuous with the small tunnels through which the blood-vessels enter or leave the substance of the bone, and the connective tissue in the canals is continuous with the fibrous lining of the tunnels. The lacunæ of one system communicate by means of canaliculi with the other lacunæ in that system, but not with those of adjoining systems. Haversian systems are present also in thin compact bone and in spongy bone.

Classification of Bones.—The bones are divided into four classes according to their shape: long, short, flat, irregular.

Long bones are found in the limbs, *e.g.*, the *humerus* or bone of the upper arm, and the *femur* or thigh bone. Small elongated bones, such as those of the fingers and toes, are called **miniature long bones.** Each long bone has a *body* or shaft and *two ends*. The **body** is a hollow, thick-walled rod of compact bone. The space inside is called the **medullary cavity**, and, when the bone is fresh, it is filled with soft, yellowish material known as *yellow marrow* [*medulla* = marrow]; the yellow colour is due to abundance of fat. Around the medullary cavity, inside the compact bone, there is a layer of coarse spongy bone. The medullary cavity serves not only for the lodgment of the marrow. Its presence makes the bone lighter, and it makes it stronger also, for up to a certain point a hollow cylinder is more resistant than a solid one of the same thickness and material. The body of a long bone is never quite straight; it is curved usually in more than one plane; its curvatures increase its strength and resistance, the more so as there is a greater thickness of compact bony tissue in the concavities of the curves than elsewhere. The **ends** of a long bone are broader and thicker than the body. They consist of spongy bone covered with a thin layer of compact bone; the cavities in the sponge-work makes the bone lighter. The objects gained by the greater bulk of the end of the bone are: (1) The surface for articulation is wider, and therefore movements at the joint can be regulated more precisely; (2) the chances of dislocation are diminished; (3) shocks received by the bone are diffused.

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[1] The actual percentages are given as: organic matter, 31·03; calc. phos., 58·23; calc. carb., 7·32; calc. fluor., 1·41; mag. phos., 1·32; sod. chlor., 0·69.

Short bones are more or less cubical in shape. They consist of spongy bone enclosed in a thin shell of compact bone. Examples of short bones are the eight *bones of the wrist* and the seven *bones of the hinder half of the foot.* **Sesamoid bones** are included among short bones. A sesamoid bone is one which is developed in the substance of a tendon or sinew; the patella or knee cap is by far the largest of the sesamoid bones. They get their name from the resemblance that some of them have to sesame seeds.

Flat bones are such as the *ribs*, the *shoulder blade,* and the bones of the *skull cap.* They are **thin** rather than flat, for nearly all "flat" bones are curved or bent. They consist of two thin plates of compact bone which enclose between them a layer of spongy bone. In the flat bones of the skull the layer of spongy substance is called the **diploë** [διπλόη (diploē), a fold or doubling, a junction of two plates].

Irregular bones are of various shapes, and include all those that cannot be classed as long, or short, or flat. Many of the *skull bones* are irregular, and so are the *vertebræ.* The thinner parts of irregular bones are like flat bones and consist of two plates of compact substance with spongy substance between them. The bulky parts, especially in vertebræ, are like short bones, and consist of spongy substance surrounded with a layer of compact substance.

Most of the flat bones and many of the irregular bones of the skull have spongy substance between their two layers of compact substance, but in some of them the spongy tissue is more or less completely removed, and is replaced by cavities containing air, the walls of the cavities being composed of compact bone. Those cavities are called **air sinuses**; they give lightness to the bones and act as resonating chambers for the voice; they are extensions from the cavity of the nose, with which they are permanently in communication (Figs. 146, 147); their walls are lined on the inside with a membrane, called *muco-periosteum*, which is continuous with the similar membrane lining the interior of the nose; inflammation of the mucous lining of the nose in a "cold in the head" extends to the lining of the sinuses and gives rise to dull headaches. The air cells in the part of the skull called the mastoid temporal are, however, rather different; they are extensions from the cavity of the tympanum or drum of the ear, and lie in the midst of spongy bone, having replaced the marrow and some of the spongy substance. The bones of the skull which have air cavities in their interior, are called **pneumatic bones** [πνεῦμα (pneuma) = wind or air].

Characters of Living Bone.—The following five points are to be noted in connexion with a bone when it is living, or when it is in the "recent state"—that is, when it has been only recently removed from the body and has not been cleaned and dried.

(1) The articular parts are covered with a layer of cartilage called **articular cartilage.** That is the case in all bones, except some of those of the skull. At joints at which the bones are free to move the articular cartilage is smooth and polished to facilitate movement.

(2) The whole of the bone, except the articular part, is covered with a membrane of fibrous tissue called **periosteum** [περί (peri) = around; ὀστέον (osteon) = a bone]. The periosteum is adherent to the bone owing to the number of blood-vessels and nerves which pass from the periosteum into the bone, and because numerous minute bundles of fibres, called the *perforating fibres* of Sharpey, pass from the periosteum into the substance of the bone; within the bone the bundles are calcified like the rest of the bone, and nail the bone lamellæ together. The blood-vessels which carry the blood to and from the bone and marrow lie in the periosteum before they enter the bone (arteries), and after they leave it (veins); if the periosteum is stripped off a living bone by accident or disease the underlying part of the bone may die owing to the loss of its blood supply.

(3) The muscles, tendons, intermuscular fibrous septa, and the ligaments are attached partly to the periosteum and partly to the bone directly. In muscles with fleshy attachments the muscle fibres have microscopic tendinous ends which blend with the periosteum; some of the fibres of the tendons, the septa, and the ligaments blend with the periosteum, but a great many are prolonged into the bone as perforating fibres, and therefore the tendons, etc., are very firmly attached to bone.

(4) The medullary cavity is filled with yellow marrow, and the cavities in spongy bone with red marrow.

(5) The cavities in spongy bone are lined with a delicate membrane of fibrous tissue called **endosteum** [ἔνδον (endon) = within]; and, in a long bone, the medullary cavity is lined with endosteum continuous with that in the ends of the bone. The endosteum within a bone is connected with the periosteum on the outside by means of the fibrous lining of the tunnels through which the blood-vessels pass, and the loose connective tissue in the Haversian canals.

Appearances of a Dried Bone.—The bones used for study have been macerated and dried. Maceration is a process by which all the structures attached to a bone, including the periosteum and articular cartilage, are removed. In the subsequent drying the marrow and endosteum shrivel up.

Though the articular cartilage is removed the **articular part** of a bone can still be identified. In the case of the vertebræ where the articular cartilage covering the upper and lower aspects of the bodies does not have a free surface, but is adherent to fibro-cartilage (see p. 88), the part covered by the articular cartilage can be recognised by its peculiar appearance, which resembles unglazed porcelain; but in most bones the articular cartilage has a free surface which is smooth and polished, and the bone which it covers is also smooth and polished; some other parts of the bone may be quite smooth but do not have the polished or glazed appearance. Over all the surfaces of a bone, except the smooth articular surfaces, there are numerous small apertures; the apertures are the outer ends of the canals or tunnels through which the blood-vessels pass on their way to and from the bone marrow and the substance of the bone. At the ends of a long bone those small foramina [*foramen* = a hole] are scattered near the margins of the articular surface. On the body of a long bone the foramina are very minute, and are barely visible to the naked eye, but there is always one relatively large foramen, called the **nutrient foramen**, the position of which is fairly constant for the same bone in different subjects; the tunnel into which it leads is the *nutrient canal*; the vessels which pass through it are called the *nutrient artery* and *vein*, and they convey the blood to and from the bone marrow and the substance of the shaft.

The exterior of bones shows many grooves and hollows, ridges, eminences, and projections. The depressions and elevations are chiefly for the attachment of muscles, tendons, and ligaments. For any one bone they vary in different subjects, but are sufficiently alike for a general description to be applicable to all. The **surfaces** of a bone are named usually from the direction in which they face; *e.g.*, a surface directed *forwards* is called the *anterior* surface. Sometimes surfaces are named according to their relative propinquity to a cavity; *e.g.*, the *outer* surface of a rib is the one further away from the cavity of the chest. Some surfaces are named after neighbouring structures; *e.g.*, the *costal* surface of the shoulder blade is the surface directed towards the ribs [*costa* = a rib]. The edge or ridge between two surfaces is called a **border** or margin, and is named from the direction in which it looks.

The depressions and elevations receive general names, most of which are included in the alphabetical list below, and special names according to their position or characters.

A student is often asked to say whether a given bone or other bilateral organ belongs to the right or the left half of the body. It is a ready means of testing whether he knows the broad, main features of the organ; for if a structure is held in the position it occupies in the erect body (*i.e.*, with its upper end upwards and its anterior surface facing forwards), then its lateral surface or end or border will look towards the side to which it belongs. If a student does not know enough about a structure to enable him to distinguish which is the upper part, which is the front, and which is the lateral part, there is little merit and no advantage in his knowing whether it is left or right.

Definition of Terms.

The terms *median*, *medial*, *lateral*, etc., are explained on pp. 4 and 5.

Aditus. The entrance into a cavity. [*Aditus* = an entrance.]

Ala. A projection or a surface shaped like a wing. [*Ala* = a wing.]

Alveolus. A deep narrow pit. [*Alveolus* = a small cavity.]

Antrum. A cavity or hollow filled with air and lined with mucous membrane in the interior of a bone. [Ἄντρον (antron) = a cave.]

Canal. A passage or tunnel; unlike the artificial watercourses of the same name, a canal has complete walls round about it.

Condyle. A smooth rounded eminence covered with articular cartilage. [Κόνδυλος (condylos) = a knuckle.]

Cornu. A projection or prolongation shaped like a horn. [*Cornu* = a horn.]

Crest or *Crista.* A sharp upstanding ridge of bone; sometimes applied also to a border when it is sharp and prominent.

Epicondyle. A prominence or projection situated above a smooth articular eminence, though that eminence may not be called a condyle. [Ἐπί (epi) = above.]

Facet. A small smooth area usually covered with articular cartilage. Nearly all smooth articular surfaces on bones are referred to at times as facets.

Foramen. A hole; it may be an aperture through which one can see, or it may be the end of a canal.

Fossa. A depression, usually broad and shallow. [*Fossa* = a ditch].

Fovea. A small shallow depression. [*Fovea* = a small pit.]

Hamulus. A projection shaped like a hook. [*Hamulus* = a small hook.]

Hiatus. A slit or gap.

Incisura. A notch.

Labium or *Lip.* The margin of a groove or a hollow; when a ridge or a border is broad its margins are called its lips.

Lamina or *Lamella.* A thin plate or sheet.

Ligula or *Lingula.* A projection shaped like a tongue.

Line or *Linea.* A low ridge, usually narrow.

Meatus. A short canal. [*Meatus* = a way, passage.]

Planum. A flat surface.

Process or *Processus.* Any kind of projection or prolongation.

Sinus. A cavity in a bone lined with mucous membrane and filled with air; used with very different meanings in other systems. [*Sinus* = a curve, fold, interior, hiding place, bay, or gulf.]

Spina or *Spine.* A sharp pointed projection.

Squama. A portion of bone shaped like a scale. [*Squama* = a scale.]

Sulcus. A groove or furrow.

Trochlea. A pulley or pulley-shaped surface. [Τροχιλία (trochilia) = the sheave of a pulley.]

Tuber, *Tubercle*, and *Tuberosity* [*tuber* = a bump or swelling] are terms applied, without much distinction, to any kind of rounded swelling or eminence, large or small, smooth or rough. The term *tubercle*, with quite another meaning, is well known, owing to the endemic prevalence of disease caused by tubercle bacilli, but the origin of the term is the same. Tubercular diseases were so named because hard nodules or *tubercles* were found on the surface of affected organs.

Uncus. A part shaped like a hook. [*Uncus* = a hook or barb.]

Cartilage.

Cartilage or gristle is present in many parts of the body. It is supplementary to bones, and in many situations it takes the place of bone. It is much more abundant in a young animal than in a adult, for much of the cartilage present in the young animal is replaced by bone during the period of growth; but in many places cartilage persists throughout life. Cartilage is one of the few substances in which neither blood-vessels nor nerves have been found; it is nourished by lymph. It is elastic, but is not hard like bone; it is less yielding and pliable than tendons and ligaments, though it is cut more easily with a knife. Cartilage is covered with a fibrous membrane called **perichondrium**; the only exception is articular cartilage, which has a covering only on its margins. [Περί (peri) = around; χόνδρος (chondros) = cartilage.]

Classification of Cartilage.—There are three main varieties — hyaline cartilage; white fibro-cartilage; yellow fibro-cartilage.

Hyaline cartilage is bluish-white in colour, rather brittle, and easily cut into slices; the cut surface, to the naked eye, is homogeneous in texture, and a thin slice is translucent—hence the name "hyaline," from ὕαλος (hyalos) = glass. The following cartilages are of the hyaline variety: (1) The *costal cartilages*, which are connected with the anterior ends of the ribs. (2) The strips of cartilage between the segments of the *sternum* or breastbone, and a great part of the *xiphoid process*, which is the lowest part of the sternum. (3) The cartilages of the *nose*; most of the cartilages of the *larynx* or voice box; the cartilaginous rings of the *trachea* or windpipe and of the *bronchi*, which are the branches of the trachea. (4) The *cartilage which precedes bone.* At birth a great deal of that cartilage has been changed into bone already; but much of it still persists, especially at the ends of bones, and is gradually replaced by osseous tissue as growth goes on. In the case of some bones the change is not complete until the body is fully grown; therefore a growing person has more hyaline cartilage in the body than an adult has; a ready example is furnished by edible animals: there is far more gristle about the bones in veal and lamb than in beef and mutton. (5) *Articular cartilage* is part of the hyaline cartilage in which a bone is formed; and it remains cartilaginous throughout life.

White fibro-cartilage consists of cartilage mixed with strong bundles of white fibrous tissue; it is therefore less homogeneous than hyaline cartilage and is tougher. It is found in the following situations: (1) In a few tendons as *sesamoid cartilages.* (2) In the joint between the lower jaw and the skull, the joints at each end of the collar bone and at the wrist joint, in the form of *articular discs.* (3) In the shoulder joint and the hip joint, in the form of a ring, called a *labrum glenoidale*, attached to the rim of the articular socket of the shoulder blade and hip bone respectively. [*Labrum* = labium = a lip; γλήνη (glēnē) = a socket.] (4) In the knee joint, in the form of two semilunar bodies called *menisci* [μηνίσκος (mēniscos) = a crescent, diminutive of μήνη = moon]. (5) In the backbone in the form of a thick plate, called an *intervertebral fibro-cartilage*, between the bodies of each two vertebræ and attached firmly to both of them uniting them together; those plates account for most of the white fibro-cartilage in the body; they are easily recognised between the bodies of the vertebræ on the sawn surface of a sirloin of beef. (6) A similar plate unites the two hip bones at the *symphysis pubis*—that is, the joint in the middle line at the lower part of the front of the abdomen.

Yellow fibro-cartilage resembles white fibro-cartilage, but it contains yellow elastic fibres. It is found in the *ear*, in the *auditory tube*—that is, the passage between the drum of the ear and the throat,—and in some of the cartilages of the *larynx.*

Development of Bone.

Bones are formed in mesodermal tissue (p. 27). In some cases, as in the vault of the skull, the mesoderm becomes fibrous tissue, and the bones are formed in it. In most cases, however, a small model of the bone is made of cartilage formed in the mesodermal tissue; the first step is a closer aggregation of the mesodermal cells in the situation where the model is to be made; the aggregation of cells is the **rudiment** of a bone, and the cells assume an appearance intermediate between fibrous tissue and cartilage, forming a substance called **pro-cartilage**, which is gradually transformed into true *hyaline cartilage.* The process of transformation of the fibrous tissue or of the cartilage into bone is called **ossification.** The bones ossified in fibrous tissue are called *membrane bones*, because the fibrous tissue is arranged in the form of a membrane. The bones which are preceded by cartilage are called *cartilage bones.*

Formation of Cartilage.—Each of the cells in the interior of the bone rudiment enlarges, and as it does so it makes a thick *capsule* or envelope round about itself, and then divides into two; each of the two enlarges, makes a capsule and divides; and so on—two new capsules being formed inside each older one. In that way the rudiment increases in size, until a mass of tissue is formed consisting of cells, now called *cartilage cells*, which are imbedded in a dense substance of fused capsules made by the cells themselves and called the **cartilaginous periblast** (or *matrix*, an unsuitable name). The outermost part of the bone rudiment is retained as the **perichondrium**, which consists of an outer layer mainly fibrous, and an inner layer mainly cells and blood-vessels. [Περί (peri) = around; βλαστάνω (blastanō) = grow; χόνδρος (chondros) = cartilage.]

Appearance of Ossific Centres.—The process of ossification commences at different dates in different bones, but nearly all the bones begin to be ossified during the second month of intra-uterine life, and the date is fairly constant for any one bone in different subjects. The point in a bone where ossification begins is called a **centre of ossification**, and the centre is said to *appear* at such and such a date. Many of the bones are ossified from more than one centre. When a bone has several centres of ossification and the centres appear at widely separated dates, the first to appear is called the **primary centre** and the others are called **secondary centres.** By far the largest part of a bone is ossified from the primary centre. When ossification starts at more than one point in a bone about the same time, each of those centres is called a primary centre.

Ossification in Cartilage.—Ossification begins usually about the *middle* of a cartilage bone. At that point there is a great *increase* both in the size of the cartilage cells and in the amount of the substance around the cells; and the next step is the *deposition of* calcareous or lime *salts* in that substance. As the process spreads from the centre the *cartilage cells* just ahead of the calcifying region *multiply* rapidly, so that the size of the "bone" as a whole is increased, the multiplication and increase in a long bone taking place chiefly lengthwise. The deposit of calcareous material goes on till, in a little while, the cartilage cells become imprisoned inside the calcareous walls built around them, and, having their supply of nutriment cut off at the same time, they die and shrivel, leaving the *spaces* they occupied *nearly empty.*

The calcified cartilage is not bone, though the process is called ossification; but while those changes have been taking place in the centre a similar change leading to the *production of real bone* has been taking place on the outside of the cartilage. The cells of the deeper layer of the perichondrium have formed a clear substance round about themselves; fibres have been laid down in that, and **bone** is produced by the deposit of lime salts between and among the cells and fibres and within the fibres themselves; so that the calcified cartilage in the interior is encased in bone formed by the perichondrium; the perichondrium, since it now surrounds bone, is called periosteum, and that bone is called **subperiosteal bone.**

The calcified cartilage is short-lived. Blood-vessels grow in from the deeper layers of the periosteum, and they are accompanied by more than one kind of cell. Some of those cells are called **osteoclasts** [κλάω (claō) = break, destroy]. They eat their way through the subperiosteal bone, making passages through it for the blood-vessels they accompany to run along; and when they come to the calcified cartilage they consume a large proportion of it and so enlarge the spaces in the interior. Other cells accompanying the blood-vessels are called *osteoblasts* or **bone-forming cells** [βλαστάνω (blastanō) = grow, produce]. They are the same kind of cells around which, and under the influence of which, the bone is formed underneath the periosteum; they form layers of bone on the calcified cartilage that the osteoclasts have so far left untouched, and thus enclose the enlarged spaces with bony walls; the spaces become filled with marrow by the multiplication of fat-cells and other cells that accompany the blood-vessels. The remains of the calcified cartilage on which those layers of bone are laid down become in time destroyed by the osteoclasts, until no vestige of cartilage or cartilage cells is left in the interior.

Both under the periosteum and in the interior some of the bone-forming cells are left in little cavities between succeeding layers of bone; but they are not cut off from nutritive supply, and survive, under the name of *bone corpuscles*, as long as the bone lives.

It is not only the calcified cartilage that is destroyed by osteoclasts. The cavities in spongy adult bone are much larger than the cavities in newly-formed bone. The cavities are larger because osteoclasts have removed a great quantity of the first-formed bone, so that several of the original cavities or spaces run into one. The strength of the bone, however, is maintained and increased because bone-forming cells lay down additional layers of bone on what remains of the original bone, so that the walls of the enlarged cavities are thickened. And it is not only in the bone which is formed in cartilage that those changes occur; the original subperiosteal bone also is largely destroyed and is replaced by a second osseous deposit. If the horizontal diameters of the body of a vertebra of a new-born child are compared with the diameters of the body of an adult vertebra, it will be clear that only a small part in the centre of the adult bone is pre-formed in cartilage. The greater part in those diameters is formed by layer after layer deposited under the periosteum. In that subperiosteal bone the same process has gone on as in the centre—ingrowth of blood-vessels, excavation by osteoclasts, and a rebuilding and a strengthening of the remains by bone-forming cells; and that strengthening is especially marked in the last-formed layers in the adult bone so as to produce the compact bone at the surface.

Some of the tissue which grows in with the blood-vessels from the periosteum becomes converted into the perforating fibres of Sharpey.

In bones that have a medullary cavity the osseous tissue which succeeds the calcified cartilage is entirely removed in order that the cavity may be created; and, further, while new bone is being formed on the outside under the periosteum, osteoclasts are continually eating away the bony tissue next the medullary cavity in order to enlarge the cavity both in length and width, until it attains adult size. In a bone like the femur none of the bony tissue present at birth and none that was created during early life is left at all, for the medullary cavity of the adult femur is larger than the whole femur of a child.

The **Haversian systems** are produced in the following way: Blood-vessels from the periosteum grow into the original subperiosteal bone, and the osteoclasts create long and relatively wide spaces around those vessels. Then the bone-forming cells multiply and arrange themselves round the inside of the wall of the space, and produce layer after layer around the space, forming a series of concentric tubes, the innermost one enclosing the original space, now called the Haversian canal. As successive layers are produced, bone-forming cells are left between them as bone-corpuscles in lacunæ. Among the Haversian systems a few of the original layers of the subperiosteal bone survive, and they are called *interstitial lamellæ*; while, at the surface of the bone, the last-formed layers of subperiosteal bone are left unaltered and are called *circumferential lamellæ*.

Ossification in membrane occurs in certain skull-bones, in the lower jaw bone and in part of the collar bone. The cartilaginous stage is missed out; in other respects the process of ossification is the same as in a cartilage bone. There is a deposit of osseous tissue in or underneath the outer layers of the sheet or membrane of mesoderm, which thereupon becomes periosteum; that is followed by excavation by osteoclasts and rebuilding by bone-forming cells, just in the same sequence as in the case of ossification under the periosteum of a bone pre-formed in cartilage.

Formation of Joints.—The mesodermal tissue between two developing bones becomes converted into the structures that bind the two bones together, and those structures vary according to the class of joint. In the case of a **diarthrodial joint**—that is, one in which there is a cavity in the joint and the bones are free to move—the outer layers of the condensed mesoderm become converted into the *articular capsule* of the joint; the cells in the interior disappear and the *joint cavity* is formed. In certain joints all the cells inside do not disappear; those that remain give rise to the discs, menisci, and ligaments which are found in the interior of certain diarthrodial joints (see Figs. in chapter on Joints).

Growth of Bones.—Most bones grow in two dimensions by deposition of osseous tissue under the periosteum, and in the third dimension by multiplication of cartilage cells prior to ossification. For example, the body of a vertebra grows in breadth and in thickness by subperiosteal deposit of bone, and in height by increase of cartilage at its upper and lower surfaces;

a long bone grows in girth (*i.e.* breadth and thickness) under the periosteum, and in length by increase of the cartilage at its ends. Some bones, on the contrary, grow in one dimension by subperiosteal deposit, and in the other two dimensions by increase of cartilage,—for example, those cubical bones of the wrist and of the foot which have two sides covered with periosteum and four sides covered with articular cartilage. In bones such as those of the skull which are developed in membrane the growth takes place under the periosteum and in the membranous tissue that separates their margins from contiguous bones.

Some short bones and some flat bones are ossified wholly from the **primary centre** of ossification. They continue to grow: (1) in the case of flat bones developed in membrane, until the bone-forming cells in the periosteum and in the tissue separating the margins of bones cease to function as bone-forming cells; and (2) in the case of bones developed in cartilage, until the subperiosteal bone-forming cells cease to function and the cartilage cells in the cartilage covering an articular surface cease to multiply. At the articular part of a bone the multiplication of cartilage cells and the process of ossification cease before the cartilage is all used up, so that a layer of articular cartilage is left which survives till death or until destroyed by disease.

All the long bones and many of the others acquire **secondary centres** that appear in outlying cartilaginous parts into which ossification from the primary centre has not had time to extend. Nearly all the secondary centres appear after birth, and the method of ossification from them is the same as from primary centres—multiplication of cartilage cells, calcification, subperiosteal deposit of bone, etc.

The part of a bone ossified from the primary centre is called (without good reason) the **diaphysis.** A part ossified from a secondary centre is called an **epiphysis,** and a secondary centre is therefore often called an *epiphyseal centre.* [Επίφυσις from ἐπί (epi) = upon, φύω (phyō) = make to grow.]

Ossification in the cartilage (accompanied by ossification under the perichondrium) proceeds from the secondary centre till only one part or two parts of the cartilage are left: (1) A thin plate, called the **epiphyseal cartilage,** persists for a time between the diaphysis and the epiphysis; its edge at the surface of the bone is called the **epiphyseal line.** (2) In cases where the epiphysis is the articulating part of the bone the articular layer of cartilage survives.

As long as the epiphyseal cartilage lasts the bone continues to grow on each side of it—that is, both diaphysis and epiphysis continue to grow, the rate of growth being much more rapid in the diaphysis than in the epiphysis; both of them go on constantly increasing at the expense of the part of the cartilage nearest them, and the cartilage cells in the middle layers of the plate go on multiplying in order to maintain the existence of the plate. But a time comes when the cartilage cells cease to multiply, and the ossifying process in the diaphysis and that in the epiphysis, invading the cartilage from both sides, use it all up and meet together. The epiphysis is then said to have joined or *fused with* the diaphysis; and the bone ceases to grow in that situation. In the same way the bone increases under the articular cartilage. When the cells of that cartilage cease to multiply the growth of bone ends there also, but does so before the cartilage is all used up. Therefore articular cartilage persists, while epiphyseal cartilage disappears.

The growth of bone ceases when a person becomes an adult, but it can be resumed. Healthy periosteum retains the faculty of producing new bone when it is required; otherwise broken bones would not heal, nor would bony ridges become more pronounced to provide firmer attachments for muscles when they become stronger and larger as a result of unaccustomed exercise.

Epiphyses (Figs. 199, 222).—The shaft or body of a long bone is developed from a primary centre, and the shaft is therefore the diaphysis. Every long bone has an epiphysis at one end; most of them have epiphyses at both ends; in some bones there are more than one epiphysis at the end, *e.g.,* the distal end of the humerus, the proximal end of the femur. When a long bone has an epiphysis at only one end, it is at the end at which there is the more movement. Most epiphyses are ossified from one centre, but some are ossified from more than one, and the different parts ossified from those separate centres coalesce before the union with the diaphysis, *e.g.* the proximal end of the humerus. When there are more than one epiphyseal centre at the end of a bone, and the parts ossified from those centres do not coalesce but join the shaft separately, each part is called an epiphysis, *e.g.* the parts at the proximal end of the femur.

Dates of Appearance of Epiphyses.—Though most epiphyseal centres appear after birth, there is one notable exception and sometimes three. The centre for the *distal end of the femur* appears during the ninth month of intra-uterine life; the centre for the proximal end of the tibia often appears towards the end of that month, and the centre for the head of the humerus sometimes does so also. A still-born child is assumed to be at full time if one of those epiphyses is present.

The epiphyseal centres of *long bones* appear during **Infancy** and **Childhood.** A notable **exception** is the collar bone, which has an epiphysis only at its medial end, and the centre for that does not appear till the eighteenth or twentieth year. That epiphysis joins not later than 25. Its presence is useful for determining the age at death of a body found in a state of decomposition. If it is present, the age was not less than 18 and not more than 25.

In any one long bone the epiphyseal centres do not appear at the same time: weeks, months, or even years may elapse between the appearance of its centres. Nor do the epiphyses fuse with the shaft at the same time; there may be an interval of months or years. The epiphysis whose centre appears first is the last to fuse; the fibula is an exception to that rule, for the epiphysis at its distal end fuses first, though its centre appears before that of the proximal end. The end of a bone at which the epiphyseal cartilage lasts longer is sometimes called the "growing end" of the bone; and in those bones which, like the collar-bone, have an epiphysis at only one end, that term applies to the end that has the epiphysis. The nutrient canal of a long bone is directed towards the epiphysis which fuses first; in bones that have only one epiphysis it is directed towards the end which does not have an epiphysis.

Many epiphyseal centres do not appear till **puberty**, *e.g.* most of those of the *hip bone* and of the *shoulder blade*, those of the *ribs* and of the *vertebræ.* The most important of the epiphyses of a vertebra are those which are formed in the hyaline cartilage covering the upper and lower surfaces of its body. In lower animals those epiphyses are thin plates; in Man they are flattened rings. Those ring-like epiphyses do not fuse with the body of the vertebra till the full adult stage is reached at the 25th year or later; the back, therefore, goes on growing for a longer time than the limbs, for the limb bones have usually all ceased to grow before the 25th year.

Separation of Epiphyses.—The epiphyseal plates of cartilage in long bones are not flat discs. If that was the case the epiphyses would be knocked off too easily, especially as the growing years of life are the most active and careless. The cartilages and the opposed surfaces of diaphyses and epiphyses have pronounced elevations and depressions which fit into one another, so that the bones can withstand knocks and jars and twists. None the less, an epiphysis sometimes is broken off. When a limb of an adult is subjected to great violence, a bone may be broken or put out of joint. Either accident may befall a boy or girl too, but while the bones are growing there is an added danger: an epiphysis may break away. When that happens, the epiphyseal cartilage is often so much injured that the bone ceases to grow at that end after diaphysis and epiphysis have reunited. When a bone is broken near one end in a young person, it may be either an ordinary fracture or a separation of the epiphysis. It is important to recognise at the outset which it is; and it is important, therefore, to remember the dates at which epiphyses usually join. Moreover, in an X-ray photograph of a young person an epiphyseal cartilage appears as a clear line which may be mistaken for a line of fracture, if it is forgotten that there is an unjoined epiphysis in the region.

Epiphyses can be seen in X-ray photographs and in museums where the skeletons of relatively young people or animals are kept. They can be seen at home also: epiphyseal plates of vertebræ can be seen in a sirloin of young beef; epiphyses of limb bones can be found in a leg of lamb.

THE SKELETON.

The human body is divided into the following parts: the **head** and **face**; the **neck**; the **trunk**, subdivided into the chest or *thorax* and the belly or *abdomen*; the two **upper limbs** or superior extremities; and the two **lower limbs** or inferior extremities. The abdomen is further divided into a larger, upper part called the *abdomen proper*, and a smaller part called the *pelvis*, situated below and behind the abdomen proper, between the two hips. The bones in the head, face, neck, and trunk are 80 in number in the adult and constitute what is called the *axial skeleton.* Excluding the small sesamoid bones, which are inconstant in number, there are 32 bones in each adult upper limb and 31 in each adult lower limb, and they constitute the *appendicular skeleton.*

The adult **axial skeleton** includes—(*a*) the backbone or vertebral column, which is made up of 26 separate bones; (*b*) the breastbone or sternum; (*c*) 12 pairs of ribs; (*d*) the skull, built up of 8 pairs of bones and 5 unpaired bones; (*e*) the lower jawbone or mandible; (*f*) the hyoid bone; and (*g*) 3 pairs of tympanic ossicles.

The **vertebral column** is the fundamental part of the skeleton; it is common to all the great class of animals called *vertebrates,* namely, fishes, amphibians, reptiles, birds, and mammals. It is situated in the middle line of the back of the body and extends through the whole length of the neck and the trunk. The **sternum** lies in the middle line of the front of the thorax. The twelve **ribs** form the framework of the side and front and back of each half of the thorax. The **skull** is the skeleton of the head and the upper part of the face, while the **mandible** supports the lower part of the face. The **hyoid bone** lies in the front of the neck, below the mandible and the tongue. The **tympanic ossicles** are little bones situated in the drum of the ear or tympanic cavity.

The bones of the **appendicular skeleton** are summarised in the sections on limbs.

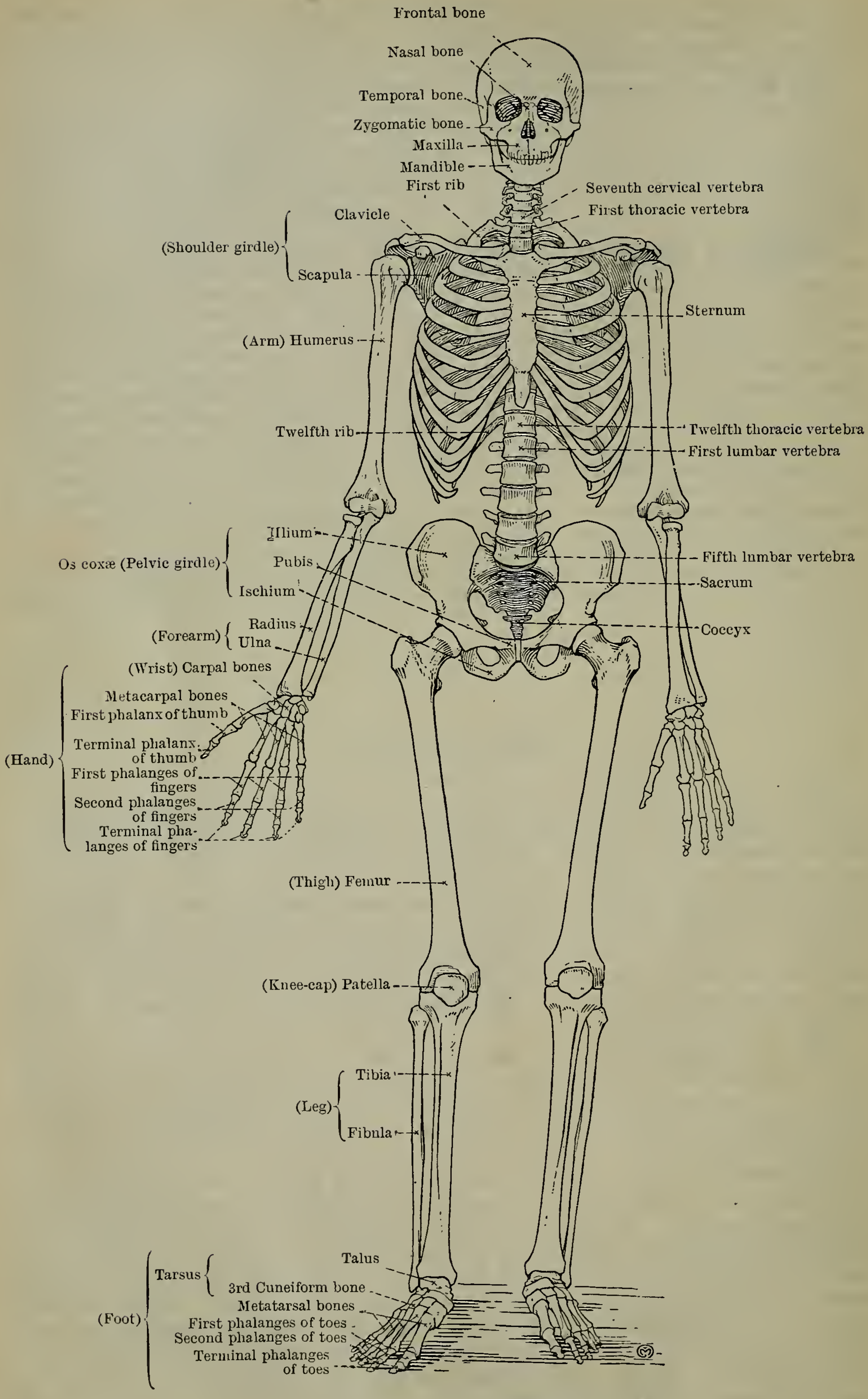


Fig. 109.—Anterior View of the Skeleton of a Male.
The bones of the left forearm and hand are in the position of pronation.

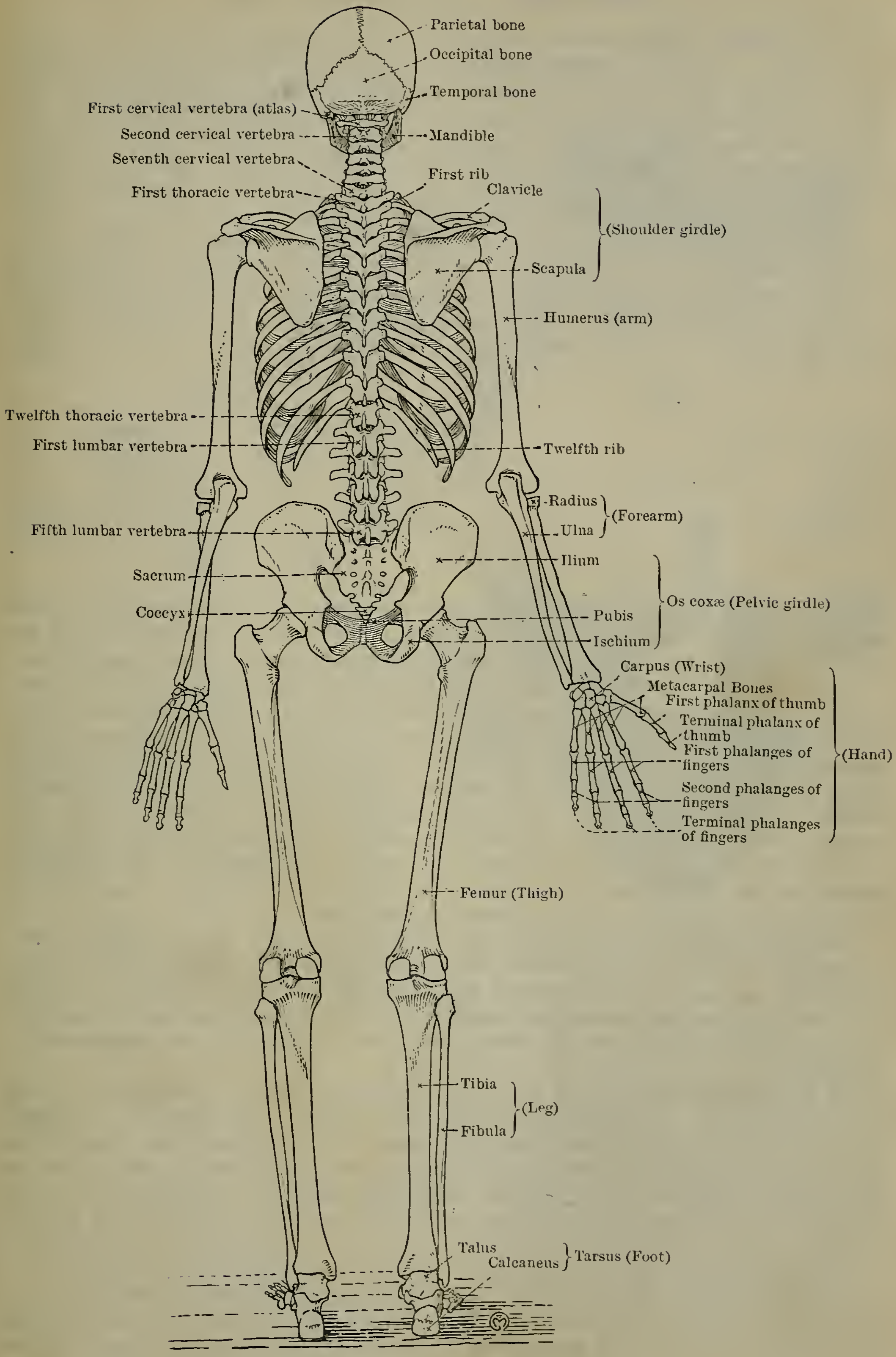


FIG. 110.—POSTERIOR VIEW OF THE SKELETON OF A MALE.
The bones of the left forearm are in the position of pronation.

COLUMNA VERTEBRALIS.

The **vertebral column** or backbone is a long, curved pillar (Fig. 120) composed of a number of segments, called **vertebræ**, which are placed in a series one above the other, and are connected together by fibro-cartilages and ligaments. The bulky part of each vertebra is its anterior part and is called its *body* (Fig. 111). The most posterior part of a vertebra is a projection called its spine or *spinous process*, whence arose the names "spine" and "spinal column" used as synonyms for backbone. The spines can be felt in the floor of the median furrow that begins at the nape of the neck and ends between the buttocks.

In the **child** there are 33 separate vertebræ, but in the **adult** vertebral column there are only 26 separate bones, for the lowest nine vertebræ are fused together to form two single bones; the upper of those two bones is called the *sacrum* and consists of 5 fused vertebræ; the lower is called the *coccyx* and consists of 4 fused vertebræ (Fig. 121). The vertebræ are classified in five groups from above downwards:—

Child.		*Adult.*		
Cervical vertebræ	7	Cervical vertebræ .	7	True or movable vertebræ
Thoracic ,, ...	12	Thoracic ,, .	12	
Lumbar ,, ...	5	Lumbar ,, .	5	
Sacral ,, ...	5	Sacrum . . .	1 = 5	False or fixed vertebræ
Coccygeal ,, ...	4	Coccyx . . .	1 = 4	
	33		26	

The **cervical vertebræ** constitute the bony axis of the *neck*, and form a very flexible part of the vertebral column [*cervix* = neck]. The **thoracic vertebræ** lie in the posterior wall of the *chest* and the 12 pairs of ribs are attached to them [θώραξ (thōrax) = a cuirass]. The **lumbar vertebræ** lie in the *loins* or "small of the back" [*lumbus* = the loin]; they are the only bones that belong exclusively to the *abdomen proper*, which is less supported by the skeleton than any other part of the body. The **sacrum** lies in the dorsal wall of the *pelvis* in the hollow between the upper part of the hips, and between the two hip bones, to which it is firmly attached by strong fibrous bands or ligaments [*os sacrum*, a sacrificial bone in ancient times]. The **coccyx** or os coccygis has a fancied resemblance to the bill of a bird [κόκκυξ (coccyx) = a cuckoo]. It forms the lower end of the vertebral column and lies below the sacrum in the dorsal wall of the *pelvis*, in the floor of the groove between the buttocks just above the *anus* or opening of the bowel.

Vertebræ belong to the class of *irregular* bones. Most of them have characters in common, but the vertebræ of each group have also special characters by which they can be distinguished from those of the other groups; and while each vertebra has the distinctive characters of its own group, many of them have their own special features by which they can individually be recognised at a glance.

A Typical Vertebra (Fig. 111).—It is usual to select a vertebra from the *middle* of the *thoracic* region as a type. The beginner can pick out a thoracic vertebra from among the others because it has articular *facets* on the sides of the body; none but a thoracic vertebra has those facets; and those in the middle of the thoracic region have long spines. The main parts of a vertebra are a *body* and an *arch*; they enclose a large hole called the *vertebral foramen*; and various processes project from the arch, namely, the *spinous process*, a pair of *transverse processes*, and two pairs of *articular processes*—a superior pair and an inferior.

The **body** is the bulky, anterior part. The **vertebral foramen**, situated behind the body, is large enough to admit a finger; when the vertebræ are in column the series of vertebral foramina makes a long tunnel, called the *vertebral canal*, for the lodgment of the spinal medulla (spinal cord). The **vertebral arch** consists of four essential parts which bear the seven processes named above. The essential parts are a right and a left *root of the arch* or *pedicle* at the sides of the foramen, and a right and a left *lamina* at the back of the foramen; the two laminæ fuse together in the median plane. When the vertebræ are in column there is, on each side, a row of holes, called the *intervertebral foramina,* between the pedicles; a spinal nerve passes through each intervertebral foramen. The **spinous process** or **spine** projects backwards and downwards from the junction of the two laminæ; its downward slant enables the beginner to distinguish the upper part of the vertebra from the lower; the tip of the spine is the only part of a vertebra that is *easily* felt in the living person, and owing to the slope it is at the level of the body next below. The other processes are at the junction of the pedicles with the laminæ; the **transverse processes** are the large projections that jut out from the sides of the arch; **superior articular processes** project upwards from the side of the arch; the **inferior** pair project downwards and articulate with the superior pair of the vertebra next below; in the thoracic vertebræ they are less distinct than the superior pair, and are on the lamina rather than at the junction of the lamina and pedicle.

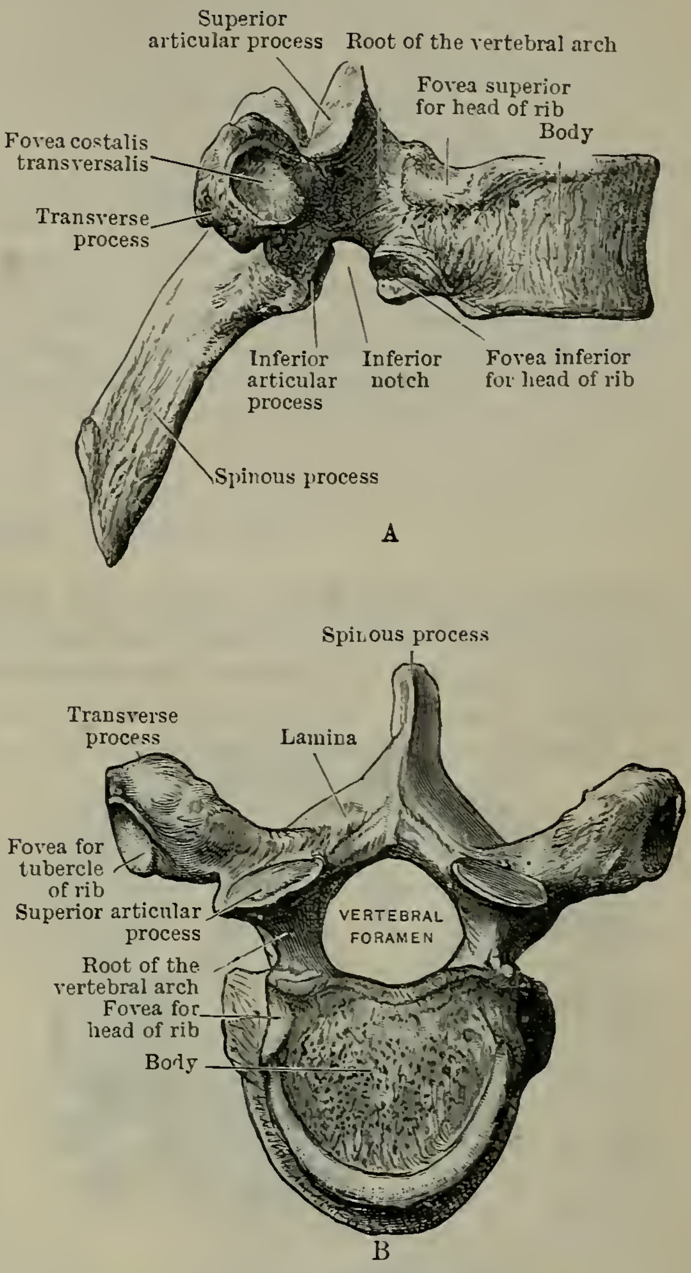

Superior articular process
Root of the vertebral arch
Fovea superior for head of rib
Body
Fovea costalis transversalis
Transverse process
Inferior articular process
Inferior notch
Fovea inferior for head of rib
Spinous process
A
Spinous process
Transverse process
Lamina
Fovea for tubercle of rib
Superior articular process
VERTEBRAL FORAMEN
Root of the vertebral arch
Fovea for head of rib
Body
B

Fig. 111.—Fifth Thoracic Vertebra, (A) as viewed from the right side, (B) as viewed from above.

The **body** has an *upper* and a *lower* surface; a *posterior* surface, forming the anterior boundary of the vertebral foramen; an *anterior* surface, merging into the *right* and *left* sides, so that the three form a continuous surface which is highly convex from side to side, and slightly concave from above downwards. The upper and lower surfaces are separated from and attached to the bodies of the vertebræ immediately above and below by thick plates of *fibro-cartilage*; and two long fibrous ribbons, called the *anterior* and *posterior longitudinal ligaments,* lie on the front and the back of the bodies, and are attached to them and to the fibro-cartilages throughout the series of movable vertebræ. **Nutrient foramina** are present here and there on the front, the sides, and the back; the largest is on the back and transmits a vein.

The **roots** or **pedicles** of the arch project backwards from the back of the body and are continuous with the laminæ posteriorly. The upper and lower borders of each root are slightly concave, forming the floors of notches called the **superior** and **inferior vertebral notches**; in the thoracic and lumbar regions the superior notch is very shallow, for the pedicle springs from the upper part of the body. The pedicles are the only parts of two contiguous vertebræ that are not united by ligaments; they are separated by the **intervertebral foramen,** which is bounded *above* and *below* by the vertebral notches, *posteriorly* by the articular processes of the two vertebræ, *anteriorly* by the upper of the two bodies in the thoracic and lumbar regions and by both bodies in the cervical region. When the vertebræ are in column there is a linear series of intervertebral foramina on each side, through which the spinal nerves and vessels pass on their way from and to the spinal medulla.

The **laminæ** are plates of bone which slope towards each other from the posterior ends of the pedicles and fuse together in the median plane behind the vertebral foramen. [*Lamina* = a plate, a leaf.] Their posterior surfaces are covered by and give attachment to muscles (see p. 109). Laminæ of contiguous vertebræ are united by flat fibro-elastic bands, called *ligamenta flava,* which are attached to their borders and the rough lower parts of their anterior or inner surfaces and upper parts of their outer surfaces. [*Flavus* = yellow.]

The **vertebral canal,** formed by the series of **vertebral foramina,** is bounded *anteriorly* by the bodies of the vertebræ, the fibro-cartilages, and the posterior longitudinal ligament, *posteriorly* by the laminæ and the ligamenta flava, *at each side* by the pedicles, between which are the intervertebral foramina. The canal *contains* the spinal medulla and its membranes, the roots of the spinal nerves, vessels supplying the spinal medulla and the vertebræ, and a quantity of loose fat.

The **spines** of the vertebræ are united by fibrous bands called *interspinous ligaments*, which lie in the interval between each two, and *supraspinous ligaments*, which pass from tip to tip forming a continuous band from the sacrum to the neck, where they form a wide sheet called the *ligamentum nuchæ*, which is set as a median partition between the muscles of the two sides of the back of the neck, and is attached superiorly to the posterior part of the base of the skull. [*Nucha* (derivation uncertain) = the nape of the neck.] Numerous muscles are attached to the spines (see p. 109).

The **transverse processes** give attachment to numerous muscles (see p. 109), and are connected with those of the vertebræ above and below by weak fibrous bands called *intertransverse ligaments.* In the case of a typical thoracic vertebra each transverse process articulates with a rib, and has a facet on the front of its free end, and is connected to ribs by ligaments.

The **superior articular processes** have smooth articular surfaces on their posterior aspects The **inferior articular processes** are not so prominent; they are surfaces rather than processes in cervical and thoracic vertebræ, and look forwards to articulate with the superior pair of the vertebra below. The margins of the articulating surfaces give attachment to the *joint capsules*, and the non-articulating parts give attachment to muscles (see p. 109).

Vertebræ Cervicales.

Cervical vertebræ are small; their distinctive character is that each of them has three holes in it—the large **vertebral foramen** posteriorly, and a smaller hole at each side, called the **foramen transversarium** because it is partly bounded by the transverse process. The foramina transversaria form a vertical series on each side, and through the upper six of them there runs a large artery called the *vertebral artery.* In most cervical vertebræ the **transverse process** has two tubercles at its free end called the *anterior* and *posterior tubercles* of the transverse process. The free ends are little more than an inch from the median plane, and can be felt as an uneven bony resistance when pressure is made on the side of the neck. The lower border of the *third* vertebra is at the level of the upper border of the thyreoid cartilage—that is, the prominence in the front of the neck known as the laryngeal prominence or "Adam's apple." The *sixth* vertebra is at the level of the cricoid cartilage—that is, the rounded bar felt in the front of the neck below the thyreoid cartilage; the anterior tubercle of its transverse process is called the *carotid tubercle* because the carotid artery can be compressed against it.

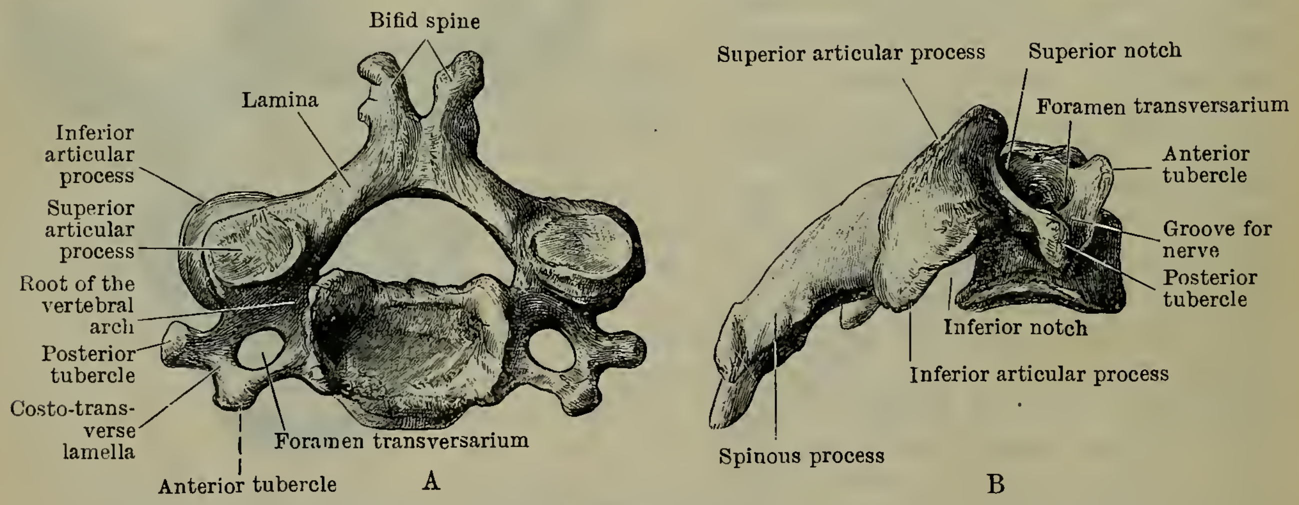


FIG. 112.—FOURTH CERVICAL VERTEBRA, (A) from above, and (B) from the right side.

The first, the second, and the seventh cervical vertebræ have special characters, but the other four are very much alike and are regarded as typical vertebræ.

A Typical Cervical Vertebra.—The **body** is small and is elongated transversely. It is lipped up at the sides on the upper surface and correspondingly bevelled off on the lower surface; between the lip and the bevel of contiguous vertebræ there is a small diarthrodial joint at the side of the fibro-cartilage. The posterior surface is flat. The lower part of the anterior surface juts downwards and overlaps the fibro-cartilage below; the upper part of the surface may be slightly bevelled.

The **vertebral foramen** is triangular in outline, with the angles rounded off; and it is large in order that the spinal medulla shall not be compressed in the movements of the neck, and also because the medulla is thicker in the neck than lower down.[1] The **roots** of the arch are short and rounded, and project laterally and backwards; the superior and inferior **vertebral notches** are nearly equal in depth. The **laminæ** are thin and sloping; compared with laminæ in other regions, they are long in their horizontal measurement, and narrow from above downwards.

The **spine** is short, compressed from above downwards and bifid at its free end, and it overlaps the spine below. The articular surfaces of the **articular processes** are nearly flat; the upper pair look backwards and upwards; the lower pair look in the opposite direction. The **transverse processes** are short and inclined slightly downwards and forwards. Each has two distinct parts or roots—an anterior and a posterior. The *anterior root* corresponds to a rib and is sometimes called the *costal process*; it springs from the side of the body and ends laterally as the *anterior tubercle.* The *posterior root* is the true transverse process; it springs from the arch at the junction of pedicle and lamina, and ends laterally as the *posterior tubercle,* which is farther from the median plane than the anterior tubercle. Near their free ends the lower margins of the two roots are united by a curved bar of bone called the *costo-transverse lamella.* The **foramen transversarium** is bounded by the side of the body, the pedicle, the two roots of the transverse process and the costo-transverse lamella; in some vertebræ it is divided into two by a spicule of bone; it transmits the vertebral artery surrounded by a network of veins and a network or plexus of delicate sympathetic nerves derived from the inferior cervical ganglion. The cervical nerves, on emerging from the intervertebral foramina, lie behind the vertebral artery, where each one divides into an anterior and a posterior ramus; the posterior ramus turns backwards above the posterior root of the transverse process; the anterior ramus proceeds in a lateral direction and lies on the costo-transverse lamella.

The **Atlas** or **first cervical vertebra** is a ring of bone. It has no body and no spine. The two bulkier parts of it are called the **lateral masses**; they are united by two curved bars of bone called the **anterior arch** and the **posterior arch**, of which the posterior is much the longer. **Transverse processes**, enclosing **foramina transversaria**, project laterally from the lateral masses; they are further apart than the transverse processes of other cervical vertebræ; the tip of each is an inch and a half from the median plane, and is the bone felt by the finger pressed into the hollow below the ear. The lateral masses rest upon the second cervical vertebra, and they support the skull—hence the name "Atlas." Their upper and lower surfaces are readily distinguished, for the facets on their *lower* surfaces are fairly flat, while the facets on their *upper* surfaces are elongated and concave. The upper facets articulate with the occipital condyles at the sides of the foramen magnum—that is, with the smooth articular bosses at the sides of the large hole on the base of the skull.

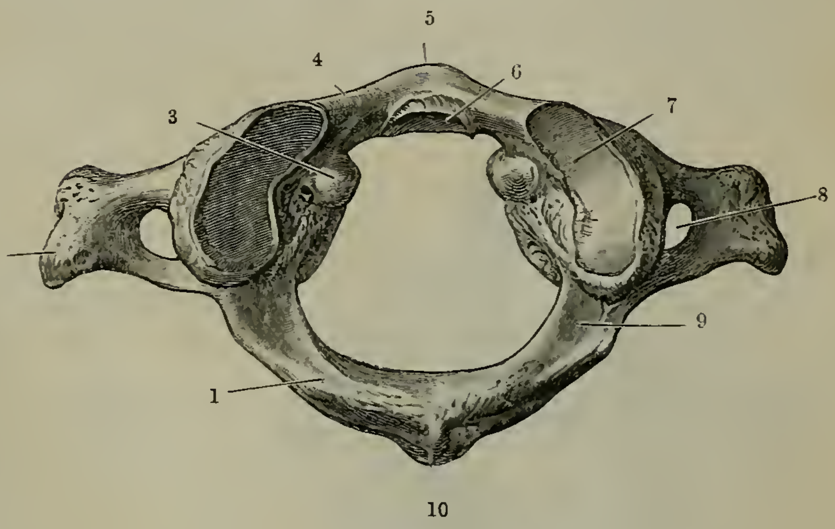


FIG. 113.—THE ATLAS FROM ABOVE.

1. Posterior arch.
2. Transverse process.
3. Tubercle for transverse ligament.
4. Anterior arch.
5. Anterior tubercle.
6. Surface for articulation with dens.
7. Superior articular surface.
8. Foramen for vertebral artery.
9. Groove for vertebral artery.
10. Posterior tubercle.

The **anterior arch** is short and is compressed from before backwards. On its posterior surface there is a facet for articulation with a part of the second vertebra called the dens or odontoid process. On its anterior surface there is a smooth eminence, called the **anterior tubercle** of the atlas, which gives insertion to the upper ends of the longus colli muscles. A continuation of the anterior longitudinal ligament is attached to the *lower margin* of the arch. A fibrous sheet, called the anterior atlanto-occipital membrane, stretches upwards from the *upper margin* to the anterior margin of the foramen magnum.

The **posterior arch** springs on each side from the back of the lateral mass and the posterior root of the transverse process. On the middle of its posterior surface there is a small projection, called the **posterior tubercle** of the atlas, which corresponds to a spinous process, and gives origin to a pair of small muscles named the recti capitis posteriores minores. On the *upper surface* of the arch, close to each lateral mass, there is a broad, oblique groove in which the vertebral artery lies, as it runs from the first foramen transversarium to the foramen magnum, and the first cervical nerve lies in the groove below the artery. The remainder of the upper surface or border gives attachment to a thin fibrous sheet, called the posterior atlanto-occipital membrane, which stretches upwards to the posterior margin of the foramen magnum and also upwards and laterally to fuse with the capsule of the joint between the lateral mass and the skull; the infero-lateral margin of the membrane therefore bridges across the groove for the vertebral artery, and is sometimes ossified, converting the groove into a foramen. The *lower margin* of the arch is connected with the laminæ of the second vertebra by ligamenta flava.

The **transverse processes** are larger than those of other cervical vertebræ, and the *tubercles* are usually fused together. Each process gives origin to the following muscles—the rectus capitis lateralis, the obliquus capitis superior and a slip of the levator scapulæ, and insertion to the obliquus capitis inferior and a slip of the splenius cervicis.

The *lower surface* of each **lateral mass** is oblique, nearly flat, and nearly circular, and articulates with the second cervical vertebra. The *upper surface* articulates with the occipital condyle. The articular facet is oblong, concave, and set obliquely so that it slopes downwards and medially, and its anterior end is nearer the median plane than the posterior; it is often notched at the sides and may be divided into two parts. The capsules of the joints are attached to the margins of the upper and lower articular surfaces. The *posterior surface* is connected with the posterior arch. The *anterior surface* blends medially with the anterior arch, and laterally it gives origin to the rectus capitis anterior muscle. The transverse process springs by two roots from the *lateral surface*. The *medial surface* is rough and uneven, and has a small round *tubercle* for the attachment of a fibrous band, called the *transverse ligament* of the atlas, which stretches from one lateral mass to the other, across the back of the dens of the second vertebra, and keeps the dens in place against the anterior arch. The large hole surrounded by the lateral masses and the arches is divided by the transverse ligament into two parts—an anterior, which holds the dens, and a posterior, which is the vertebral foramen and contains the spinal medulla and its membranes.

The **epistropheus** or **second cervical vertebra** is easily distinguished. A thick process called the **dens** stands up from the upper surface of the body. The **spine** is very thick compared with other cervical spines; it can be felt two or three inches below the *external occipital protuberance, i.e.*, the knob in the middle line where the back of the head joins the back of the neck; the spine is the first bony resistance encountered by the finger as it is drawn downwards from the protuberance.

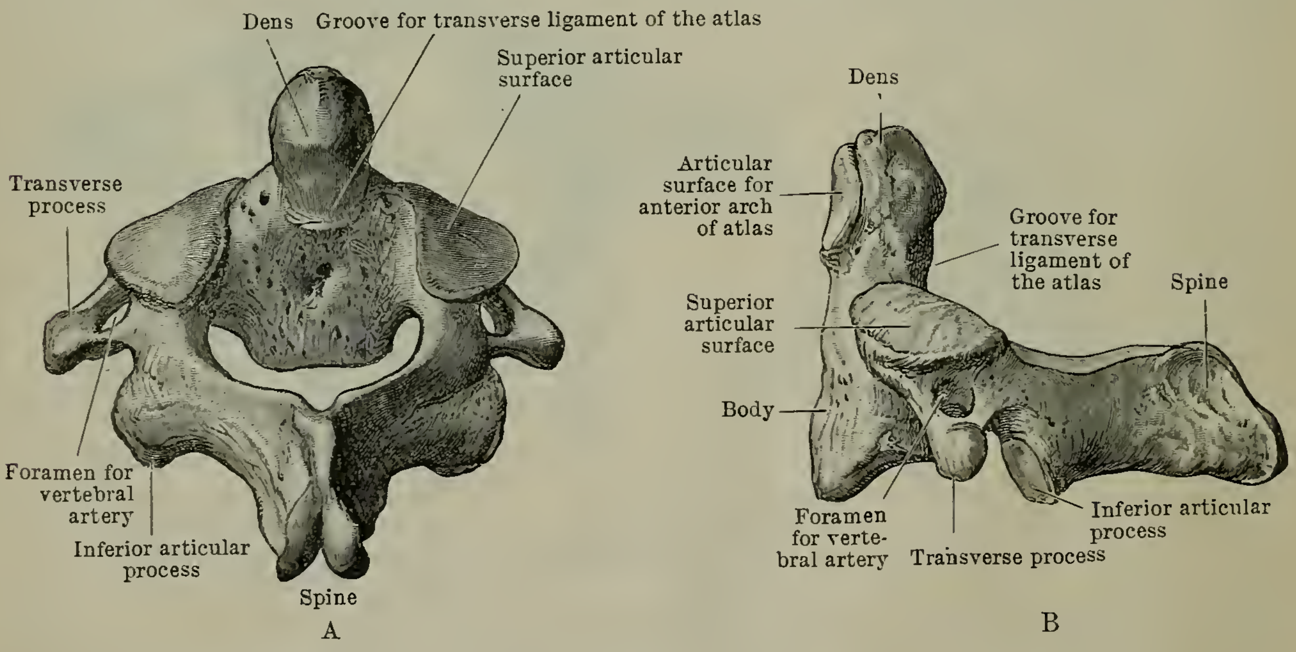

Dens
Groove for transverse ligament of the atlas
Superior articular surface
Transverse process
Foramen for vertebral artery
Inferior articular process
Spine
A
Dens
Articular surface for anterior arch of atlas
Groove for transverse ligament of the atlas
Spine
Superior articular surface
Body
Foramen for vertebral artery
Transverse process
Inferior articular process
B

FIG. 114.—EPISTROPHEUS (O. T. AXIS), (A) from behind and above, (B) from the left side.

The **second cervical vertebra**, when looked at from the front, is relatively very long in its vertical measurement, because of the upstanding dens and because the lower part of the front of the body juts downwards very considerably. The **dens** or **odontoid process** [ὀδούς (odous, *genitive* odontos) = dens = a tooth] is really the body of the atlas fused with the body of the second vertebra. When the first two vertebræ are fitted together properly the dens lies in the anterior compartment of the ring of the atlas; its anterior surface is smooth for articulation with the back of the anterior arch of the atlas and its posterior surface also is smooth for contact with the transverse ligament. The top of the dens is pointed. A weak band of fibres, called the ligamentum apicis dentis or *suspensory ligament*, stretches from the apex to the anterior margin of the foramen magnum; and a strong band of fibres, called the alar or *check ligament*, stretches from each side of the apex to a tubercle on the side of the foramen magnum. When the head and face are turned from side to side, the atlas, carrying the skull, pivots round the dens, and the movement is prevented from going too far by the alar or check ligaments.. Since the dens is the pivot round which the head turns, the second vertebra is given the convenient name of *axis*, and also the unwieldy name of *epistropheus* [ἐπί (epi) = upon ; στρέφω (strephō) = turn].

The **inferior vertebral notches** are deep; the **superior** are absent; the **laminæ** are thick. The **spine** is broad and thick, deeply grooved on its lower surface and keeled on its upper surface; it gives attachment to several muscles (p. 109), the most important of which are the rectus capitis posterior major and obliquus capitis inferior arising from it, and a great part of semispinalis cervicis inserted into it. The **transverse processes** are the smallest of the series; the *anterior root* is inclined backwards and the *anterior tubercle* is absent. The **foramen transversarium** is directed laterally as well as upwards, because the transverse process of the atlas is more laterally placed. The **inferior articular surfaces** are situated on typical *articular processes.* The **superior articular surfaces** are not situated on processes at the junction of the roots of the arch and the laminæ, but are placed on the body and the roots; they articulate with the lower surfaces of the lateral masses of the atlas, and through them the weight of the head is transmitted from the lateral masses to the bodies of the vertebræ below. The joints between them and the lateral masses of the atlas, and also those between the lateral masses and the occipital condyles correspond not to the joints between typical articular processes, but to the small joints between the bodies of the cervical vertebræ at the sides of the fibro-cartilages; therefore the first and second cervical nerves issue behind the joints connecting the atlas with the skull and with the second vertebra, while other spinal nerves issue through the intervertebral foramina in front of the joints formed by the articular processes.

The **seventh cervical vertebra** is distinguished from the others because its **spine** is long, and is not bifid, but is thickened at its free end; the end of the spine is the upper of the two prominences at the root of the back of the neck, and on that account the seventh vertebra is called the *vertebra prominens.* The *posterior root* of the **transverse process** is large, the *anterior root* is small and the *anterior tubercle* is often absent, but in some rare cases the anterior root is large and separate, forming a **cervical rib.** The **foramen transversarium** is usually small, for it does not transmit the vertebral artery; on one or both sides it may be double; a small vein goes through it sometimes.

Vertebræ Thoracales.

Thoracic vertebræ are of medium size, and increase in size from above downwards; their distinctive character is that they all have facets or foveæ on their sides for articulation with the heads of ribs (see Figs. 111 and 115). The **body** of each of the upper eight articulates with two pairs of ribs—the pair with which it corresponds numerically and the pair below; for example, the body of the **first** articulates with the heads of the *first* pair of ribs and the upper part of the *second* pair; the **second** body with the lower part of the heads of the *second* pair and upper part of the *third* pair; and so on to the **eighth** body, which articulates with part of the *eighth* pair of ribs and part of the *ninth* pair. The bodies of the lower four articulate only with the ribs with which they correspond numerically. The upper ten have a facet or fovea on each **transverse process** for articulation with the tubercles of the ribs (see Fig. 128) with which they correspond numerically. The lower two do not have facets on the transverse processes. The thoracic transverse processes are thick, their posterior surfaces lie under cover of the muscles of the back, and their tips are a little more than one inch from the median plane. The **spines** are long and sloping, especially in the middle of the series, where the slope is so steep that the spine is almost vertical, and therefore one can say at once whether a given vertebra is from the middle of the series or not. In the upper and lower vertebræ the spines are shorter and slant very little in comparison; and the lower can be distinguished from the upper by the large size of the bodies. The spine of the *first* thoracic vertebra forms the lower of the two knobs felt at the root of the back of the neck. The spine of the *third* is on a level with the point where the spine of the scapula joins the vertebral border, and that point is easily found in the living body. The spine of the *seventh* is on a level with the inferior angle of the scapula (Figs. 110, 132).

The first two thoracic vertebræ and the lower four have special characters by which they can be distinguished individually; the other six belong to a common type; but when the whole series in hand are from the same skeleton they are easily placed in their proper order, if the gradual changes in appearance are noted and experiments are made in fitting them together.

A Typical Thoracic Vertebra (Fig. 111).—The *upper* and *lower surfaces* of the **body** are almost flat, and are somewhat heart-shaped in outline. The *posterior surface* is slightly concave from side to side; it is slightly deeper than the *anterior surface*, and therefore from fœtal life onwards the thoracic part of the backbone is curved with the concavity forwards. There are two unequal *facets* on each side of the body, set far back, the larger one at the upper border and the smaller at the lower border. The lower facet of one vertebra is just above the upper facet of the vertebra next below; the two facets, together with the side of the fibro-cartilage between the bodies, make a socket for the head of the rib that corresponds numerically with the lower of the two vertebræ.

The **pedicle** or **root** of the vertebral arch is compressed from side to side, and is inclined upwards. It springs from the body nearer the upper border than the lower, and, therefore, the **superior vertebral notch** is very shallow, while the **inferior** is deep. The **laminæ** are deep and overlap the laminæ below; overlapping of laminæ is called *imbrication* [*imbrex*=a tile]. The **vertebral foramen** is circular and is smaller than in the cervical or lumbar regions.

The **spine** is long, slender, and three-sided, and its free end is slightly thickened; it slopes so as to overlap the spine below. The **transverse processes** are long, thick, and rounded, and are inclined backwards and upwards. The free end of each is clubbed, and bears on its anterior aspect a *facet* for articulation with the tubercle of the rib of corresponding number; the process is connected with that rib by a joint capsule and by two bands called the ligament of the tubercle and ligament of the neck of the rib, and it is connected with the neck of the rib below by a flat band called the anterior costo-transverse ligament. The *superior articular surfaces* are flat, and look backwards and slightly upwards and laterally; they are situated on distinct **articular processes.** The *inferior articular surfaces* are situated partly on the lower parts of the laminæ near the pedicles, and partly on short **articular processes** that jut downwards from the laminæ; their direction is the opposite of that of the superior surfaces.

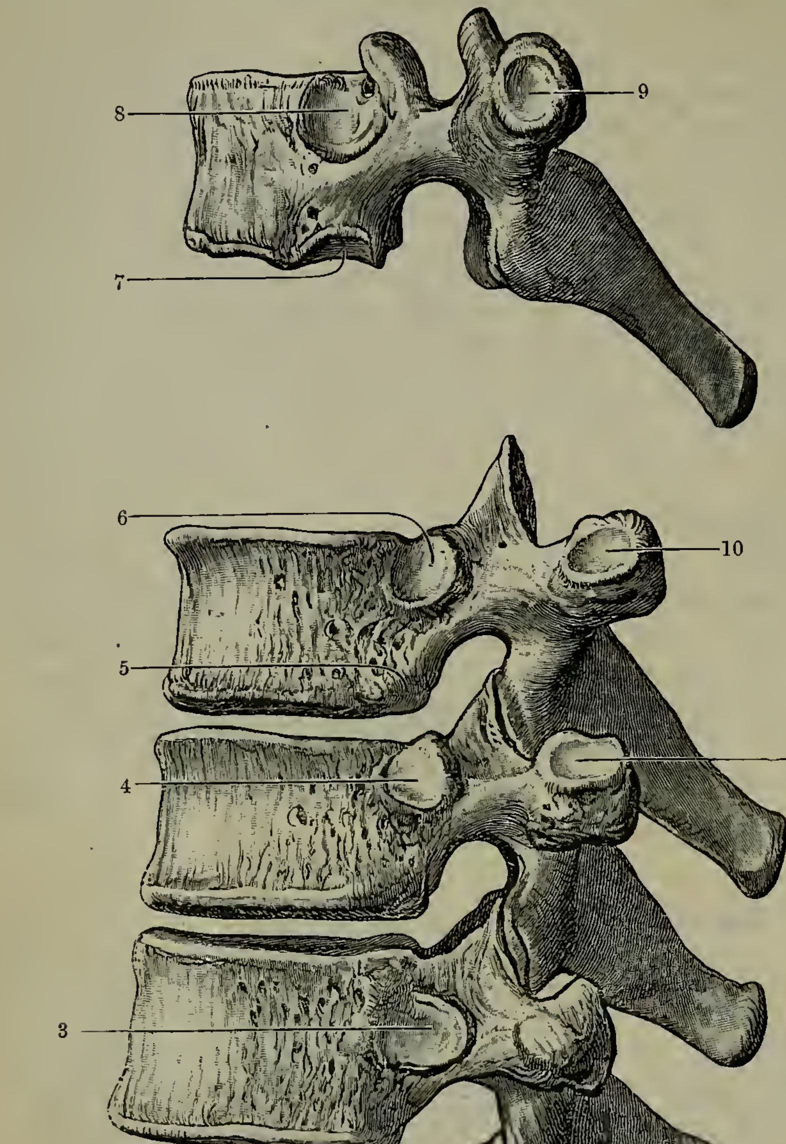


Fig. 115.—First, Ninth, Tenth, Eleventh, and Twelfth Thoracic Vertebræ from the Left Side.

1. Inferior articular process.
2. Single facet for head of XIIth rib.
3. Single facet for head of XIth rib.
4. Single facet for head of Xth rib.
5. Occasional facet for head of Xth rib.
6. Facet for head of IXth rib.
7. Facet for head of IInd rib.
8. Single facet for head of Ist rib.
9. Facet for tubercle of Ist rib.
10. Facet for tubercle of IXth rib.
11. Facet for tubercle of Xth rib, in this particular instance well marked.

S. Superior } Tubercles corresponding to { Mamillary.
I. Inferior } Tubercles corresponding to { Accessory.
E. Lateral } Tubercles corresponding to { Transverse of lumbar.

The *body* of the **first thoracic vertebra** resembles that of a lower cervical vertebra in general outline, and the facets on the sides of the body differ from those of a typical vertebra. It has a complete full-sized facet on each side, near the upper border, for the whole of the head of the first rib, and a small facet at the lower border for the upper part of the head of the second rib.

The **second** often closely resembles the first, but the large facet at the upper border is not quite complete.

The **ninth** has only one facet on the body; it is at the upper border and is incomplete; it is for articulation with the lower part of the head of the ninth rib. There may be a small facet at the lower border also, in which case the ninth would be a typical vertebra, and the tenth would resemble a ninth. Occasionally, the facet on the ninth is complete; in that case the eighth would resemble a ninth, and the ninth would not be readily distinguished from a tenth unless it was known that they both belonged to the same skeleton.

The **tenth, eleventh,** and **twelfth** have *large bodies* resembling those of lumbar vertebræ, and each of them has only one facet on each side of the body. The facet is large and complete, and is situated on the root of the arch as well as on the body; it is for articulation with the head of the rib of corresponding number. The facet on the *tenth* is near the upper border, while that on the *eleventh* is lower down; the tenth has a facet on the transverse process, and the eleventh does not; therefore, those two can usually be distinguished, though it is not always easy when they are from different skeletons. The **twelfth** is easily identified. Its *transverse processes* are short, and broken up into three tubercles. The articular surfaces of the *inferior articular processes* look in a lateral direction, while in other thoracic vertebræ they look forwards. In some skeletons the inferior articular processes of the eleventh resemble those of the twelfth, but the transverse processes of the eleventh are not broken up.

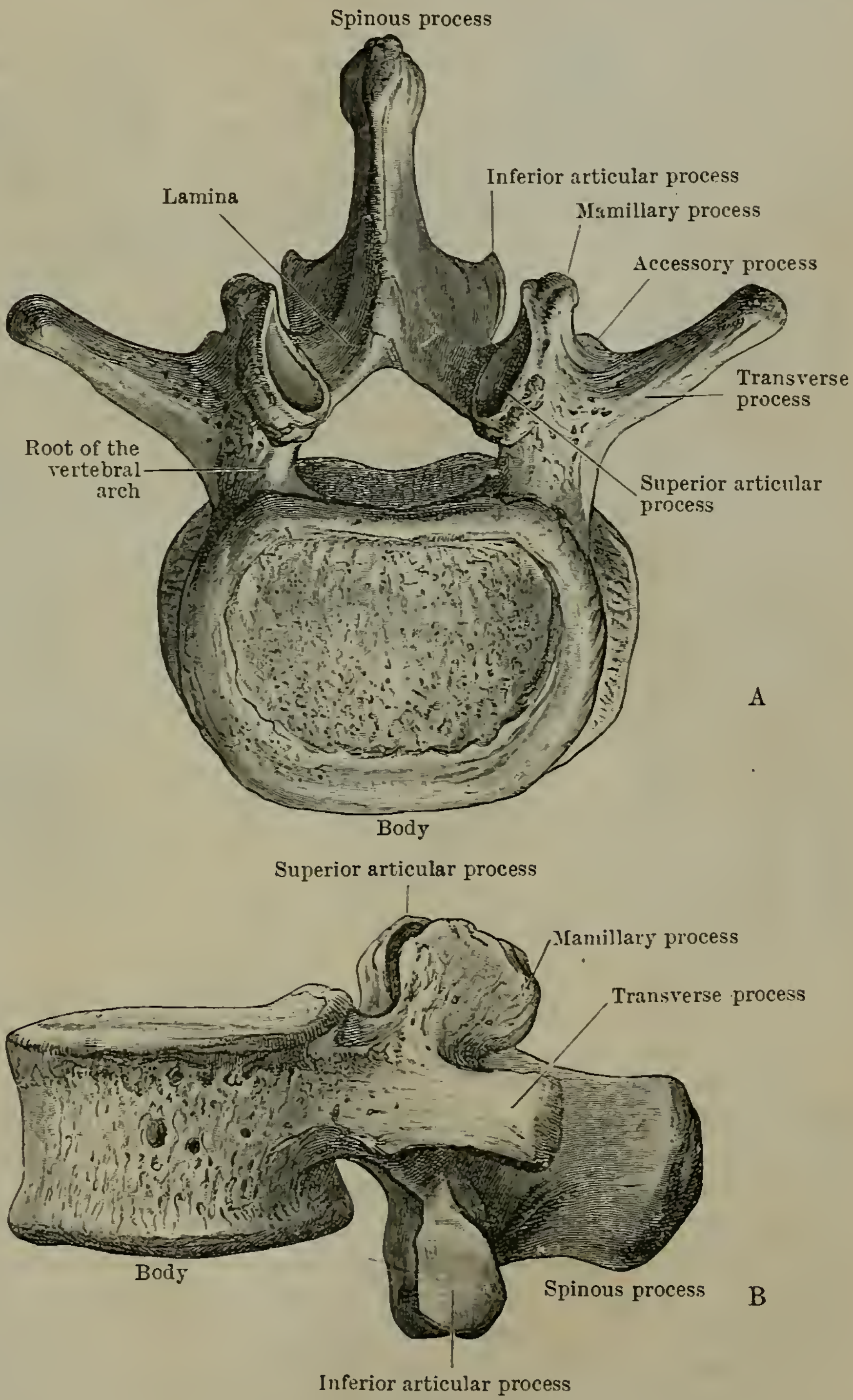


FIG. 116.—THIRD LUMBAR VERTEBRA, (A) from above, and (B) from the left side.

Vertebræ Lumbales.

Lumbar vertebræ are large. Their *large size* distinguishes them at a glance from cervical vertebræ and most thoracic vertebræ; the *thin transverse processes* and *hatchet-shaped spine* distinguish them (all except the fifth) from the bulky lower thoracic vertebræ. The negative distinctive characters common to all lumbar vertebræ are the *absence* of a foramen in the transverse process and the *absence* of facets for ribs.

The **bodies** are about an inch in depth; they are almost two inches wide at their widest part, and therefore structures that lie alongside the bodies are about an inch from the median plane; and the tips of the **transverse processes** are rather more than an inch and a half from the median plane. The **umbilicus** is opposite the fibro-cartilage between the bodies of the *third* and *fourth*. The *fourth* is on a level with the *highest* part of the **iliac crest** (Fig. 109), and the *fifth* is on a level with the *tubercle* of the **iliac crest.** The **laminæ** droop considerably below the level of the pedicles, so that though the spine is nearly horizontal its posterior edge is on a level with the lower part of the body of its own vertebra and the upper part of the body next below. The laminæ do not overlap (Fig. 132); there is an interval between the spines and laminæ of two contiguous lumbar vertebræ through which an instrument can be passed into the vertebral canal in a living person, the operation being called *lumbar puncture.* Lumbar vertebræ measure about three inches from the edge of the spine to the front of the body, and therefore account for a large proportion of the antero-posterior diameter of the trunk about the level of the umbilicus.

The fifth lumbar vertebra has distinguishing features of its own; the others belong to a common type.

A Typical Lumbar Vertebræ.—The **body** is large; its *upper* and *lower surfaces* are nearly flat and are somewhat kidney-shaped in outline; the *posterior surface* is slightly concave, and, in the lower three, is less in depth than the *anterior*, in conformity with the curve of the lumbar part of the backbone, which is convex forwards; the greater part of that convexity is, however, accounted for by the fact that the intervertebral fibro-cartilages are thicker in front than behind.

The **pedicles** or **roots** of the arch are horizontal and are compressed sideways; they spring from the upper part of the body, and therefore the **superior vertebral notches** are shallow, the **inferior** are deep. The **laminæ** are thick and uneven; they droop considerably below the level of the roots, but do not imbricate. The **vertebral foramen** is triangular in outline with rounded corners; it is larger than in the thoracic region, but smaller than in the cervical region.

The **spine** is large, hatchet-shaped and almost horizontal. The **superior articular processes** are broad and uneven; their articular surface is on the medial side, is concave from before backwards and faces medially and slightly backwards. The posterior border of each process is smooth, rounded, and slightly enlarged, and is called the *mamillary process* [*mamilla* = a nipple, a teat]. The **inferior articular processes** project downwards from the lower part of the laminæ. They fit in between the superior processes of the vertebra below; therefore they are closer together than the superior pair, and the articular surfaces look in a lateral direction and are convex.

The **transverse processes** are long and thin, being compressed from before backwards, and they incline slightly backwards and upwards. In the lower vertebræ they spring from the pedicle as well as from the junction of pedicle and lamina. On the back of the root of each process there is a little tubercle called the *accessory process.* The accessory process and the mamillary process correspond to the transverse process of a thoracic vertebra; the transverse process of a lumbar vertebra is the homologue of a rib. If the last two thoracic vertebræ and the first lumbar vertebra are placed together in proper order, the transition from the thoracic transverse process to the lumbar mamillary and accessory processes can be seen. In some rare cases the transverse process of the first lumbar vertebra exists separately as a **lumbar rib.**

The **fifth lumbar vertebra** is usually the largest of the lumbar vertebræ, though its body is usually of less depth than the fourth. The front of the **body** is usually much deeper than the back. The **spine** is small and its corners are rounded off. The **transverse process** is short, thick, and conical; its root is attached not only to the junction of lamina and pedicle, but also to the side of the pedicle and even to the side of the body; a strong band called the ilio-lumbar ligament stretches from its tip to the adjoining part of the iliac crest. The **inferior articular processes** are as wide apart as the superior, or even wider, for they have to articulate with the widely separated superior articular processes of the sacrum.

Os Sacrum et Os Coccygis.

The **sacrum** is a large bone made of the five sacral vertebræ, which are fused together in order to increase the stability of the pelvis. It lies below the small of the back between the upper part of the two hips and can be felt there as an uneven bony surface; it is wedged in between the two hip bones and forms by far the greater part of the dorsal wall of the cavity of the pelvis; it is held in place by exceedingly strong ligaments. It has the form of an inverted triangle, and possesses a wide upper end or **base**, a small lower end or **apex**, right and left **borders**, a rough, uneven **dorsal surface**, and a relatively smooth **pelvic surface.**

The **pelvic surface** is concave and looks downwards and forwards; it presents a large median column of bone separated from a smaller mass on each side by a vertical series of four holes. The median column consists of the **bodies** of the five sacral vertebræ and the ossified intervertebral cartilages all fused together. The block of bone on each side is called the **lateral mass** of the sacrum. The four pairs of holes are called the **anterior sacral foramina**; the anterior rami of the upper four pairs of sacral nerves issue through them. In specimens in which the coccyx has fused with the sacrum there are five pairs of foramina.

The **base** is directed forwards and upwards. In the middle there is the upper surface of the **body** of the first sacral vertebra; its anterior border is a prominent lip called the *promontory* of the sacrum. On each side of the body there is a wide, spreading surface called the ala of the sacrum; it is the upper end of the lateral mass. The promontory and the smooth anterior borders of the two alæ form the posterior part of the brim of the pelvis minor. The **vertebral foramen** is the large opening behind the body and it leads into a tunnel called the *sacral canal.* The **superior articular processes** are the upstanding projections at the sides of the vertebral foramen.

The **apex** is the lower surface of the body of the fifth sacral vertebra.

Each side or **border** of the sacrum is broad above and narrow below. The broad, upper part is a sharply defined area that has some resemblance to an ear turned the wrong way, and is therefore called the **auricular surface**; it articulates with a corresponding auricular surface on the hip bone to form the *sacro-iliac joint.* The narrow, lower part of the border, as it is traced downwards, turns abruptly towards the body of the fifth vertebra, where it ends; the point where the change of direction takes place is called the **inferior lateral angle** of the sacrum.

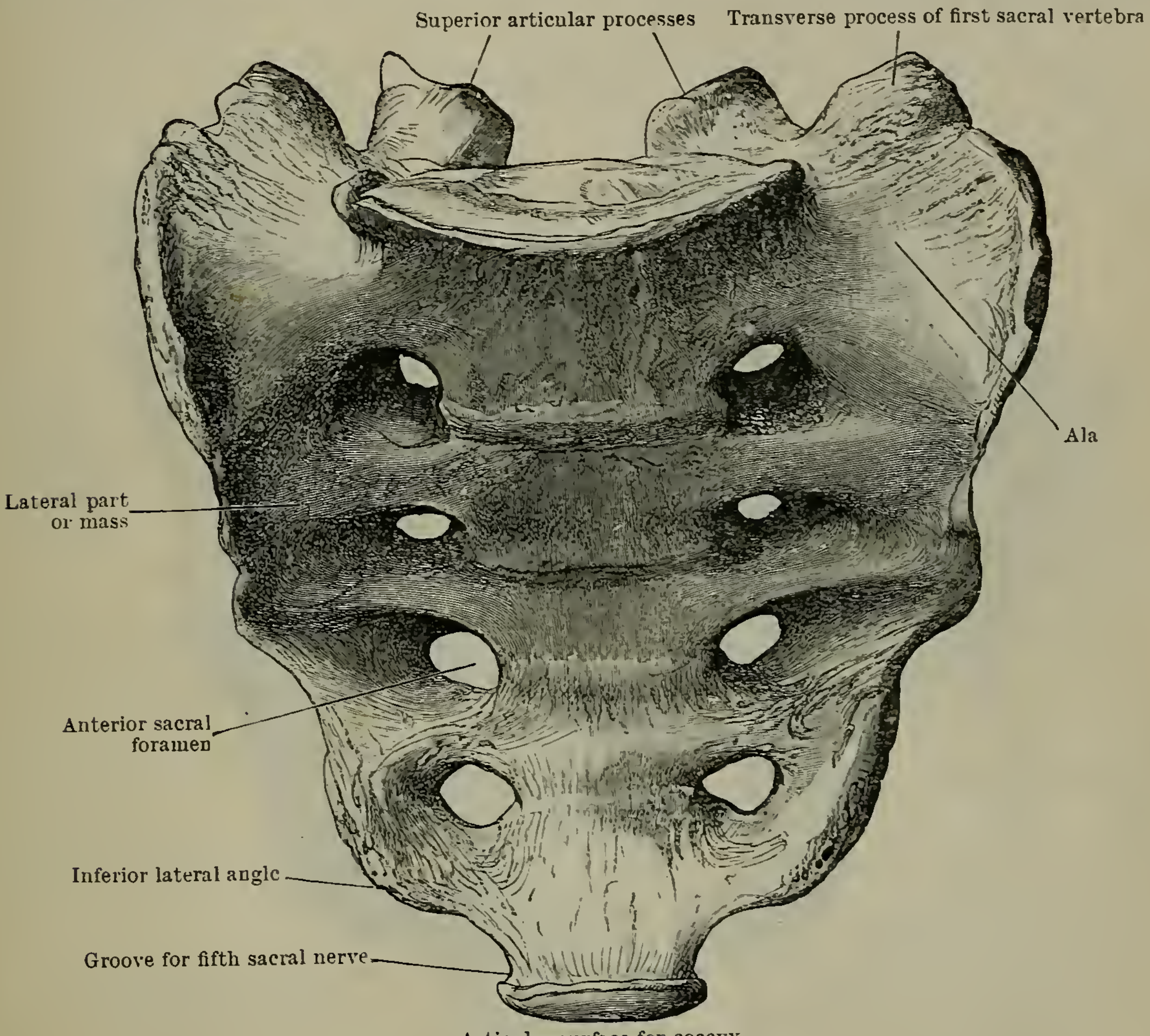

Superior articular processes
Transverse process of first sacral vertebra
Ala
Lateral part or mass
Anterior sacral foramen
Inferior lateral angle
Groove for fifth sacral nerve
Articular surface for coccyx

Fig. 117.—The Sacrum (anterior view).

The **dorsal surface** is very rough and uneven, and is convex. In the median plane there is a row of tubercles; they are the **spines** of the sacral vertebræ, and may be fused together, forming a *median crest.* About an inch lateral to the median plane there is a vertical row of four holes called the **posterior sacral foramina**; they are exactly opposite the anterior foramina, and the posterior rami of the upper four sacral nerves issue through them. The posterior parts of the vertebral arches of the lower two sacral vertebræ are absent, so that the median crest or row of spines does not reach the lower end. The lowest complete vertebral foramen is the lower end of the sacral canal; it is an oblique opening; its margins are prolonged downwards to the fifth vertebra and end as two blunt projections called the **sacral cornua.**

The chief contents of the **sacral canal** are the roots of the sacral and coccygeal nerves, the filum terminale and the lowest parts of the dura mater and the arachnoid. The lower end of the sacral canal gives exit to the fifth pair of sacral nerves, the pair of coccygeal nerves and the filum terminale. (Dura mater and arachnoid are the names given to the outer two of the three membranes that surround the spinal medulla; they are continued downwards around the roots of the nerves as far as the second piece of the sacrum. The innermost membrane is called the pia mater; the filum terminale is a long, slender glistening thread continued downwards from the lower end of the pia mater and it ends by blending with the periosteum on the back of the coccyx.)

The **coccyx** forms the lower end of the backbone; it lies in the floor of the groove between the buttocks a little above the anus, and, at the same time, in the dorsal wall of the pelvis below the sacrum. It is composed of four small incomplete vertebræ fused together, and, like the sacrum, it is triangular in outline with the apex below. It has a base, an apex, a pelvic surface, a dorsal surface, and two sides or borders. The **first vertebra** is much the largest; its *upper surface* is the base of the coccyx and articulates with the apex of the sacrum; from its **dorsal surface** two processes called the coccygeal **cornua** project upwards; and from each side or border a **transverse process** juts out. The lower three vertebræ are mere nodules of bone, diminishing in size from above downwards, and the lowest one forms the apex of the coccyx. Occasionally the coccyx consists of three or of five pieces instead of four.

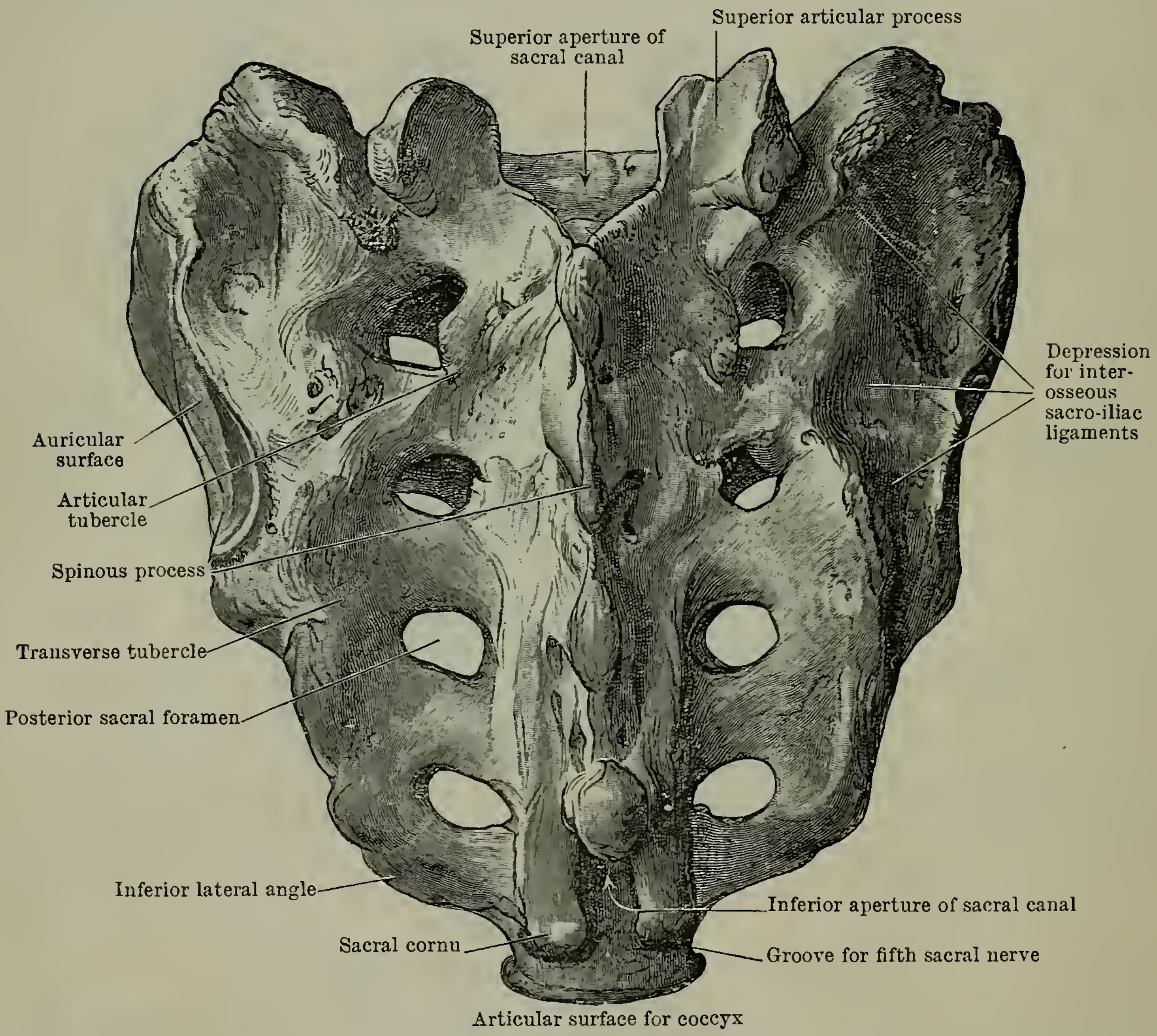

Superior articular process
Superior aperture of sacral canal
Depression for inter-osseous sacro-iliac ligaments
Auricular surface
Articular tubercle
Spinous process
Transverse tubercle
Posterior sacral foramen
Inferior lateral angle
Inferior aperture of sacral canal
Sacral cornu
Groove for fifth sacral nerve
Articular surface for coccyx

Fig. 118.—The Sacrum (posterior view).

The **pelvic surface** of the **sacrum** is concave from above downwards, and slightly concave from side to side also, the degree of concavity varying greatly in different specimens. The fact that there are five bodies in the median column is indicated by four *transverse lines* or ridges.

The bodies diminish in size from above downwards; they are flattened from before backwards especially towards the lower end; and if a sagittal section (p. 5) is made, the remains of the fibro-cartilages are found between them. The four pairs of **anterior sacral foramina** are at the ends of the transverse lines; they also diminish in size from above downwards. Each foramen transmits the anterior ramus of a sacral nerve, a branch of a lateral sacral artery, and an accompanying vein; a short, shallow groove, in which the ramus lies, extends from the foramen on to the lateral mass. The **lateral mass** is made up of the *transverse processes* of one side all fused together. In the sacral region, as in the cervical region, a transverse process consists of a *rib element* in front and a *true transverse process* behind; the costal elements form the larger part of the lateral mass (Fig. 125), especially in the upper three segments, which articulate with the ilium.

The middle sacral artery, with a companion vein on each side, runs down the middle of the pelvic surface of the sacrum and ends on the pelvic surface of the coccyx. The sympathetic trunk runs down across the medial parts of the anterior sacral foramina and joins its fellow of the other side on the front of the coccyx. The greater part of the piriformis muscle arises from the middle three pieces of the sacrum between the anterior foramina. The rectum is closely related to the pelvic surface of the lower three pieces of the sacrum and the coccyx.

On the **base** of the sacrum the constituent parts of the first sacral vertebra may be made out fairly clearly. The upper surface of the **body**, situated in the middle anteriorly, resembles the body of the fifth lumbar vertebra in outline; it is bound to that body by the lowest intervertebral fibro-cartilage and the lower ends of the anterior and posterior longitudinal ligaments. The **vertebral foramen** is large, sloping, and triangular, and has the usual boundaries of body and **vertebral arch**. The **superior articular processes** stand up from the sides of the arch; their concave articular surfaces look medially and backwards and articulate with the inferior articular processes of the fifth lumbar vertebra, to which they are bound by articular capsules. The **laminæ** are connected with the laminæ of that vertebra by the lowest pair of ligamenta flava. The **root** of the arch or **pedicle** is the part between the superior articular process and the body; it may be marked off from the ala by a pit, or, in rare cases, by a foramen; it forms the lower boundary of the intervertebral foramen through which the fifth lumbar nerve issues, and the anterior ramus of the nerve, running downwards, forwards, and laterally from the foramen, sometimes makes a shallow groove on the ala. The **ala** is the transverse process; its posterior part is the *true transverse process* and may be marked off from the rest by a slight depression; the postero-lateral angle of the ala is the tip of the true transverse process and may be marked off from the margin in front of it by a notch. The ala is continuous with the iliac fossa of the hip bone when the bones are articulated; the lumbo-sacral ligament and some fibres of iliacus are attached to it. Its lateral margin is the upper or anterior boundary of the auricular surface.

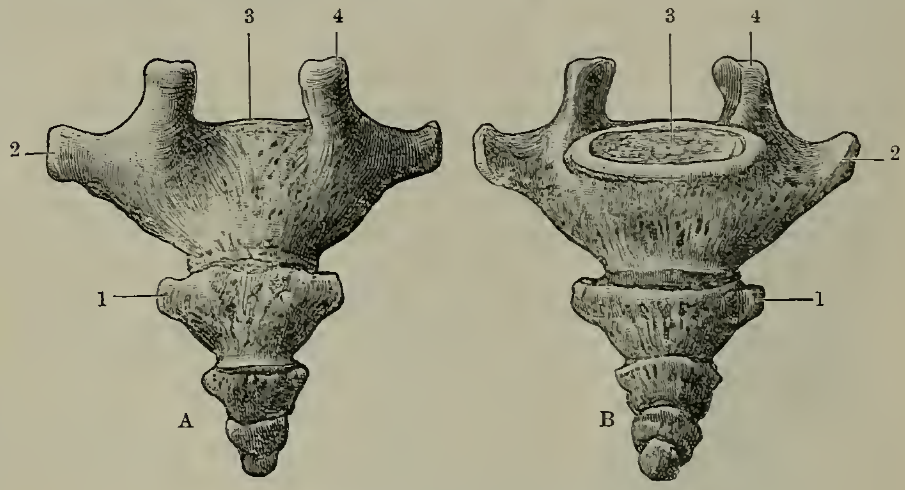


Fig. 119.—The Coccyx.

A. Posterior Surface. B. Anterior Surface.

1. Transverse process. 2. Transverse process. 3. For Sacrum. 4. Cornu.

The **apex** is the oval lower surface of the body of the fifth sacral vertebra. It is attached to the body of the first coccygeal vertebra by an intervertebral fibro-cartilage and by anterior and posterior sacro-coccygeal ligaments.

The **lateral border** is curved sinuously as it is traced downwards, for the third piece of the sacrum is rather wider than the second, and the border turns abruptly towards the body of the fifth piece. The **auricular surface** overlies the lateral aspects of the upper three pieces; it is uneven and usually rough, though it is the articulating surface at a diarthrodial joint; its inequalities fit into reverse inequalities of the auricular surface of the hip bone, so that very little movement is possible at the joint. The anterior and lower parts of the joint capsule are together called the anterior sacro-iliac ligament, which is attached to the convex margin of the auricular surface; the posterior or upper part is the interosseous sacro-iliac ligament, which is very thick and strong, and is attached to the concave margin of the surface and to the wide uneven depression behind and above it. The pelvic surface of the upper part of the sacrum is wider than the dorsal surface, and the auricular surface slopes accordingly, so that in the articulated pelvis the sacrum is the reverse of the keystone of an arch; the interosseous ligaments of the two sides are the principal factors in holding it in place.

The narrower part of the lateral border gives attachment to part of the sacro-tuberous ligament; the upper parts of the sacro-spinous ligament and coccygeus muscle are attached to the side of the fifth piece in front of the sacro-tuberous ligament; and the **inferior lateral angle** is connected with the transverse process of the coccyx by the lateral sacro-coccygeal ligament.

The **dorsal surface** is directed upwards and backwards. The row of **spines** or **median crest** varies greatly in its degree of prominence; its upper end gives attachment to a supraspinous and an interspinous ligament connecting it with the lowest lumbar spine, and the lower part of the lumbo-dorsal fascia is attached to each lip of the crest. At each side of the root of the crest there is a rough plate of bone consisting of the laminæ fused together. Lateral to that plate there are the four **posterior sacral foramina**; they diminish in size from above downwards, and each one transmits the posterior ramus of a sacral nerve, accompanied by small terminal branches of the lateral sacral vessels. At the medial margin of each foramen there is a small projection, called an **articular tubercle**, because it represents the inferior and superior articular processes of two contiguous sacral vertebræ fused together. The lowest of the series is the **sacral cornu**, which represents an inferior articular process of the fifth sacral vertebra; the two sacral cornua are connected by ligaments with the coccygeal cornua. Lateral to the posterior sacral foramina, on the back of the lateral mass, there is a row of **transverse tubercles**, representing the tips of the fused true transverse processes. The multifidus and sacrospinalis muscles are attached to the uneven surface between the tubercles and the median plane. The short posterior sacro-iliac ligament is attached to the first and second transverse tubercles (the first being the postero-lateral angle of the ala); the long posterior sacro-iliac ligament to the third tubercle; part of the sacro-tuberous ligament to the fourth and fifth; fibres of the gluteus maximus arise from the back of the sacrum, but they spring from those ligaments and the lumbo-dorsal fascia rather than from bone.

The **sacral canal** is the lowest part of the vertebral canal. It lies between the fused bodies and the fused laminæ. It is triangular above, flattened from before backwards below. On each side of it there is a series of four large apertures that correspond to **intervertebral foramina**; they transmit the upper four sacral nerves, and each one divides into two parts which end as an anterior and a posterior sacral foramen. The canal *contains* (1) a quantity of soft fat in which there lie small arteries and fairly large, thin-walled veins, (2) the roots of the sacral and coccygeal nerves, (3) the filum terminale, (4) the lower part of the spinal dura mater and arachnoid. The lower part of the posterior wall of the canal is deficient owing to the absence of the laminæ and spine of the fifth vertebra and, very often, of the fourth also. The lower opening of the canal is therefore very oblique, and is called the *hiatus sacralis.*

The coccygeal cornua correspond to pedicles and superior articular processes. In specimens in which the sacrum and coccyx are fused together the ligaments connecting the sacral and coccygeal cornua may be ossified, and so also may be the ligaments connecting the inferior lateral angles of the sacrum with the transverse processes of the coccyx; in such a case there are a *fifth pair* of intervertebral foramina and of anterior sacral foramina.

The filum terminale is attached to the back of the first piece of the **coccyx**, and a few fibres of the gluteus maximus arise from it. The lower parts of the sacro-tuberous ligament, the sacrospinous ligament, and the coccygeus muscle are attached to its margin, in that order from behind forwards. The posterior fibres of the levator ani muscle are inserted into the side of the lower pieces; the sphincter ani externus and the ano-coccygeal body—a fibrous nodule situated behind the anal canal—are attached to its apex.

Sexual Differences.—In the male the curve of the sacrum is fairly uniform and is deepest opposite the third piece. In the female the sacrum is said to be flat above and sharply bent forwards below. The female sacrum is shorter and wider, and is set more obliquely so that its pelvic surface looks more downwards than in the male. The auricular surface is borne by the first two pieces, instead of three as in the male. The coccyx is more movable in the female and less liable to be fused with the sacrum, and the first piece of the coccyx more often fails to fuse with the second piece than in the male.

VERTEBRAL COLUMN AS A WHOLE.

The **vertebral column** is about 28 inches (70 cm.) long in the male and 24 inches (60 cm.) in the female; the intervertebral fibro-cartilages account for nearly one-fourth of its length. In the male, approximate measurements for the different regions are: cervical, 5 in.; thoracic, 11 in.; lumbar, 7 in.; sacrum and coccyx, 5 in.

The vertebræ are joined together by the fibro-cartilages between the bodies and by the various ligaments that connect the body, laminæ, and processes of one vertebra with corresponding parts of its two immediate neighbours, so that the vertebræ make a strong column for the support of the trunk and neck and a pedestal for the head. It is not, however, a rigid column, but is flexible and resilient; although the vertebræ are firmly bound together, a little movement is possible between each two (with the exception of the segments of sacrum and coccyx), and the sum of the movements between each two over the whole movable part of the column is very considerable. [*Vertere* = to turn.]

The column of **bodies** is the chief axis of support; the **vertebral arches** close in the vertebral canal, in which the spinal medulla lies in safety; the **articular** processes permit movement but also control its direction and help to limit its range; the **spines** and **transverse processes** are levers to which muscles are attached.

Curvatures.—The column is not straight. **At birth** it has two curves, both concave forwards. They are called **primary curvatures**; the lower one is formed by the sacral and coccygeal vertebræ, the upper one by all the rest of the column; the point where the two curves meet, at the junction of the last lumbar vertebra and the first sacral, is called the **sacro-vertebral angle.** **In the adult** there are four curves—cervical, thoracic, lumbar, and sacro-coccygeal.

The **cervical curvature** is convex forwards. It begins at the atlas, and, at its lower part, merges into the thoracic curve; the lower border of the second thoracic vertebra is taken as the level where the two curves meet, for that is the level of the upper border of the breast-bone, and the upper two thoracic vertebræ lie, therefore, in a sense, in the neck. The cervical curvature is the least marked of the four curves and is undone when the neck is bent forwards. It is a *secondary* or *compensatory* curve and is due chiefly to the shape of the fibro-cartilages; it begins to be formed two or three months after birth, when the child begins to lift its head up from the chest, and it becomes further developed at the eighth or ninth month when the child begins to sit upright. The **thoracic curvature** is concave forwards; it extends to the twelfth thoracic vertebra, where it merges into the lumbar curve; it is a primary curve and is due to the shape of the bodies of the vertebræ. The **lumbar curvature** is convex forwards; it is more pronounced in a woman than in a man, and in a youth than in an elderly person; it extends to the sacro-vertebral angle; it is a *secondary* or *compensatory* curve and is due chiefly to the shape of the fibro-cartilages; it begins to appear a year after birth, when the child, adopting the erect attitude, lifts up its trunk, straightens out its lower limbs and begins to walk. The **sacro-coccygeal curvature** is the original lower *primary curve* and is concave downwards and forwards.

Besides having those four curvatures the column of bodies is often slightly convex towards the right side in the thoracic region. That **lateral curvature** may be due to the greater muscularity and use of the right upper limb, for it is said to be convex towards the left in left-handed people; but much more probably it is due to the pressure that the upper part of the descending aorta exerts by its pulsations on the left side of the bodies of the middle four thoracic vertebræ, and in the rare cases in which the aorta is on the other side of those vertebræ the curve is convex towards the left. (The aorta is the great artery that springs from the heart and conveys blood to be distributed by its branches to all parts of the body.) When the lateral curvature is well marked there are compensatory curves, in the opposite direction, above and below it.

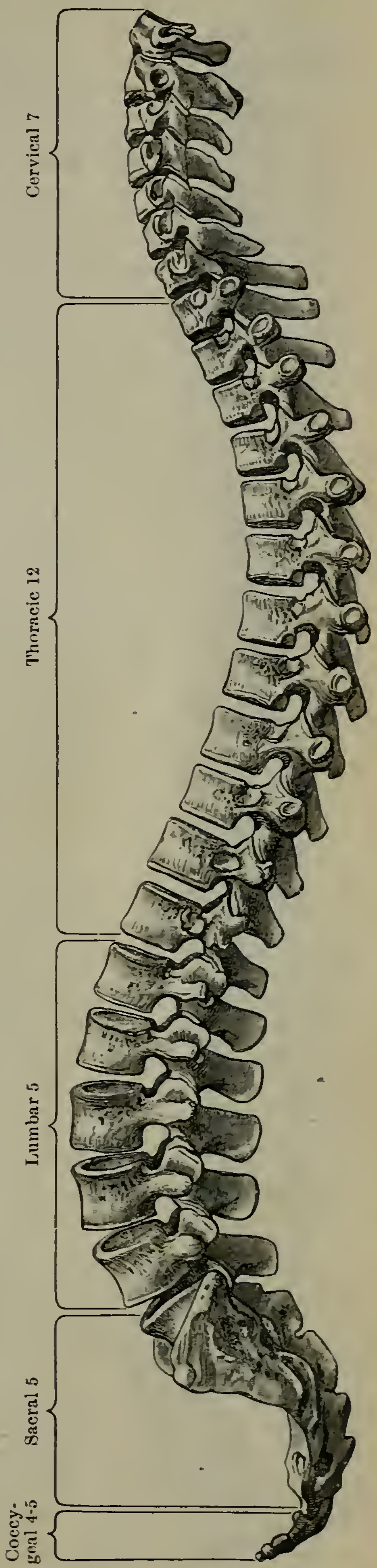


Fig. 120.—Vertebral Column from the Left Side.

The curvatures of a line drawn along the tips of the spines are not repetitions of the curvatures of the bodies, owing to the varying length and obliquity of the spines; and lateral curvature of the spines may be greater or lesser in degree than that of the bodies. Occasionally one or more spines may be deflected very considerably to one side without corresponding rotation of the body towards the opposite side and without any sign of past disease or of recent accident.

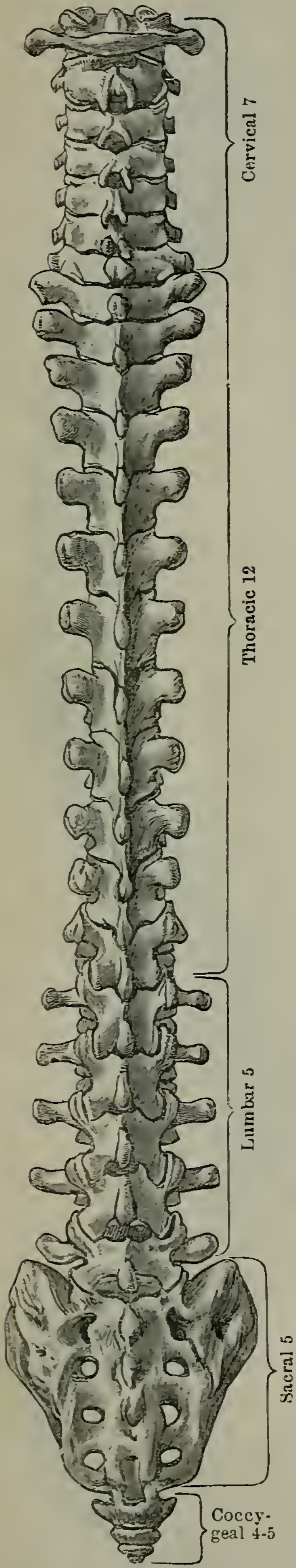


Fig. 121.—Vertebral Column as seen from behind.

Curvatures of the backbone may become accentuated and distortions may occur as a result of weakness, disease, or accident. With advancing years the column loses its flexibility and resilience and becomes more or less set and rigid, especially in rheumatic people. In many skeletons evidence of rheumatism is seen in the "lipping" of the margins of the vertebræ and rough ridges and protuberances here and there.

The following points may be noted in the vertebral column:—

When viewed from the Side.—(1) The four curvatures. (2) The antero-posterior diameters of the **bodies** increase gradually down to the *second lumbar*, and then gradually diminish. (3) The **costal facets** on the sides of the bodies, from the first thoracic downwards, gradually take up a position farther back till that on the twelfth is more on the root of the arch than on the body. (4) The **intervertebral foramina** increase in size from above downwards. (5) The **transverse processes** of *cervical* and *lumbar* vertebræ are in front of the articular processes, while those of *thoracic* vertebræ are behind and have more of a backward inclination; they are between the intervertebral foramina in the *cervical* region, and behind the foramina in the *thoracic* and *lumbar* regions; the change of characters is abrupt between cervical and thoracic regions, and more gradual between thoracic and true lumbar transverse processes. (6) Owing to the direction of **articular surfaces** the clefts of the joints between articular processes are visible in the cervical and thoracic regions, but not in the lumbar region. (7) The varying length and slope of the **spines** and consequent lack of conformity of the curves of the spines and those of the bodies; the slope of the spines, though varying greatly, is always downwards, while in most lower animals the spines slope towards an "anticlinal" vertebra situated in the hinder part of the thoracic region. (8) The antero-posterior diameter of the *lumbar vertebræ* is much greater than that of the others.

When viewed from the Front.—(1) The lateral curvatures, when present. (2) The column is widest at the base of the sacrum; the **bodies** increase in width from the second cervical to the first thoracic and diminish slightly from the first to the fourth; they increase gradually from the fifth thoracic to the first sacral, below which there is progressive diminution in width. (3) The side-to-side convexity of the bodies is sharper in the middle thoracic region than elsewhere. (4) In the vertical diameter the body of the second cervical vertebra is deeper than those of the lower five, which are nearly equal in depth; below that there is gradual increase in depth down to the third or fourth lumbar; the fifth lumbar is usually of less depth than the other lumbar vertebræ; in different skeletons any one of the thoracic vertebræ may be of less depth than the one above it. (5) The **transverse processes** of the *atlas* are outstanding and are wider apart than the next five pairs, the tips of which are at nearly equal distances from the median plane; those of the *seventh* are almost as long as the first thoracic; they gradually diminish from the first thoracic to the twelfth, where they are mere tubercles; they are outstanding again in the lumbar region and vary in length, and though the third is usually the longest, its tip is not necessarily the furthest from the median plane, owing to the greater width of the fourth and fifth vertebræ as a whole. (6) The *sacrum* and *coccyx* rapidly diminish in width from above downwards, but there is little difference between the second and third pieces of the sacrum, and the third is usually the wider; the diminution is very sudden below the inferior lateral angle of the sacrum, and, again, below the transverse process of the coccyx.

When viewed from the Back.—(1) Differences in the lengths of the **transverse processes** as seen also from the front; in the cervical region they are hidden by the articular processes, so that only the posterior tubercles are visible; the transition from thoracic transverse process to lumbar mamillary and accessory processes is well seen. (2) The **articular processes** of the lower six cervical vertebræ are at equal distances apart, and are wider apart than those of the thoracic vertebræ; the distance gradually diminishes from the first thoracic to the first lumbar, below which it increases; the joint clefts between articular processes are clearly visible in the lumbar region, less so in the cervical region and not at all in the thoracic region. (3) The **laminæ** overlap in the thoracic region; in the lumbar region there are intervals between them; in the cervical region they overlap very slightly when the neck is straight, but there are intervals between them when the neck is bent forwards, and there is always a fairly wide interval between the atlas and the second vertebra, and also between the atlas and the skull. (4) The different characters of the **spines** and their lateral curvatures or deflections if present. (5) The **vertebral groove** is the wide furrow alongside the spines; it is shallow in the neck and the loins, where its floor is made of the laminæ and inferior articular processes, and deep in the thoracic region, where its floor is formed of laminæ, inferior articular processes and transverse processes.

Ligaments and Muscles attached to movable Vertebræ.

Bodies.

Anterior and posterior longitudinal ligaments, 2 C to sacrum.
Articular capsules of joints at sides of fibro-cartilages, 2-7 C.
Articular capsules and lig. radiata of costo-vertebral joints, 1-12 T.
Medial lumbo-costal arch, 2 L.
Longus colli, 2-7 C, 1-3 T.
Psoas minor, 12 T, 1 L.
Psoas major, 12 T, 1-5 L.

Laminæ.

Ligamenta flava, ALL.
Rotatores, 1-11 T.

Articular processes.

Articular capsules, ALL.
Longissimus capitis
Semispinalis capitis } 4-7 C.
Semispinalis cervicis
Multifidus, 4-7 C, 1-5 L.

Transverse processes.

Intertransverse ligaments, ALL.
Sibson's fascia, 7 C.
Articular capsules
Ligament of tubercle of rib } 1-10 T.
Ligament of neck of rib
Costo-transverse ligaments } 1-11 T.
Lumbo-costal ligament, 12 T, 1 L.
Lumbo-costal arches, 1 L.
Lumbo-dorsal fascia, 1-5 L.
Ilio-lumbar ligament
Lumbo-sacral ligament } 5 L.
Rectus capitis lateralis
Obliquus capitis superior } 1 C.
Obliquus capitis inferior
Levator scapulæ
Splenius cervicis } 1-4 C.

Transverse processes—(contd.)

Intertransversales, 1 C-5 L.
Scalenus medius, 2-6 C.
Longissimus cervicis, 2-6 C, 1-6 T.
Longus capitis
Longus colli } 3-6 C.
Scalenus anterior
Scalenus posterior
Ilio-costalis cervicis } 4-6 C.
Levatores costarum, 7 C, 1-11 T.
Longissimus capitis
Semispinalis capitis } 1-6 T.
Semispinalis cervicis
Multifidus, 1-12 T.
Longissimus dorsi, 1-12 T, 1-5 L.
Rotatores, 2-12 T.
Semispinalis dorsi, 7-12 T.
Psoas major
Quadratus lumborum } 1-5 L.

Spines.

Ligamentum nuchæ, 2-7 C.
Interspinal and supraspinal ligaments
Lumbo-dorsal fascia } All T and L.
Obliquus capitis inferior
Rectus capitis posterior major } 2 C.
Semispinalis cervicis, 2-5 C.
Spinalis cervicis, 2-4 C, 7 C-2 T.
Interspinales
Multifidus } 2 C-5 L.
Semispinalis dorsi, 6 C-4 T.
Rhomboideus minor, 7 C, 1 T.
Serratus posterior superior, 7 C-3 T.
Splenius, 7 C-5 T.
Trapezius, 7 C-12 T.
Rhomboideus major, 2-5 T.
Spinalis dorsi, 4-8 T, 11 T-2 L.
Sacro-spinalis, 1-5 L.

OSSIFICATION OF VERTEBRÆ.

A **typical vertebra** is ossified from three primary centres and five secondary centres. The three **primary** centres are one in the *body* and one in each half of the *vertebral arch*; the five **secondary** centres appear at the tip of the *spine*, the tips of the *transverse processes*, the upper and lower surfaces of the *body*.

The *primary centres* for the **arch** appear gradually from above downwards, appearing first in the upper cervical region about the seventh week of fœtal life and reaching the sacrum about the twentieth week. They appear at the roots of the articular processes; the arch and its processes are ossified from them, and also the postero-lateral parts of the body—the parts of the body which, in thoracic vertebræ, articulate with the ribs.

The *centre* for the median, larger part of the **body** appears dorsal to the notochord, first in the lower thoracic region about the tenth week; the process spreads up and down till by the twentieth week centres have appeared in all the bodies except in the coccyx, where they do not appear till after birth. Occasionally there are two centres for the body which coalesce, but may fail to do so, so that in rare cases the body ossifies as two separate halves, or one half only ossifies.

At birth the vertebra consists of three pieces of bone—the median, larger part of the body and the two parts ossified from the centres for the arch. The laminæ are not osseously united; the spine is cartilaginous. The median part of the body is joined to each postero-lateral part by a plate of cartilage; the joint is called the *neuro-central synchondrosis*; the line of the joint is antero-posterior in the cervical region, oblique in the thoracic, and nearly transverse in the lumbar region (Fig. 125).

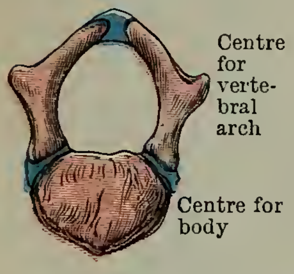


Fig. 122.—Ossification of Vertebræ.

The union of laminæ begins in the lumbar region soon after birth, and, spreading upwards, is completed in the cervical region early in the second year, but is deferred in the sacrum till between the seventh and tenth years. After fusion of the laminæ the ossifying process extends into the spine. The union of the body and arch, *i.e.* the disappearance of the neuro-central synchondrosis, begins in the neck in the third year, and spreading downwards, is completed in all regions in the sixth or seventh year.

The *secondary centres* appear at **puberty**, and the epiphyses formed from them fuse with the rest of the bone at 25. The epiphyses on the body are in the form of flat rings on the circumferential part of the upper and lower surfaces. In the thoracic region the epiphysis on the tip of a transverse process includes part of the articular facet.

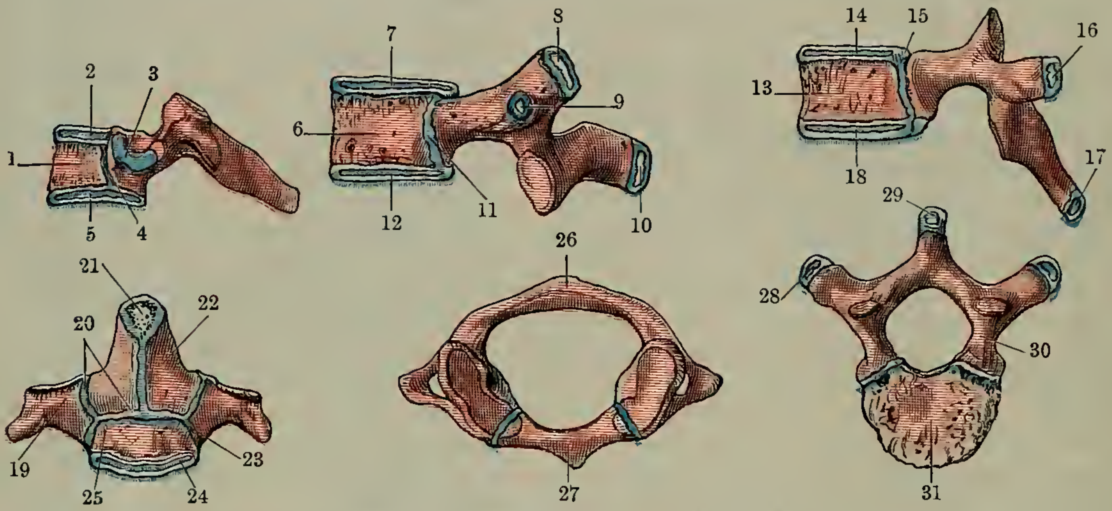


Fig. 123.—Ossification of Vertebræ.

Cervical vertebra.

1. Centre for body.
2. Superior epiphyseal ring.
3. Anterior bar of transverse process ossified by lateral extension from root of vertebral arch.
4. Neuro-central synchondrosis.
5. Inferior epiphyseal ring.

Lumbar vertebra.

6. Body.
7. Superior epiphyseal ring.
8. Centre for mamillary process.
9. Centre for transverse process.
10. Centre for spinous process.
11. Neuro-central synchondrosis.
12. Inferior epiphyseal ring.

Thoracic vertebra.

13. Centre for body.
14. Superior epiphyseal ring.
15. Neuro-central synchondrosis.
16. Centre for transverse process.
17. Centre for spinous process.
18. Inferior epiphyseal ring.

Epistropheus.

19. Centre for transverse process and vertebral arch.
20. Synchondroses close about 3rd year.
21. Centre for summit of dens.
22. Centre for lower part of dens.
23. Neuro-central synchondrosis.
24. Inferior epiphyseal ring.
25. Single or double centre for body.

Atlas.

26. Posterior arch and lateral masses ossified from a single centre on each side. In this figure the posterior arch is represented complete by the union posteriorly of its posterior elements.
27. Anterior arch and portion of superior articular surface ossified from single or double centre.

Thoracic vertebra.

28. Centre for transverse process.
29. Centre for spinous process.
30. Centre for vertebral arch on each side. The arch is here shown complete posteriorly.
31. Centre for body.

	Centres for arch.	Centre for body.	Laminæ unite.	Arch joins body.	Epiphyses appear.	Epiphyses join.
Cervical . .	7th week	15th week	Early 2nd yr.	3rd year	Puberty	25th year
Thoracic . .	10th ,,	10th ,,	1st year	4-5 years	,,	25th ,,
Lumbar . .	15th ,,	15th ,,	Early 1st yr.	6th year	,,	25th ,,
Sacral . .	20th ,,	20th ,,	7-10 years	7th year	18th year	25th ,,
Coccygeal . .	*none*	1st year to puberty	*none*	*none*	*none*	*none*

In many of the vertebræ the ossification departs from type.

In the **cervical region** the bifid tips of the **spines** have *two* epiphyses.

The Atlas Vertebra.—A primary centre for each half of the vertebral arch, including the lateral mass, appears at the seventh week. The two halves unite posteriorly in the third year, and their union may be preceded by a secondary centre in the cartilage between them. The anterior arch is cartilaginous at birth. One centre (sometimes two) appears in it during the first year and it fuses with the lateral masses about the seventh year. It includes the anterior part of the upper articular surface of the lateral mass. The epiphyses on the transverse processes unite about 18.

The Second Cervical Vertebra.—A primary centre for each half of the vertebral arch appears in the seventh week; one or two for the lower part of body early in the fifth month; two appear side by side for the upper part of the body and the lower part of the dens later in the fifth month, and fuse during the seventh month. *At birth* the vertebra consists of four bony pieces which unite between the third and sixth years. An epiphysis for the top of the dens appears between the third and sixth years and fuses before 12; another appears on the lower surface of the body at puberty and fuses about 25.

The **sixth** and **seventh cervical vertebræ** may have separate primary centres in the costal processes, which join the rest of the bone about the fifth year. Sometimes in the seventh it does not join but forms a cervical rib.

Lumbar vertebræ have additional epiphyses on the *mamillary processes.*

The **first lumbar vertebra** may have a separate primary centre for its *transverse process*, which may remain separate as a **lumbar rib.**

The **fifth** may have two primary centres in each half of the arch, and the two parts of each half are united by a plate of cartilage set obliquely between the superior and inferior articular processes; its transverse process may have two epiphyses.

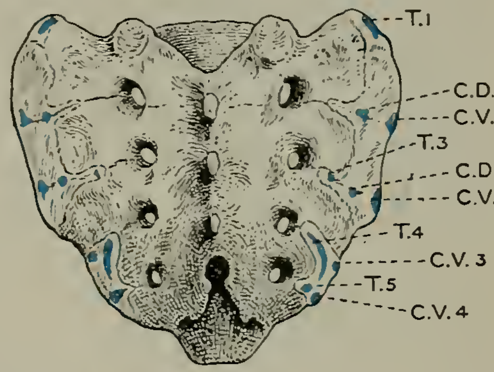


Fig. 124.—Diagram (after Fawcett) of the Arrangement of the Costal and Transverse Epiphyses at the Eighteenth Year.

T., Epiphysis of transverse process.
C.V., Ventral epiphysis of costal process.
C.D., Dorsal epiphysis.

The numbers indicate the segments to which the epiphyses belong.

Sacrum.—**Primary centres** appear between the third and eighth months. One centre for each body and one for each half of the vertebral arch, and one for the costal element on each side in the case of the upper three or four vertebræ. The costal parts fuse with the arches at the fifth year. The arches fuse with the bodies a little later. The halves of the arches unite posteriorly between the seventh and tenth years. The segments of the lateral mass fuse together at puberty. **Epiphyseal centres** appear on the upper and lower surfaces of the bodies at puberty; the epiphyses fuse with the bodies and the bodies fuse together from below upwards between 18 and 25. Numerous epiphyseal centres appear on the ends of the costal and true transverse processes at 18. From them are formed an epiphysis which covers the auricular surface, and another which completes the margin below the auricular surface.

The **coccyx** is cartilaginous at birth. Each segment has one **primary** centre. They appear, from above downwards, between the first year and puberty. Fusion between segments takes place from below upwards, but is very variable. Epiphyses on the surface of the bodies and in the cornua have been described.

VARIATIONS IN VERTEBRÆ.

Variation in number is usually due to the coccygeal vertebræ being reduced to three or increased to five or even six. Variations in other regions may occur through increase or reduction or re-arrangement among the regions, so that the formula may be altered in several ways, as follows:—

Cervical . .	7	7	7	6	7	7	7
Thoracic . .	13	12	12	13	13	12	12
Lumbar . .	5	6	4	5	4	6	4
Sacral . .	5	5	5	5	5	4	6
Coccygeal . .	4	4	4	4	4	4	4
	34	34	32	33	33	33	33

Atlas.—One or other of the arches may be incompletely ossified, or may have a facet for articulation with the margins of the foramen magnum. The foramen transversarium may be incomplete owing to absence of the anterior root of the transverse process. A bar of bone may bridge across the groove for the vertebral artery. The upper articular facet may be divided. The transverse process may be bifid; and it may articulate with an occasional projection, called the paroccipital process, that juts from the jugular process of the occipital bone. The atlas may be partially fused with the occipital bone, or with the second cervical vertebra.

Epistropheus.—The dens is sometimes a separate bone called the **os odontoideum.** Its apical part may be partially or completely detached. It may articulate with the anterior margin of the foramen magnum. A bifid or double dens has been described. The foramen transversarium may be incomplete, owing to imperfect development of the posterior root of the transverse process.

Small nodules representing ribs have been observed in one or two cases in the **fourth** and **sixth** cervical vertebræ.

The **seventh** has a cervical rib fairly often. The foramen transversarium may be absent on one side.

The **first thoracic vertebra** may have its transverse process connected with the neck of the first rib by a bar of bone ; the posterior part of its vertebral arch has been found separate from the rest of the bone. The facets on the body of the **ninth** are variable. The **tenth** may have no facets on its transverse processes. The inferior articular processes of the **eleventh** may resemble those of the twelfth, on one or both sides, and the superior processes of the **twelfth** correspondingly resemble those of a lumbar vertebra.

In some cases the mamillary and accessory processes of the **lumbar vertebræ** are large, and occasionally are connected by a bridge of bone, forming a small foramen. The transverse process of the **first** is sometimes separate, forming a lumbar rib. The transverse process of the **fourth** has been observed springing from the side of the body, without connexion with the arch. A foramen has been observed in the transverse process of the **fifth.** The posterior part of the vertebral arch of the fifth, comprising the spine, the laminæ, and inferior articular processes, is occasionally separate from the rest of the bone, union during life being effected by synchondroses ; the same condition has been seen in the fourth. The fifth may be fused with the sacrum partly or wholly, and may have pronounced sacral characters on one or both sides.

The **sacrum** may have six vertebræ, owing most often to inclusion of the first coccygeal, but occasionally to inclusion of the fifth lumbar. More seldom there are only four vertebræ ; sometimes the first sacral is not united, or is only partially united, to the second, and it may resemble a lumbar vertebra on the un-united side. The posterior wall of the **sacral canal** is usually defective at its lower end, but may be defective in its whole length. A foramen may be present in the lateral part of the first sacral vertebra, between the pedicle and the costal element. The degree of curvature varies greatly in different specimens.

The **coccyx** varies in its number of segments and the extent to which they are fused together. The second piece may have rudimentary transverse processes and pedicles.

SERIAL HOMOLOGIES OF VERTEBRÆ.

The **body** is the only part which is present in the case of every vertebra from the first cervical to the last coccygeal. The homology of the bodies is manifest throughout the series, except that the median part of the body of the first cervical is detached from its own vertebra and fused with the second, forming the dens or odontoid process. The lateral parts of the body of the atlas, *i.e.* the parts which in other vertebræ are ossified from the vertebral arch, form the anterior, larger parts of the lateral masses. The anterior arch of the atlas does not correspond to the front of the body of a vertebra, but is ossified from a persistent "hypochordal bow," which disappears in the case of other vertebræ (p. 123).

The **vertebral arches** are incomplete below the third and fourth sacral, and wholly absent from the third and fourth coccygeal segments. Their homology is equally obvious, but the **pedicle** of the atlas is obscured in the posterior part of the lateral mass ; the roots of the coccygeal cornua are pedicles, and there may be rudiments of pedicles on the back of the second piece of the coccyx. The **laminæ**, including the posterior arch of the atlas, are complete down to the third sacral ; those of the fourth sacral may or may not be complete ; those of the fifth are usually unossified ; and they are quite unrepresented in the coccyx.

The **spine** of the atlas is represented by the tubercle on the posterior arch. Spines are absent below the level of the third sacral vertebra.

The **articular processes** of the atlas and the superior articular processes of the second cervical vertebra are absent ; the articular surfaces of the lateral masses of the atlas and the upper articular surfaces of the second vertebra are not homologous with articular processes, but with the very small articular areas on the lateral parts of the bodies of the other cervical vertebræ. The superior articular processes of the first sacral vertebra function as ordinary articular processes ; the other sacral articular processes are fused together to form the row of articular tubercles on the back of the sacrum, except the inferior articular processes of the fifth piece, which jut downwards as the sacral cornua. The upper parts of the coccygeal cornua are homologous with superior articular processes ; they are absent from the other coccygeal segments.

The **transverse processes** are present in the whole series down to and including the first coccygeal vertebra ; but their homologies are less obvious. The transverse processes of the **thoracic** vertebræ are taken as the type and standard. In a **cervical** vertebra the true transverse process is represented by the posterior root and posterior tubercle of the transverse process ; the anterior root and tubercle are the homologue of a rib ; the costo-transverse lamella corresponds to the joint between a transverse process and a tubercle of a rib ; the foramen transversarium is homologous with the interval between a transverse process and the neck of a rib. In a **lumbar** vertebra the process called the transverse process is the homologue of a rib ; the true transverse process is represented by the mamillary process and the posterior part of the root of the transverse process including the accessory process. There is no interval left between the costal and true transverse elements as in the cervical and thoracic region, except in the rare instances where there is a foramen in the fifth lumbar transverse process. In the **sacrum** the lateral mass is made of the true transverse processes posteriorly, and the costal elements anteriorly, the ends of the true transverse processes forming the row of transverse tubercles on the back; each transverse tubercle represents part of the ends of two true transverse processes, for the end of each process expands, growing upwards and downwards, and unites with similar expansions of the process above and below to form the tubercles lateral to the posterior sacral foramina.

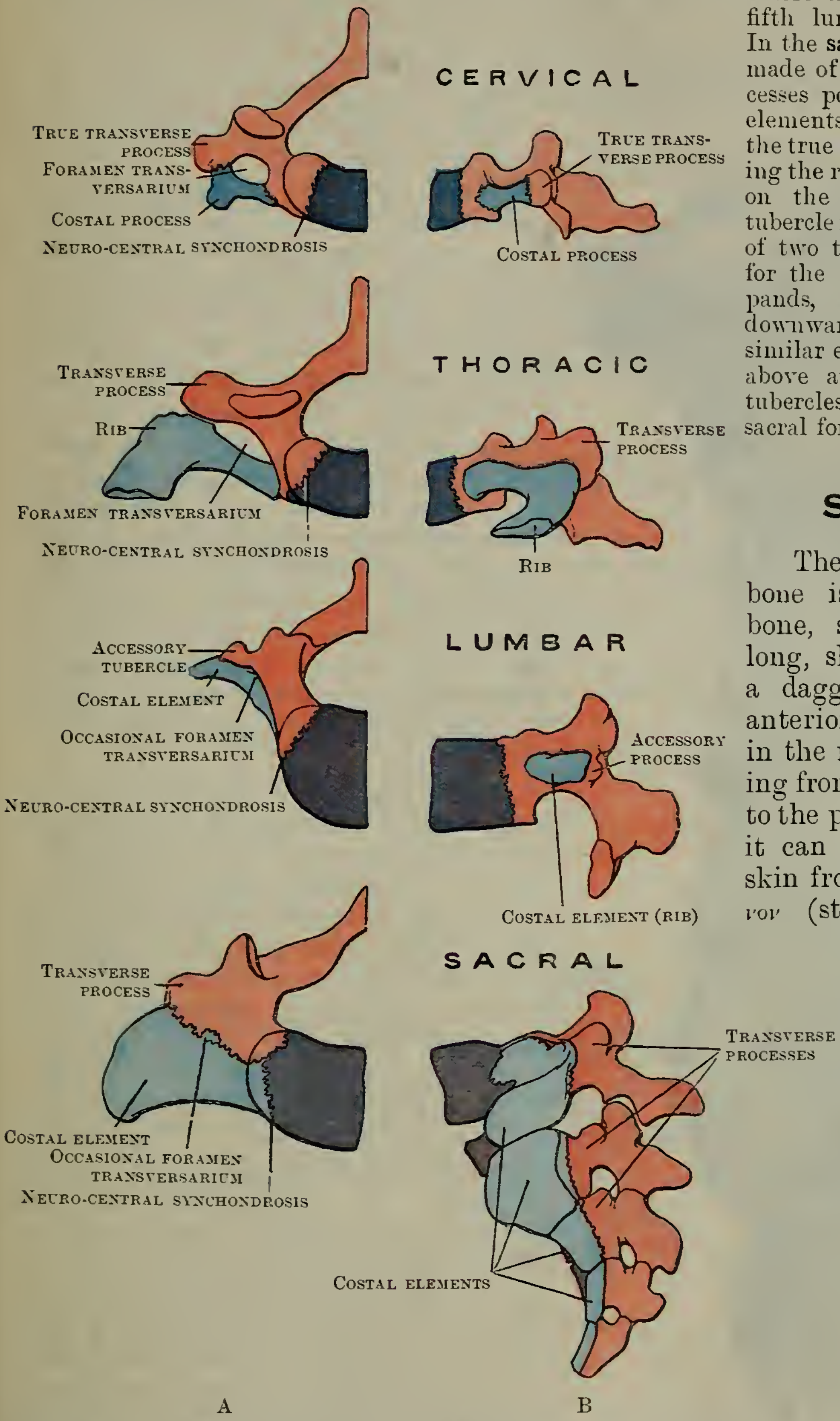


Fig. 125.—Diagram to illustrate the Homologous Parts of the Vertebræ. The bodies are coloured purple; the vertebral arch and its processes, red; the costal elements, blue. A, from above. B, from the side.

STERNUM.

The **sternum** or breast-bone is an elongated flat bone, six to eight inches long, shaped somewhat like a dagger. It lies in the anterior wall of the thorax in the median plane, extending from the root of the neck to the pit of the stomach, and it can be felt through the skin from end to end. [στέρνον (sternon) = the breast.] It has an upper and a lower end, an anterior and a posterior surface, a right and a left border; the two clavicles articulate with its upper end, and the cartilages of the upper seven pairs of ribs articulate with it at intervals along its borders. It is divided into three main parts, named, from above downwards, the *manubrium*, the *body*, and the *xiphoid process*; the body, in youth, is divided into four segments.

Manubrium Sterni.—The **manubrium** [= a handle] is the widest piece of the sternum, and, unless the skeleton is that of an old person, it is a separate bone; for the manubrium and the body are united by cartilage and do not fuse together till an advanced age. It is triangular in outline, each side measuring about two inches; and the apex is cut off, so that it has a short lower border. The *posterior surface* is slightly concave from side to side and is not so rough as the *anterior surface*. The *upper border* is the upper end of the sternum and is more than twice the width of the lower border. The middle part of the upper border is concave from side to side and can be felt in the root of the neck forming the floor of the **jugular** or *suprasternal* **notch** [*jugulum* (from jungere) = collar bone, and, later, the neck]; on each side of the jugular notch there is a larger notch or depression for articulation with the medial end of the clavicle or collar bone. On the *right* and *left margins*, just below the **clavicular notch**, there is a rough mark or a pit on which the cartilage of the first rib is implanted.

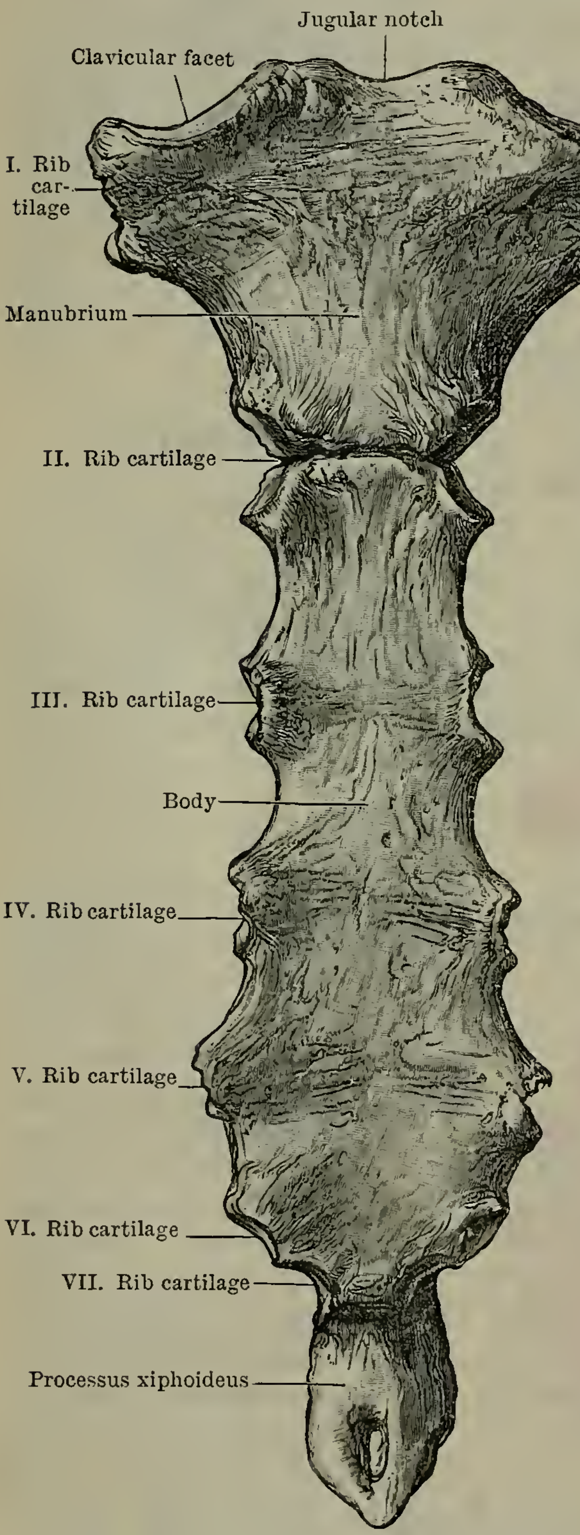


FIG. 126.—THE STERNUM (anterior view).

The lower border of the manubrium and the upper end of the body of the sternum, together, can be felt and often seen as a transverse ridge on the front of the chest, for the two bones are slightly thickened at their junction, and the manubrium is not quite in line with the body, but joins it at a very obtuse angle called the **sternal angle.** The ridge is about two inches below the jugular notch; it can be felt in stout people as well as in thin, and is the most serviceable of the landmarks on the front of the chest. The cartilage of the second rib joins the side of the sternum at the junction of manubrium and body, *i.e.*, at the sternal angle, and therefore the second rib is easily identified.

Corpus Sterni.—The **body** is the longest of the three parts of the sternum; it is about twice as long as the manubrium; it is about an inch wide at its *upper end,* increases slightly down to the fourth segment and then dwindles in breadth, so that the *lower end,* at its junction with the xiphoid process, is the narrowest part. The *posterior surface* is slightly concave from above downwards and usually is smoother than the *anterior surface.* Each *margin* bears four pits for articulation with costal cartilages. The upper three pairs of pits are at the ends of indistinct **transverse lines** that indicate the subdivision of the body into four segments; those three pairs of pits are therefore at the junction of segments; the fourth pair are on the sides of the fourth segment. In addition there are, on each side, an articular pit or notch between the body and the manubrium, and one between the body and the xiphoid process, the latter notch being on the front of their junction rather than at its side. The second rib cartilage articulates with the notch between manubrium and body; the third, fourth, fifth, and sixth with the pits or notches on the body; and the seventh with that between the body and the xiphoid process.

Processus Xiphoideus.—The **xiphoid process** or ensiform cartilage is the smallest piece of the sternum; it juts down into the anterior wall of the abdomen in front of the liver. It can be felt in the floor of the depression known as the *epigastric fossa* or "pit of the stomach." Its junction with the body—the *xiphi-*

sternal joint—can be felt as a short transverse ridge in the upper margin of that fossa; the ridge marks the lower limit of the thorax in the middle line in front, and is the landmark, in the middle line, for the diaphragm, the upper surface of the liver, and the lower border of the heart.

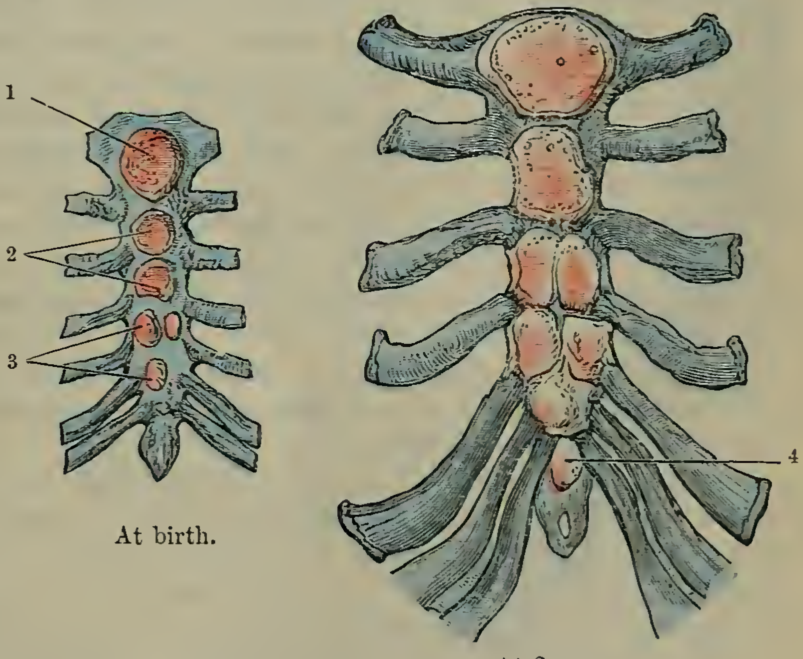
The xiphoid process is usually flat and pointed [ξίφος (xiphos) = *ensis* = a sword; εἶδος (eidos) = *forma* = shape], but it may be almost any shape; it may have a hole in the middle of it or it may be bifid. It is made of cartilage with a central core of bone; the osseous core enlarges with age at the expense of the cartilage, till the process is quite ossified; therefore it is more yielding in youth than in old age. At first it is united to the body by cartilage or fibrous tissue, but fuses with it after middle age.

The sternum slopes from above downwards and forwards, the manubrium slanting more than the body. The *upper* margin of the **manubrium** is on a level with the *lower* border of the **second** thoracic vertebra; the **sternal angle** with the *upper* border of the **fifth**; the **xiphisternal joint** with the *middle* of the **ninth** thoracic vertebra (Fig. 131).

The **manubrium** is thicker at its upper and lower parts than in the middle. Its thickest and strongest part is below and medial to the clavicular notch, where it receives shocks transmitted through the clavicle. The slightly raised area on the *anterior surface*, below the medial part of the clavicular notch, gives origin to the sternal head of the sterno-cleido-mastoid; part of the pectoralis major arises from the large concave area that accounts for most of each half of the front of the manubrium. On the *posterior surface* of the manubrium, part of the sterno-hyoid arises medial to the clavicular notch, and part of the sterno-thyreoid about half-way down. The capsule of the sterno-clavicular joint is attached to the margins of the **clavicular notch**; the articular disc of that joint to the junction of the manubrium and first costal cartilage; the inter-clavicular ligament, slightly, to the floor of the **jugular notch**.

The chief structures *behind the manubrium* are: (1) the edges of the pleuræ and lungs, (2) the remains of the thymus, (3) the left innominate vein, (4) the arch of the aorta and its three branches, and (5) the trachea, which ends opposite the sternal angle.

The **body** is thinner along its middle than at the margins. Its *anterior surface* gives origin to part of the pectoralis major; the lower part of its *posterior surface* to part of the transversus thoracis; the sterno-pericardial ligaments are attached to its upper and lower ends.



At birth.

At 3 years.

Fig. 127.—Ossification of the Sternum.

In this figure the second as well as the third segment of the body possesses two centres.

1. Appears about 5th or 6th month. 2. Appear about 7th month; unite from 20 to 25. 3. Appear about 8th or 9th month. 4. Appears about 3rd year or later.

The chief structures *behind the body* are the edges of the pleuræ and lungs, the pericardium and heart; and the ascending aorta and right pulmonary artery, behind the first segment.

The **xiphoid process** is thicker in the middle than at the sides. It is thinner than the body, but their posterior surfaces are flush—hence the depression called the epigastric fossa. It varies in length, so that its lower end, though palpable, is of no use as a landmark.

The linea alba is attached to its *lower end*. Fibres of the rectus abdominis and of the external and internal oblique aponeuroses are inserted into its *anterior surface*; of the internal oblique and transversus aponeuroses into its *margin*; part of the transversus thoracis and a slip of the diaphragm arise from its *posterior surface*.

The sterno-chondral ligaments are attached to the front and back of the sternum at the pits or notches for the rib cartilages, and the inter-articular ligaments, when present, to the floors of the notches.

Ossification. — The following table gives in a convenient form the approximate dates of the appearance of centres and of fusion of segments, but there is a certain amount of variation, and centres for adjoining segments may appear almost simultaneously :—

	Manubrium.	**Body, 1st Seg.**	**2nd Seg.**	**3rd Seg.**	**4th Seg.**	**Xiph. proc.**
Centres (one or two) appear	5th month of fœtal life	6th m.	7th m.	8th m.	9th m.	3rd year
Parts unite	Old age	21st yr.	Puberty	Child	Middle age	

The fourth segment does not always have a separate centre. Epiphyses have been found at the clavicular notches in an adult.

Structure and Variations.—The sternum is composed of highly vascular spongy bone enclosed in thin compact bone. Occasionally there is a hole in the lower part of the body, and more rarely the sternum is fissured longitudinally to a greater or lesser degree, the gap being wider above; the cleft is sometimes associated with *ectopia cordis*—a condition incompatible with life. Deformities, such as a bending back of the lower part of the sternum, arise from disease and in certain occupations. The two halves of the sternum are often asymmetrical, the clavicular notch being higher and the costal notches more crowded together on one side, with the junction of manubrium and body oblique; occupational use of the right upper limb may account for the asymmetry in some cases. Occasionally the manubrium includes the first segment of the body and carries three pairs of ribs, as in the gibbon; in such a case the *sternal angle* is opposite the third costal cartilage, and is felt about 3 inches below the jugular notch. The eighth costal cartilage in about ten per cent. of cases reaches the sternum, more often on the right side than the left; and in rare cases the seventh cartilage fails to reach the sternum. Small ossicles called *episternal bones* are sometimes found in the ligaments of the sterno-clavicular joint.

In women the manubrium is at a rather lower level and is narrower and longer than in men, but the body of the sternum is wider and shorter.

COSTAE OR RIBS.

There are twelve **ribs** on each side in both sexes. They are thin, narrow, curved strips of bone, and, though elongated, they are classed among the "flat" bones. They are attached posteriorly to the thoracic vertebræ and curve round the sides of the chest, slanting downwards and forwards; anteriorly each of them ends by joining a bar of cartilage called **a costal cartilage.** The ribs lie at the back, at the sides, and at the front of the thorax, and they provide protection for the sides and back of the upper part of the abdomen also. The upper seven ribs increase in length from above downwards and are called *true* ribs because their cartilages are attached to the side of the sternum. The lower five are called *false* ribs; they diminish in length from above downwards and their cartilages fail, by increasing distances, to reach the sternum; but the eighth, ninth, and tenth are each joined to the one above it, edge to edge, forming diarthrodial joints at their points of contact. The cartilages of the eleventh and twelfth, however, are free, and they are called *floating* ribs.

A rib has an anterior and a posterior end, an external and an internal surface, and a superior and an inferior border. The *posterior end* is called the **head,** and is articular; the *anterior end* is hollowed out to form a pit into which the costal cartilage fits. The *upper border* is smooth and rounded; the *lower* is thin and sharp. The *outer surface* is convex; the *inner* is concave lengthwise.

The ribs are not all curved equally. The first rib has the sharpest curve, and the curve of each succeeding one is wider or more open; therefore, if the specimens are all from the same skeleton, one can arrange them in proper order by laying them on a table in a row with their posterior ends in a straight line and observing the progressive change of curvature. It will be seen that, when laid in a row in proper order, they increase in length down to the seventh or eighth and then diminish to the twelfth; and also that they are twisted, for, if they are lying on their lower borders, the posterior part of the inner surface looks largely upwards, while the anterior part looks slightly downwards. Ribs are not only curved and twisted, they are slightly bent as well (Fig. 129). The bend is called the *angle* of a rib; it takes place from one to three inches from the head, the distance increasing as the series descends, and its position is marked by an oblique irregular ridge on the outer surface of the bone.

The **parts** of a rib are: head, neck, tubercle, body or shaft, and costal cartilage; and the body has an angle and a costal groove.

The first, second, tenth, eleventh, and twelfth have each some special characters of its own, but the third to the ninth belong to a common type.

A Typical Rib.—The **head** articulates with two thoracic vertebræ and therefore has two articular facets on it, an upper and a lower, which meet at a ridge. The two vertebræ with which a rib articulates are the one with which it is in numerical correspondence and the one above that, *e.g.*, the sixth rib articulates with the sixth thoracic vertebra and with the fifth. The **neck** immediately succeeds the head and is about one inch long. Its surfaces are usually called *anterior* and *posterior*, though they are continuous respectively with the inner and outer surfaces of the body of the rib. The **tubercle** is situated on the outer surface just where neck and body join; it articulates with the front of the tip of the transverse process of the vertebra with which the rib corresponds numerically. The **body** or shaft is all the rest of the bone. The ridge on the outer surface that marks the position of the **angle** is placed near the posterior end. In the case of the first rib the angle is at the junction of neck and body and the ridge coincides with the tubercle; in the second rib the ridge is quite close to the tubercle; as the ribs are followed down the ridge gets gradually farther away from the tubercle, down to the eighth or ninth; and below that the ridge becomes indistinct. The curve of a rib is not uniform, and it is sharpest at the angle; a curved bone is most likely to be broken where the curve is sharpest; therefore the rib is thickest there. The **costal groove** is the long, shallow groove on the inner surface of the body of the rib just above the lower border.

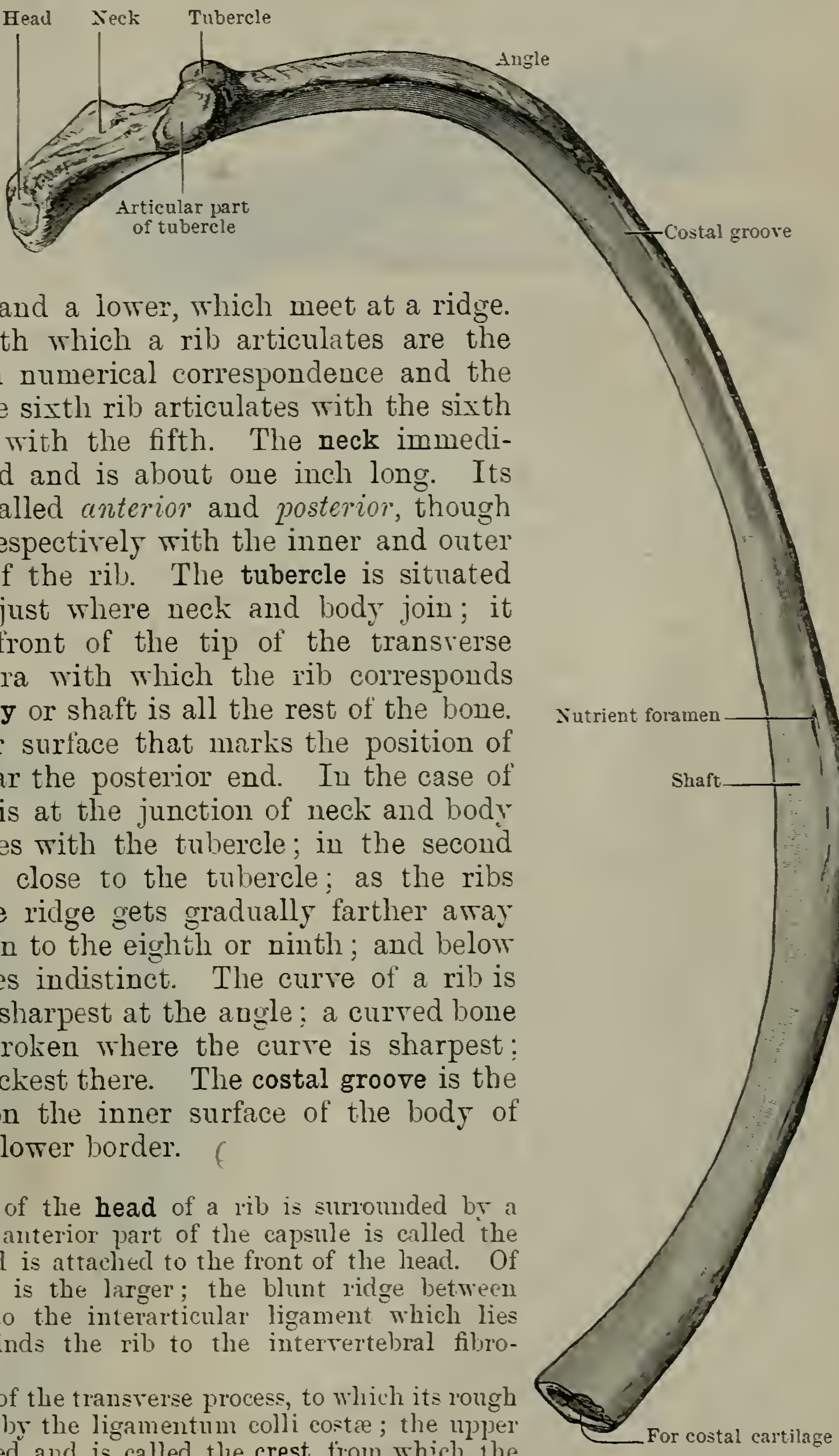


FIG. 128.—FIFTH RIGHT RIB AS SEEN FROM BELOW.

The articular surface of the **head** of a rib is surrounded by a joint capsule; the thick anterior part of the capsule is called the ligamentum radiatum and is attached to the front of the head. Of the two facets the lower is the larger; the blunt ridge between them gives attachment to the interarticular ligament which lies within the joint and binds the rib to the intervertebral fibro-cartilage.

The **neck** lies in front of the transverse process, to which its rough posterior surface is bound by the ligamentum colli costæ; the upper border is rough and raised and is called the **crest**, from which the anterior costo-transverse ligament stretches up to the transverse process next above; the anterior surface is smooth and is covered with pleura. The **tubercle** has a *facet* on its lower and medial part for articulation with the transverse process; an articular capsule surrounds the facet, and the ligament of the tubercle connects the rough part of the tubercle with the tip of the transverse process.

The *upper border* of the **body** gives insertion in all its length to an external intercostal muscle, and, internal to that, a posterior intercostal membrane is attached between the neck and the angle, while an internal intercostal muscle is inserted into the rest of the length of the border. The **costal-groove** is broad and well marked posteriorly, but indistinct in the anterior part of the rib; the intercostal vessels and nerve run along the groove. The groove has an upper and a lower lip, the lower lip being the sharp *lower border* of the bone; the external intercostal muscle arises from the whole length of its lower lip; the posterior intercostal membrane is attached to the floor of the groove between the tubercle and the angle; an internal intercostal muscle arises from the upper lip from the angle forwards. The rest of the *inner surface* of the rib is smooth and is covered with pleura.

Many muscles are attached to the *outer surface* of the ribs (p. 122). The ridge that marks the angle is for the attachment of the ilio-costalis—*i.e.* the lateral subdivision of the large composite mass of muscle, called sacrospinalis, that lies alongside the spines of the vertebræ. On the longer ribs there is often an accentuation of curvature, called the *anterior angle*, marked by an indistinct ridge on the outer surface two inches or more from the anterior end; the ridge is for the origin of slips of the serratus anterior and obliquus externus abdominis. In each of the upper ten ribs the anterior end is the widest part of the rib.

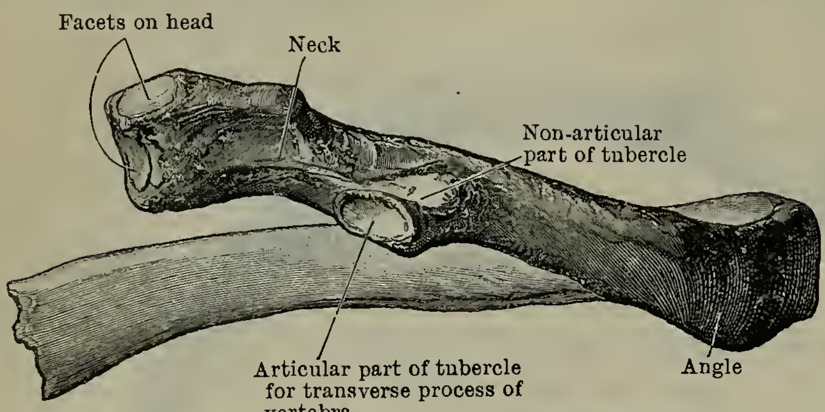

Facets on head
Neck
Non-articular part of tubercle
Articular part of tubercle for transverse process of vertebra
Angle

Fig. 129.—Fifth Right Rib as seen from behind.

The **first rib** is the shortest rib, except the twelfth; it is the most sharply curved, and it is broad in comparison with its length. It lies at the boundary between neck and thorax, largely under cover of the clavicle; its posterior end is above the level of the clavicle, and its anterior end is immediately below the clavicle (Fig. 131). Unlike the other ribs, its **surfaces** are *upper* and *lower*, its **borders** are *inner* and *outer*. The inner border is concave; the outer border is convex. The surfaces are not always easily distinguished at first glance, but if the rib is laid on the table and its head touches the table, then its lower surface is looking downwards; if it is turned upside down the head stands away from the table.

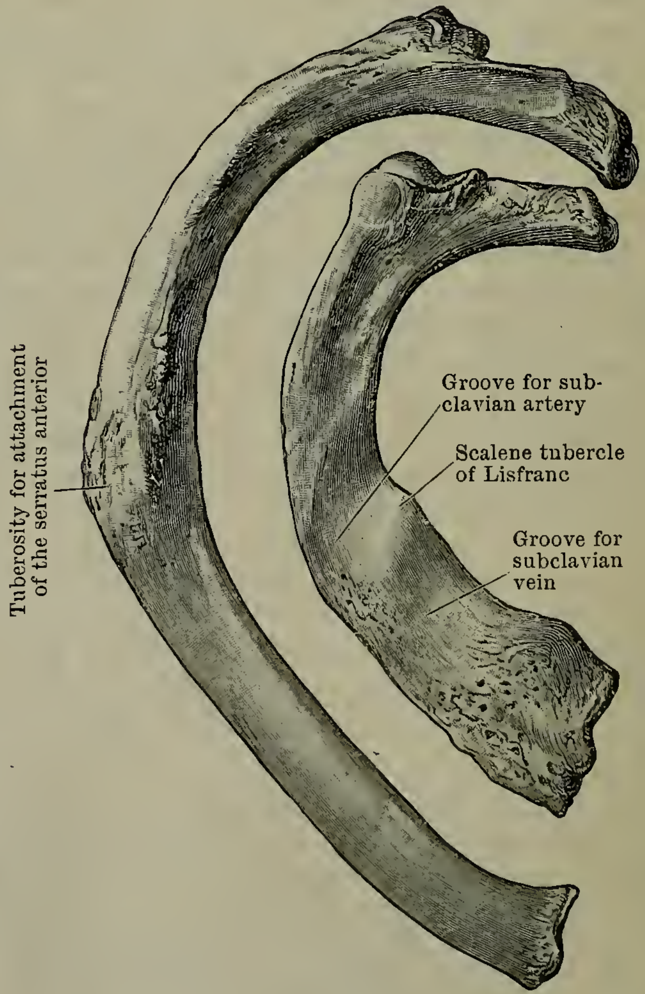

Tuberosity for attachment of the serratus anterior
Groove for subclavian artery
Scalene tubercle of Lisfranc
Groove for subclavian vein

Fig. 130.—First and Second Right Ribs as seen from above.

The **head** is small; it articulates with only one vertebra, namely, the first thoracic, and therefore it has only one facet. The **neck** is relatively long, and is compressed from above downwards; the top of the pleura and lung lie immediately in front of it. The **tubercle** is situated on the outer border and is relatively large.

The *lower surface* of the **body** is covered with pleura. The subclavian artery and vein lie across the *upper surface*, producing broad shallow grooves. The groove for the artery is about the middle of the body; the groove for the vein is nearer the anterior end. On the *inner border* there is a little tubercle continuous with a small rough area on the upper surface between the grooves for artery and vein; the tubercle is called the **scalene tubercle**, for the scalenus anterior muscle is inserted into it and into the rough area. The surface behind the groove for the artery—between that groove and the tubercle of the rib—gives insertion to the scalenus medius muscle, while the first digitation of the serratus anterior arises from it near the outer border immediately behind the groove for the artery. The greater part of the anterior ramus of the first thoracic nerve, on its way to join the brachial plexus, runs upwards and laterally in front of the neck and then lies in the posterior part of the groove for the artery, between the artery and the scalenus medius. On many specimens of the first rib the grooves and tubercle are faintly marked; while in others, there is a special groove for the lodgment of the first thoracic nerve, or the lowest trunk of the brachial plexus, immediately behind the groove for the artery. The subclavius muscle and the costo-clavicular ligament are attached to the upper surface of the rib at its junction with the cartilage.

The external and internal intercostal muscles of the first space arise from the *outer border*. A fibrous membrane, called Sibson's fascia, stretches fanwise from the transverse process of the seventh cervical vertebra to be attached to the *inner border*. (See also p. 122.)

The **second rib** is about twice as long as the first, and the sharpness of its curve distinguishes it from one of the lower ribs of similar length; it is not twisted; its surfaces are, in direction, intermediate between those of a first rib and those of a typical rib, and its costal groove is poorly marked. But the *special character* of the second rib is that on its outer surface, about its middle, there is a broad rough **tubercle** for the origin of part of the **serratus anterior** muscle. No other rib has a similar tubercle.

The **tenth, eleventh,** and **twelfth** ribs have each only one facet on the head, for each articulates with only one vertebra and that is the thoracic vertebra of corresponding number. The tenth, however, may be a typical rib. The eleventh differs from the tenth mainly in that its tubercle is small and has no articular facet, and the angle is ill defined; but the tubercle and angle of the tenth also may be ill defined, so that it is sometimes difficult to say whether a given rib is tenth or eleventh if the other ribs of the same skeleton are not at hand.

The **twelfth rib** is small and slender. It may be as short as, or shorter than, the first. *Tubercle, angle,* and *subcostal groove* are absent or are poorly marked. The **body** tapers off at the free end, while other ribs are nearly always slightly swollen at the anterior end.

Cartilagines Costales.

The **costal cartilages** are bars of hyaline cartilage which are fitted into the pits at the anterior ends of the ribs; the cartilage is held in place because its perichondrium is continuous with the periosteum of the rib. The cartilages of the **upper seven** ribs join the sternum and can be felt at the side of the sternum; they increase in length from above downwards, from one inch to four or five inches; the *first* cartilage is fitted on to a rough mark on the margin of the manubrium and is held in place by the continuity of its perichondrium with the periosteum of the sternum; the *other six* are joined to the sternum by diarthrodial joints; the first and second slope downwards slightly from the bony rib to the sternum; the third is horizontal; the fourth inclines upwards; the fifth, sixth, and seventh continue the direction of the rib for about an inch, and then turn upwards, with increasing degrees of obliquity, to reach the sternum. The cartilages of the **lower five** ribs diminish in length from above downwards; they can be felt in the costal margin between the thorax and abdomen. The eighth, ninth, and tenth continue in the direction of their ribs for about an inch and then turn upwards; they fail, by increasing distances, to reach the sternum, and each tapers off to a point; they are each united edge to edge with the one above, forming diarthrodial joints at the points of contact. The eleventh and twelfth are mere pointed cartilaginous tips on the ends of the ribs.

THORAX.

The **thorax** lodges the lungs and the heart and many other structures, and gives them protection; its skeleton provides attachment for many muscles besides those that belong to the thorax itself; but the chief use of the thorax in mammals is to act as a bellows by which air, for oxygenating the blood, can be drawn into the lungs contained within it. Its framework is a bony and cartilaginous cage, the bars of which are arranged so that they not only resist atmospheric pressure as the bellows is opened, but also, by their mobility, take share in the expanding movement.

The skeleton or cage is made of the thoracic vertebræ and intervertebral fibro-cartilages, the sternum, the ribs, and their cartilages. It is somewhat cone-shaped, being narrowest above. It is longer behind than in front, and is compressed from before backwards, so that it is wider from side to side, the greatest width being at the level of the eighth or ninth rib. The antero-posterior diameter of its interior is greatly diminished by the forward projection of the bodies of the vertebræ. It communicates with the front of the neck by a superior aperture or inlet, and with the abdomen by an inferior aperture or outlet.

The **superior aperture** is small, and is kidney-shaped in outline; it slopes from above downwards and forwards; it measures about 2 inches or 50 mm. from before backwards, and 100 mm. across. It is bounded by the first thoracic vertebra behind, the manubrium in front, and the first pair of ribs and their cartilages at the sides. It is occupied by the apices of the lungs and pleuræ, the windpipe, the gullet, and numerous vessels and nerves that pass between neck and thorax.

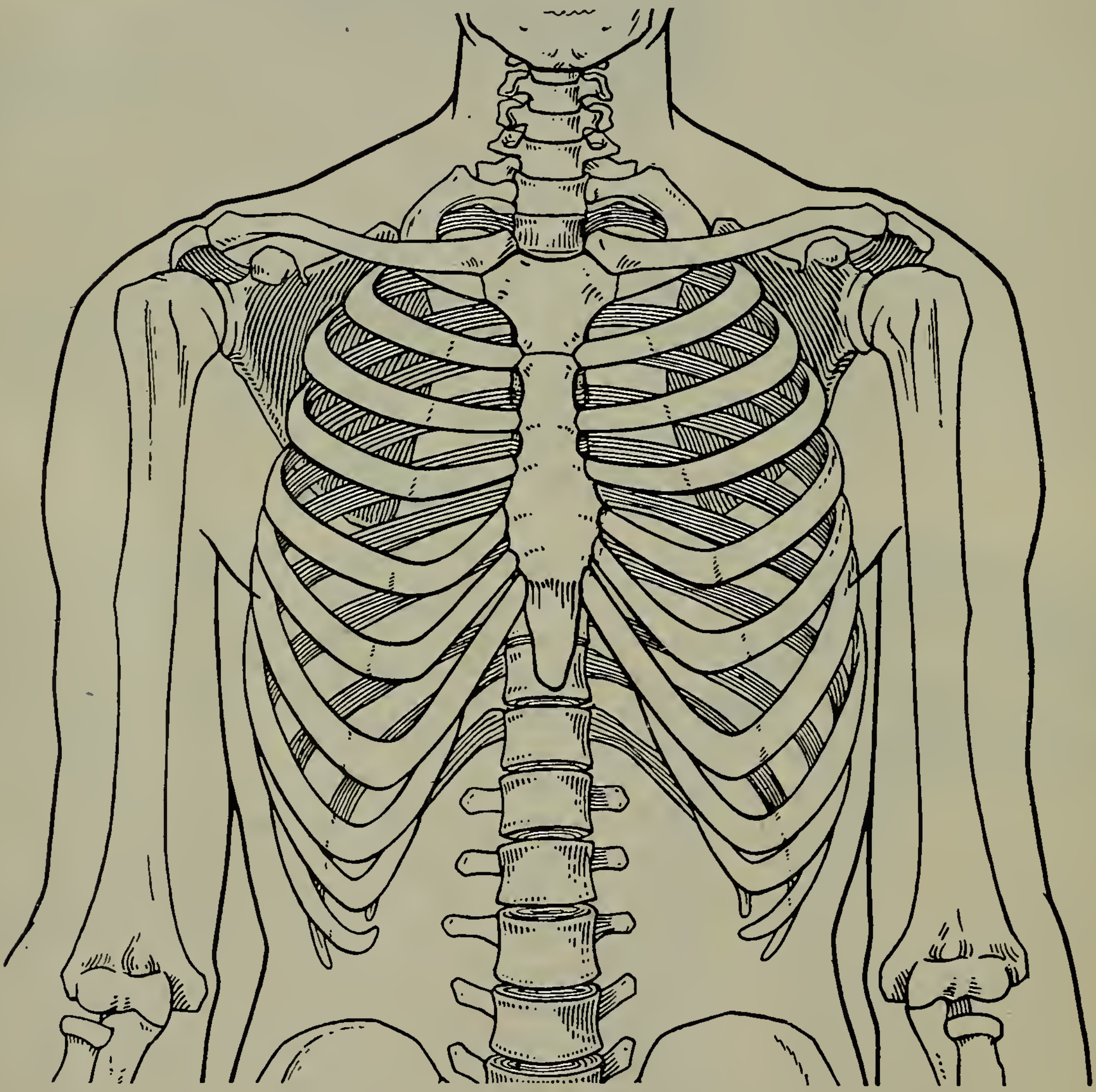


Fig. 131.—Front of Portion of Skeleton showing Thorax.
In the specimen from which the drawing was made the tenth costal cartilage did not join the ninth.

The **inferior aperture** is large and is uneven in outline. It is bounded by the xiphisternal joint, the lower six costal cartilages, and the body of the twelfth rib, and by the last thoracic vertebra. It is closed by the diaphragm, which separates the interior of the thorax from the interior of the abdomen and forms a highly vaulted and very movable floor for the thorax and roof for the abdomen. The *infrasternal angle* is situated at the anterior part of the inferior aperture; its sides are the seventh pair of costal cartilages; its apex is the xiphisternal joint; and the xiphoid process juts down into the angle.

The **posterior wall** of the thorax is made up of the thoracic vertebræ and fibro-cartilages and the posterior part of the ribs. The ribs have a backward sweep as far as their angles which makes their angles nearly flush with the tips of the spines of the vertebræ, so that Man, unlike most animals, can lie on his back with stability and ease. The forward projection of the vertebral bodies and the backward curve of the ribs create a large hollow, on each side, in the posterior part of the interior of the thorax for the lodgment of the thickest part of the lung.

The **sides** of the thorax are formed by the bodies of the ribs. The ribs are not all the same distance apart, nor are they parallel. The upper intercostal spaces are wider than the lower; and the ribs slope downwards and forwards with an obliquity which increases from the first down to the ninth or tenth, so that the intercostal spaces are wider in front than behind. The sides slope outwards, down to the level of the eighth or ninth rib, and may slope inwards slightly below that.

The **anterior wall** is formed by the manubrium and body of the sternum, the anterior ends of the upper ten pairs of ribs and their cartilages. It is shorter than the posterior wall or the sides, especially in the median plane, for the upper border of the manubrium is opposite the lower border of the second thoracic vertebra and the xiphisternal joint is opposite the ninth.

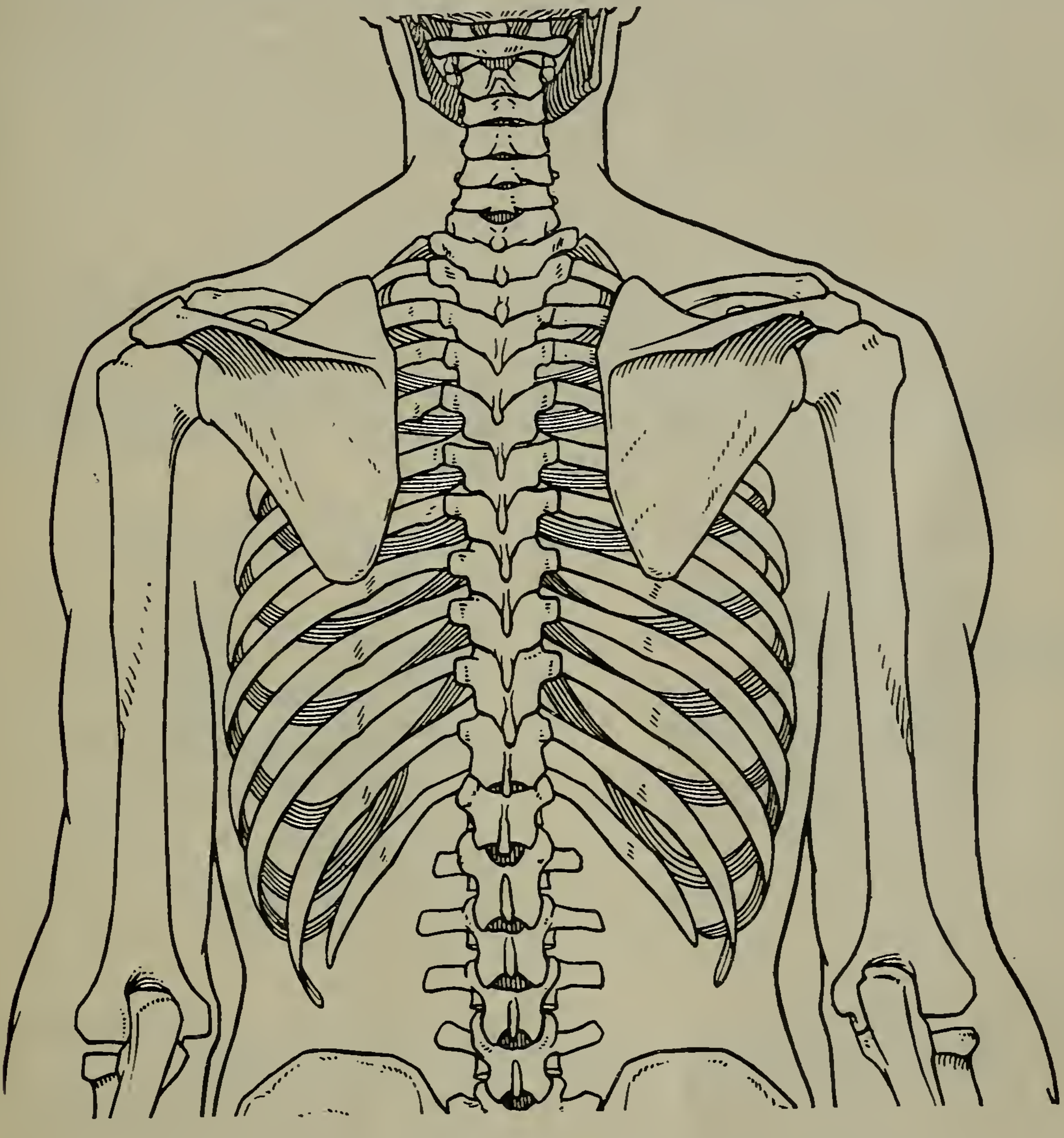


Fig. 132.—Back of Portion of Skeleton showing Thorax.

In the fœtus the thorax is compressed from side to side. At birth its form alters with the expansion of the lungs, but full expansion in a transverse direction does not take place till after the child begins to walk and to use its upper limbs more exclusively for prehensile purposes. *In a woman* the thorax is shorter and rounder than in a man, and the upper ribs are more movable.

Surface Relations.—The thorax is well covered externally with muscles belonging to the upper limb, the abdomen, the back, and the neck. There are only three parts that have no muscular covering. These are (1) a finger's-breadth down the middle of the sternum, (2) the middle line of the back, (3) a portion of the seventh rib, just medial to the lower part of shoulder blade, especially when the shoulder is drawn forwards.

The **first rib** provides the bony resistance felt in the neck above the middle of the clavicle; its cartilage is immediately below the sternal end of the clavicle.

The **second rib** is the most easily identified of all on the front of the chest, because its cartilage joins the sternum at the **sternal angle**, which is always easily felt; both angle and second cartilage are often easily seen as well as felt. When ribs have to be counted, or when a particular rib has to be located in the living person, the best method is to find the second and count downwards from it. There are rough and ready, though uncertain, guides to some of the other ribs and cartilages. The *nipple* is usually opposite the **fourth intercostal space** between the anterior ends of the bony parts of the fourth and fifth ribs. The cartilage felt on the costal margin next the sternum is nearly always the **seventh**, though occasionally the eighth cartilage reaches the sternum. The cartilage felt where the groove that marks the lateral margin of the rectus abdominis reaches the costal margin is usually the **ninth**. The **tenth** cartilage is the lowest one felt when the costal margin is examined from the front, and it is on a level with the body of the *third lumbar vertebra*. A line drawn from the medial end of the clavicle to the point a thumb's-breadth behind the lowest point of the tenth cartilage will pass through or near the junction of ribs and cartilages from the second to the tenth. If the *posterior axillary line* is followed downwards, the lowest rib it crosses is the **eleventh**. The **twelfth** rib may be felt, but sometimes it is so short that it is hidden by the sacrospinalis. **On the back** the point where the *spine of the scapula* meets the vertebral border overlies the **fourth** rib; and the *inferior angle* of the scapula overlies either the **seventh** intercostal space or the eighth rib.

Ligaments and Muscles attached to Ribs and their Cartilages.

Heads.

Articular capsules }
Ligamenta radiata } 1-12.
Interarticular ligaments, 2-9.

Necks.

Lig. colli costæ, 1-12.
Costo-transverse ligaments, 2-12.
Lumbo-costal ligament, 12.

Tubercles.

Articular capsules, 1-10.
Lig. tuberculi costæ, 1-11.

Bodies.

Costo-clavicular ligament }
Sibson's fascia } 1.
Posterior intercostal membranes }
Posterior layer of lumbo-dorsal fascia } 1-12.
Anterior and middle layers of lumbo-dorsal fascia }
Lateral lumbo-costal arch } 12.
Scalenus anterior }
Scalenus medius }
Sterno-thyroid } 1.
Subclavius }
Ilio-costalis cervicis, 1-6.
Serratus anterior, 1-8.
Ilio-costalis dorsi }
External intercostals }
Internal intercostals } 1-12.
Levatores costarum }

Bodies (contd.).

Scalenus posterior, 2.
Pectoralis minor }
Serratus posterior superior } 2-5.
Longissimus dorsi, 3-12.
Obliquus externus abdominis, 5-12.
Ilio-costalis lumborum, 7-12.
Latissimus dorsi }
Serratus posterior inferior } 9-12.
Obliquus internus abdominis, 10-12.
Quadratus lumborum, 12.
Subcostales, inconstant.

Costal Cartilages.

Articular disc of sterno-clavicular joint }
Costo-clavicular ligament } 1.
Costo-coracoid membrane }
Anterior intercostal membranes, 1-10.
Sterno-chondral capsules and ligaments, 2-7.
Interchondral capsules, 7-10.
Sterno-hyoid }
Sterno-thyreoid } 1.
Subclavius }
Pectoralis major, 1-6.
Internal intercostals, 1-12.
Transversus thoracis, 2-6.
Rectus abdominis, 5-7.
Diaphragm }
Obliquus internus abdominis } 7-12.
Transversus abdominis }
External intercostals, 10-12.

Ossification, Structure, and Variations of Ribs.

Ossification.—A rib is ossified from one primary centre and one or two or three secondary centres. The **primary centre** appears near the angle (first in the sixth rib) in the sixth week of fœtal life, and ossification spreads rapidly through the rib. **Secondary centres**

appear at *puberty* and the epiphyses fuse with the rest of the bone at 25. The **first rib** has *one* epiphysis for the **head** and *one* for the **tubercle.** The **second to the sixth,** inclusive, have *one* epiphysis for the **head,** *one* for the *articular* part of the **tubercle,** and *one* for the *non-articular* part. The **seventh to the tenth,** inclusive, have *one* for the **head** and *one* for the **tubercle.** The **eleventh and twelfth** have *one* for the **head.**

Structure and Variations.—Like other flat bones, the ribs are composed of highly vascular spongy substance enclosed in compact substance, which is thickest at the angles.

The most important variation is the presence of a **cervical rib,** which may unite with the sternum or with the first costal cartilage, or with the vertebral end of the first rib, making a bicipital rib. Part of the cervical rib may be fibrous tissue, and in some cases only the sternal end is present. In some cases increase of number is due to a lumbar rib. Diminution in number is rare, but sometimes the twelfth rib is absent, or the first rib is rudimentary and may fuse with the second, making a bicipital rib. Sometimes two ribs are partly fused together. Occasionally the posterior parts of two ribs are united by a projection jutting out from each and articulating with an intervening nodule of bone. The anterior end of a rib is sometimes very wide and may have a hole or a cleft in it. *Costal cartilages* also may be broad and perforated. The seventh cartilage sometimes throws out a projection which articulates with a similar projection from the sixth. The seventh sometimes fails to reach the sternum, but a commoner anomaly is that the eighth articulates with the sternum. In old age the cartilages may undergo partial ossification; this condition may be regarded as normal in the first costal cartilage in elderly people.

Development of Vertebræ, Ribs, and Sternum.

Vertebræ.—In the Chapter on EMBRYOLOGY it is explained that the *paraxial mesoderm* is divided by transverse clefts into a number of segments called *mesodermal somites,* and that the cells of the ventro-medial or *scleratogenous* parts of the somites proliferate and form a continuous mesodermal sheath around the notochord and neural tube [σκληρός (sclēros) = hard; γεννάω (gennaō) = produce]. The sheath is called the **membranous vertebral column**: in it the vertebræ are formed, and pass through a pro-cartilage stage and a cartilage stage before ossification. Each *pro-cartilage vertebra* consists of a body enclosed in a horseshoe-shaped vertebral bow. The **body** surrounds the notochord, and its position is such that it corresponds to the contiguous halves of two adjacent somites, its middle being opposite an *intersegmental septum, i.e.* the interval between two somites. The middle part of the **vertebral bow** is sometimes called the *hypochordal bow* [ὑπό (hypo) = below]; it is ventral to the headward part of the body to which it belongs; the two limbs of the bow slant backwards to enclose the neural tube on the tailward part of the body, and in time meet each other dorsal to the neural tube.

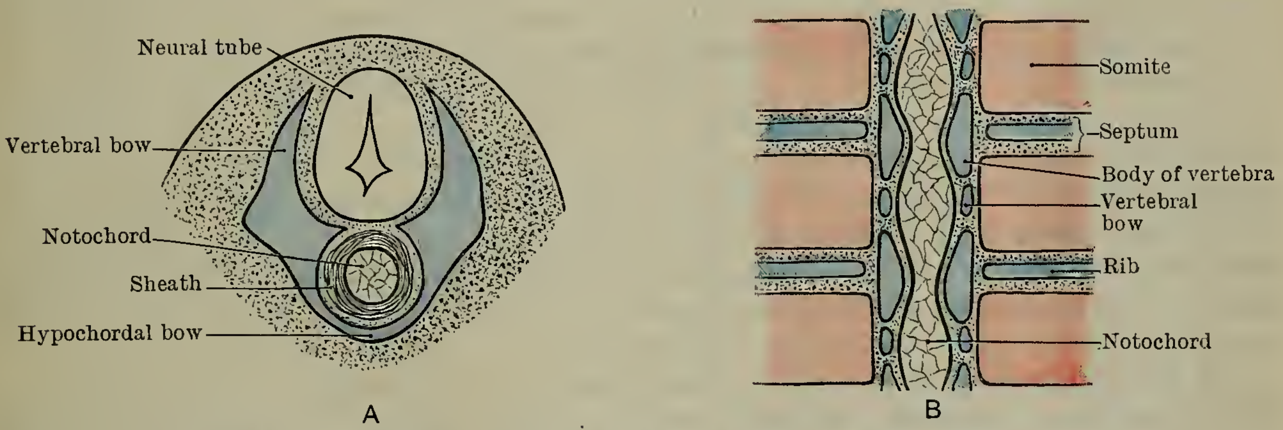


FIG. 133.—THE DEVELOPMENT OF THE MEMBRANOUS BASIS OF A VERTEBRA (after Keith).

A, in transverse section. B, in longitudinal section, showing the relation of the vertebræ to the primitive segments.

The scleratogenous tissue between two bodies, opposite the middle of a somite, begins about the fourth *week* of fœtal life to undergo fibrous and chondrifying changes, and becomes an *intervertebral fibro-cartilage.* About the fourth week also *chondrification* begins in the **body** and in the **limbs of the bow**; the body and the bow rapidly unite, and chondrification of the bow is completed dorsally during the fourth *month* of fœtal life. The body forms the median part of a body of a vertebra. The limbs of the bow form the postero-lateral part of a body and the vertebral arch and its processes; the transverse processes and the spine grow out from it into the intersegmental septum that lies on the tailward side of the two somites to which the vertebra corresponds. The scleratogenous tissue between the arches of two vertebræ becomes the ligamenta flava and the capsules uniting articular processes. *Ossification* begins at the seventh week of fœtal life in the arches and at the tenth week in the bodies.

The ventral or hypochordal part of the vertebral bow disappears, except in the case of the **atlas** vertebra, where it chondrifies and ossifies to form the anterior arch. The atlas therefore is a complete vertebral bow; its body becomes the dens of the second vertebra, and its lateral masses correspond to the parts of the body of a typical vertebra that are formed from the vertebral bow. The ligaments that connect the dens with the margins of the foramen magnum represent the fibro-cartilage between the atlas and the last occipital segment.

The rudimentary condition of a **coccygeal** vertebra is due to the failure of the limbs of the vertebral bow to develop. The incomplete condition of the laminæ of the last two **sacral** vertebræ is due to imperfect chondrification and ossification of vertebral bows. Imperfections in the formation of vertebral bows in regions farther up in the vertebral column give rise to the condition known as *spina bifida*.

The part of the *notochord* enclosed in the bodies of the vertebræ is first constricted, and finally disappears after ossification begins. The part enclosed in fibro-cartilages persists in them as their pulpy centres.

Ribs.—The ribs are developed in the intersegmental septa, and pass through pro-cartilage and cartilage stages before ossification. Each articulates at first with only one vertebra—not the vertebra opposite the septum in which the rib is developed, but the vertebra on the headward side of that. Later, the vertebral ends of the ribs, except the first, tenth, eleventh, and twelfth, are shifted headwards, so that each articulates not only with its own vertebra but also with the fibro-cartilage and the vertebra above.

Sternum.—The sternum is formed from mesodermal tissue in front of the pericardium; its origin is still under discussion (see Hanson, *Amer. Jour. Anat.* vol. xxvi. 1919–20, p. 41). The **manubrium** probably arises in association with the ventral part of the shoulder girdle, and the **body** and **xiphoid process** from two *sternal bars* which grow from the mesodermal rudiment of the manubrium and fuse together in the median plane. After chondrification the sternum becomes connected with the costal cartilages by diarthrodial joints.

THE SKULL.

The **skull** is the skeleton of the head and face. It is made of 22 bones, including the mandible, which is the skeleton of the lower part of the face, and is a movable bone. The other 21 bones are so firmly knit together that they are taken apart with difficulty; they are built together in such a way that they enclose one large cavity and three smaller ones. The large cavity is called the *cranial cavity,* and contains the brain and its membranes; the smaller cavities are the *cavity of the nose,* and the two *orbits,* which hold the eyeballs. There are lesser cavities contained within certain of the skull bones; those cavities are the *middle ear*, the *internal ear*, and the *air sinuses.* The skull bones consist of two plates or **tables** of compact substance enclosing between them a layer of spongy substance called, in the case of skull bones, **diploë**. In some of them the diploë is absorbed, leaving cavities or air sinuses between the tables of compact bone; the sinuses communicate with the cavity of the nose, and are lined with mucous membrane, continuous with that of the nose.

A specimen of skull for study is not complete without the mandible, but since the mandible is a movable, separate bone, the term "skull" very frequently means skull *minus* mandible, and is used largely in that sense in this text. The *hyoid bone,* which lies in the neck below the mandible, is described along with the skull bones, but is not part of the skull. The *auditory ossicles,* which lie in the middle ear, are described in the chapter on Organs of Sense.

Some of the 21 united bones of the skull are paired and some are unpaired. The paired bones are bracketed (2) in the following list of their names; the unpaired are bracketed (1).

Frontal (1)
Ethmoid (1)
Sphenoid (1)
Occipital (1)
Parietal (2)
Temporal (2)

Nasal (2)
Lacrimal (2)
Inferior nasal conchæ (2)
Vomer (1)
Maxillæ (2)
Zygomatic (2)

Palatine (2)

The first six in the list, eight bones in all, are those which share in the formation of the walls of the cranial cavity.

In a young person, those 21 bones, though firmly bound together, are separable; the joints by which they are held together are either *sutures,* in which the articulating parts are connected by a ribbon of fibrous tissue, or *synchondroses,* in which they are connected by hyaline cartilage. With advancing years the joints disappear and neighbouring bones fuse together gradually.

There is some confusion in regard to the meaning of *skull*, *cranium*, and *calvaria*, and the classification of the bones of the skull.

In ordinary English the word "Skull" denotes the skeleton of the head without the lower jaw bone, and in medical text-books the word "Cranium" is employed usually as a synonym for "skull" in that sense, though κρανίον (kranion) originally meant only the part of the head covered with hair; further, in medical text-books, "*calvaria*" (from *calvus* = bald) usually means the top part of the skull or skull-cap, though it is defined in Andrewe's Latin dictionary as the *brain pan*, *skull*, of man and beasts. But in catalogues of craniological collections the following meanings are attached to the terms: *Skull* = entire skeleton of head and face, including mandible; *Cranium* = skull without mandible; *Calvaria* = skull after bones of face have been removed or destroyed.

An old classification of the bones is: (1) Cranial bones = those that form the adult brain case; (2) Facial bones = all the others. In the Basle nomenclature the *ossa faciei* comprise maxilla, palatine, zygomatic, mandible and the hyoid bone; *ossa cranii* comprise all the others; and there is a subdivision also into *cranium cerebrale* and *cranium viscerale*. Quain's *Anatomy* 11th edition, suggests more than one classification. No classification has satisfied every one, and it is questionable if any classification of skull bones is either necessary or desirable.

It is much more important that the student should acquire a knowledge of the skull as a whole than of the separate bones. The detailed description of the separate bones is put at the end of the section for reference, and the skull as a whole is dealt with earlier. But so many of the parts of the skull are named from the particular bones to which they belong, that it is necessary to give a few brief, preliminary notes on the individual bones; and the student, with a skull before him, and with the aid of the figures of the skull in the text, should identify each of the bones and note the aspects of the skull in which they are visible, before commencing to read the description of the skull as a whole. It is convenient, however, to locate at the outset the following parts, for they will be referred to as landmarks.

(1) The **orbits** are the pair of large pyramidal cavities in the front of the skull (Fig. 134). They are so named because the eyes rotate in them. [*Orbita* = a wheel rut, a circuit.]

(2) The **apertura piriformis** is the large egg-shaped hole between and below the two orbits; through it one can see into the cavities of the nose. [*Pirum* = a pear; *forma* = shape.]

(3) The **external acoustic meatus** or ear-hole (Fig. 135) is the small, round, or oval hole or passage seen in the lower part of the side of the skull about midway between the front and the back. The proper position of the skull is not that which it occupies when it is set on a table. When the skull is held in its **proper position**, the lower margin of the orbit and the upper margin of the orifice of the meatus are at the same horizontal level. [Ἀκούω (akouō) = hear; *meatus* = a passage.]

(4) The **zygomatic arch** is the bridge of bone on the side of the skull that spans the interval between the lower part of the orbit and the front of the meatus [ζύγωμα (zygōma) = a bar, from ζυγόν = anything that connects two bodies.]

(5) The **foramen magnum** is the large, round hole on the lower surface of the skull a little behind its centre (Fig. 137).

(6) The **choanæ** are a pair of large openings about two inches in front of the foramen magnum; they are oval and oblique, and are set closely side by side; through them one can see into the cavities of the nose from behind [χοάνη (choanē) = a funnel].

(7) The **hard palate** is the platform of bone forming the median part of the front of the lower surface of the skull; its posterior edge is the *lower* margin of the two choanæ (when the skull is held right way up).

(8) If the interior of the skull is examined (Fig. 138), it will be noted that the lower part of the cranial cavity has a very uneven floor, and is divisible into three main regions which are at different levels. Those regions are called the **anterior**, **middle**, and **posterior cranial fossæ**; each of them has a median part and a right and a left lateral part.

Bones of the Skull.

The **frontal bone** (Figs. 134, 135, pp. 157, 158) is the large shell of bone in the anterior part of the skull; it forms the forehead and the anterior part of the top of the skull; and a pair of wide, thin shelves, called *orbital plates*, project backwards from its lower part and form the greater part of the roof of each orbit, and of the floor of each lateral part of the anterior cranial fossa. In each half of the frontal bone there is a cavity, called the *frontal sinus,* situated just above the rim of the orbit and the root of the nose. [*Frons* = the brow.]

The **parietal bone** (Figs. 135, 160, pp. 137, 192) is the large, convex, four-square bone that lies behind the frontal bone; it forms a large part of the side of the skull, and a large part of the top, meeting its fellow of the opposite side at the middle line. [*Paries* = a wall.]

The **occipital bone** (Figs. 137, 138, 162, pp. 143, 156, 194) is the large bone which lies at the back of the skull behind the two parietal bones. It is shaped like a leaf, and it is bent so that it lies in the base of the skull as well as at the back. The foramen magnum is in the occipital bone. The thick bar of bone in front of the foramen magnum is called the **basilar part** of the occipital bone or **basi-occiput.** The region at each side of the foramen magnum is called the **lateral part** of the occipital bone, or **condylar part,** because the two eminences with smooth articular surfaces at the sides of the foramen are called the occipital **condyles.** [*Occiput* (*ob, caput*) = the back of the head up to the crown, while *sinciput* (*semi, caput*) = the front part of the head from the crown to the forehead.]

The **temporal bone** (Figs. 135, 137, 138, 165, pp. 137, 143, 156, 197) lies partly in the side of the skull below the parietal bone, and partly in the base of the skull in front of the condylar part of the occipital bone. The external acoustic meatus is in the temporal bone on the side of the head. The large piece of bone, shaped like a scale, that lies above the meatus is the *squamous part* of the temporal bone or **squamous temporal** [*squama* = a scale]; the *zygomatic process* of the temporal bone or **zygoma** is a projection from the squamous temporal, and it forms the posterior half or so of the zygomatic arch. The region of bone behind the meatus is the *mastoid part* of the temporal bone or **mastoid temporal,** and its lower part is a large, rounded projection, called the **mastoid process,** which is easily felt behind the ear in the living head. The mastoid process is named from its resemblance to a teat [μαστός (mastos) = the breast] and gives its name to the mastoid temporal.

The uneven plate of bone that forms the front and lower wall of the meatus, and part of the back wall, is the *tympanic part* of the temporal bone or **tympanic plate.** The long, slender process (often broken off in specimens of skull) which projects downwards and forwards from behind the lower edge of the plate is called the **styloid process** [στῦλος (stylos) = a pillar, a stake, a pen].

The remaining part of the temporal bone is called the *petrous part* or **petrous temporal,** and gets its name from its hardness [πέτρος (petros) = a stone]. It is an uneven wedge of bone situated in the base of the skull on the medial side of the tympanic plate and in front of the condylar part of the occipital bone. It is seen much better in the inside of the skull; it is the conspicuous elevation in the floor, on either side, about midway between the front and the back of the cavity of the skull, between the middle and posterior cranial fossæ.

The temporal bone contains the *middle ear,* the *internal ear,* a small cavity called the *tympanic antrum,* and a varying number of small spaces called *mastoid air cells.*

The **sphenoid bone** (Figs. 135, 137, 138, 146, 169, pp. 137, 143, 156, 170, 203) is more difficult to identify. It is wedged in among other bones of the skull [σφήν (sphēn) = a wedge]; parts of it can be seen in the floor of the cranial cavity, on the lower surface of the base of the skull, in the side of the skull, and in the upper and lateral walls of both orbits. The sphenoid bone has a body, a pair of small wings, a pair of large wings, and a pair of pterygoid processes.

The **body** is the middle part of the bone; it lies in front of the basilar part of the occipital bone, with which it is fused after the 25th year. On the lower surface of the skull it is to a large extent hidden; in the floor of the cranial cavity it forms an uneven, median elevation that extends from a point about an inch in front of the foramen magnum to a point about an inch behind the anterior boundary of the floor. The body is hollow; it is composed of a thin shell of bone enclosing a large air space, called the **sphenoidal sinus,** divided by a thin bony septum into a right and a left half.

The **small wings** form the posterior part of the roof of the orbit, but are seen best in the floor of the cranial cavity; they resemble the wings of a bird very closely, and extend out from the anterior part of the upper surface of the body.

The **great wings** are behind the small wings and are at a lower level. They are large plates that spread out from the sides of the body in the base of the skull, and their antero-lateral parts turn up into the side of the skull. One surface of a great wing is seen in the floor and side wall of the middle cranial fossa; another surface is seen in the orbit forming the greater part of its lateral wall; a third surface is seen on the side of the skull in front of the squamous temporal; and, continuous with that surface, a fourth surface is seen on the lower aspect of the skull, lateral to the root of the pterygoid process.

The **pterygoid processes** resemble wings only remotely [πτέρυξ (pteryx) = a wing]. Each of them is a large process that projects downwards from the junction of body and great wing and is seen on the lower surface of the skull forming the lateral boundary of a choana. Each pterygoid process consists of two plates or laminæ, a lateral and a medial. It is the *medial lamina* which forms the side of the choana, like the jamb of a door; and it is separated from the *lateral lamina* by a hollow or fossa of some size called the *pterygoid fossa.*

The **ethmoid bone** (Figs. 138, 145, 146, 148, 172, pp. 156, 168, 170, 175, 206) lies in front of the body of the sphenoid and below the frontal bone, and is to a large extent hidden. It is set between the two orbits, so that the distance between the eyes depends upon the breadth of the ethmoid. It consists of a median perpendicular lamina, a pair of cribriform laminæ, and a pair of labyrinths.

The **perpendicular lamina** is a thin median plate of bone that forms part of the median partition or septum of the interior of the nose. If it has not been broken away, one can see it by looking into the nasal cavity through the apertura piriformis. The upper edge of the plate projects into the cranial cavity, forming a conspicuous crest, called the **crista galli** (cock's comb), in the median part of the anterior cranial fossa.

The **cribriform laminæ** are narrow horizontal plates placed one on each side of the crista galli. They lie in the floor of the anterior cranial fossa and, at the same time, in the roof of the cavity of the nose. They are full of little holes through which the olfactory nerves pass up from the nose to reach the brain [ἠθμός (ēthmos) = a colander; *cribrum* = a sieve].

The two **labyrinths** constitute the main part of the ethmoid bone. Each labyrinth is placed high up in the side wall of the cavity of the nose; the upper, narrow part of the nasal cavity separates it from the perpendicular lamina in the septum. The labyrinth is composed of very thin papery bone enclosing a number of irregular, small cavities which communicate with each other—hence the name "labyrinth." The cavities are called the **ethmoidal cells** or **sinuses.** From the medial or nasal side of the labyrinth, two thin plates of bone project into the nasal cavity and then curl downwards; they are called the **superior** and **middle nasal conchæ** [κόγχη (conchē) = a mussel-shell]. The lateral surface of the labyrinth is a smooth square plate of bone that forms a great part of the medial wall of the orbit, where it is easily seen; its anterior end is about half an inch behind the rim of the orbit, and it measures over an inch from before backwards and over half an inch in height.

The two **nasal bones** (Figs. 134, 181, pp. 131, 210) lie side by side in the bridge of the nose.

The **lacrimal bone** (Figs. 134, 135, 178, pp. 131, 137, 209) is a thin uneven scale of bone about the size of a finger-nail. It lies in the medial wall of the orbit near the orbital rim, immediately in front of the lateral surface of the ethmoid labyrinth. It is named "lacrimal" because its anterior part helps to form the groove in which the lacrimal sac lies. It is so thin that it is often broken away in a skull that has had much handling.

The **inferior nasal concha** (Figs. 145, 148, 177, pp. 156, 175, 208) is a thin, rough plate of bone attached by one of its edges to the lower part of the side wall of the nasal cavity; it projects into the cavity and its free edge curls downwards.

The **vomer** [= a ploughshare] is a thin bone which forms the posterior and postero-inferior part of the nasal septum (Figs. 137, 145, 179, pp. 156, 168, 209).

It lies behind and below the perpendicular lamina of the ethmoid. It is easily recognised in a skull turned upside down, for it is the partition between the two choanæ. At its upper end or border it splits into a right and a left half, called the **alæ** of the vomer, which spread out for a little distance on the lower surface of the body of the sphenoid bone [*ala* = a wing.]

The two **maxillæ** form the upper jaw. Each maxilla has a main part or body and four processes—alveolar process, frontal process, palatine process, and zygomatic process (Figs. 134, 135, 137, 146, 182, pp. 131, 137, 143, 170, 211).

The **body** of the maxilla lies below the orbit, and lateral to the lower part of the nasal cavity. Its superior or *orbital surface* forms a large part of the floor of the orbit; its medial or *nasal* surface forms the lower part of the side wall of the cavity of the nose; its anterior or *facial surface* is the bone alongside the lower part of the apertura piriformis; its *posterior surface* is the rounded surface of bone that looks backwards into the space below the great wing of the sphenoid. Those surfaces are like the walls of a box, for the body of the maxilla encloses a large cavity, called the **maxillary sinus**, which occupies its whole interior.

The **frontal process** of the maxilla is the projection which extends upwards to reach the frontal bone. It lies behind the nasal bone, taking share in the formation of the bony part of the external nose; it has a large share also in forming the medial part of the rim of the orbit.

The **zygomatic process** is the thick spur of bone that stands out from the junction of facial and posterior surfaces of the body, and is united to the zygomatic arch.

The **alveolar process** is the thick curved ridge which projects downwards from the body and carries the teeth. Its lower border is called the *alveolar margin*, and if the teeth have fallen out after the skull was dried, it presents a row of pits or *alveoli* for the roots of the teeth [*maxilla*, a diminutive of *mala*, which = the bone of the cheek that carries the teeth]. When teeth are removed during life the walls of the corresponding alveoli are soon absorbed and the alveolar process is greatly reduced in size at those points; in the skull of a person who had long lost all the teeth the alveolar process is a mere inconspicuous rim. The alveolar processes of the two maxillæ make a horseshoe-shaped ridge which bounds the hard palate in front and at the sides. The posterior part of the alveolar process is called the *tuberosity of the maxilla.*

The **palatine process** is the horizontal shelf of bone which forms the anterior, larger part of the half of the hard palate of its own side.

The **zygomatic bone** (Figs. 134, 135, 187, pp. 131, 137, 216) makes the hard prominent part of the cheek; it forms the anterior part of the zygomatic arch and has a considerable share in forming the lower and lateral parts of the rim of the orbit. The part of the zygomatic bone which projects backwards to articulate with the zygoma of the temporal bone is called its **temporal process**; the part that projects upwards along the side of the orbit to articulate with the frontal bone is called its **frontal process**, or *fronto-sphenoidal process*, because it articulates with the great wing of the sphenoid bone also.

The **palatine bone** lies in the posterior part of the hard palate and in the side wall of the nasal cavity. It is a small bone, and consists of three parts: a horizontal part, a perpendicular part, and a pyramidal process. The horizontal part is easily located; the other two parts are not (Figs. 137, 146, 185, pp. 143, 170, 214).

The **horizontal part** is the thin, square plate of bone that forms the posterior quarter or third of the corresponding half of the hard palate.

The **perpendicular part** is a still thinner plate of bone; it lies on the side wall of the cavity of the nose, directly in front of the medial lamina of the pterygoid process, and in many skulls one can see the suture between its posterior edge and the medial lamina by looking into the nose through the choana. The anterior and larger part of the lateral surface is closely applied to the medial surface of the maxilla, but the posterior part is further back than the maxilla and forms the medial wall of a space called the pterygo-palatine fossa that will be examined later. Its upper end is surmounted by two processes, an *orbital process* in front and a *sphenoidal process* behind; the gap between the two processes is called the **spheno-palatine notch.**

The **pyramidal process** is irregular and is often so closely united to the bones among which it lies that it is difficult to see its outlines. It projects from the posterior border of the palatine bone just where the horizontal and perpendicular parts join one another, and it fits in (1) between the tuberosity of the maxilla and the lower part of the pterygoid process of the sphenoid, and (2) between the lower parts of the two laminæ of the pterygoid process.

The **mandible** (Figs. 134, 135, 149, 150), or lower jawbone, has a horseshoe-shaped **body** and two flat, broad **rami** which project upwards from the posterior parts of the two halves of the body. The body bears the teeth [*mandĕre* = to chew]. Two processes project upwards from the upper border of each ramus; the anterior one is named the **coronoid process**; the posterior is named the **condyloid process**, which is divided into a *head* and a *neck*. The head articulates with the temporal bone, forming a diarthrodial joint called the *mandibular joint*. In the living person, the projection that overlaps the ear-hole from in front is called the *tragus*. The head of the mandible can be felt immediately in front of the tragus when the mouth is shut; as the mouth is opened the head can be felt gliding downwards and forwards. The **angle** of the mandible is the point where the posterior border of the ramus joins the lower border; it is easily felt two or three finger-breadths below the lobule of the ear. The oblique opening on the medial side of the ramus is called the **mandibular foramen**; the narrow groove that extends downwards and forwards from the lower margin of the foramen is called the **mylo-hyoid groove**; the oblique ridge on the medial side of the body is called the **mylo-hyoid line.**

The mandible is a separate bone, and is not dealt with under the skull as a whole. It is an important bone, and is described on p. 177.

THE SKULL AS A WHOLE.

The **exterior of the skull** is examined from five points of view: from the front, the back, above, below, and from the side. Each of those aspects is called a "norma" [=a square]; and they are named, respectively, norma frontalis, occipitalis, verticalis, basalis, and lateralis. There are no boundary lines between the aspects, for they overlap each other to a large extent.

Norma Verticalis.

The **top of the skull** has convex contours, so that any impact received at a particular point is distributed over a considerable area, and the danger of fracture is thereby lessened. The horizontal outline varies considerably in different specimens, but in most European skulls the outline is ovoid, the wider part being nearer the back than the front.

The top of the skull is made of portions of four bones—the **frontal** bone in front, the **occipital** bone behind, and the right and left **parietal** bones in the middle between them, the occipital bone having only a very small share. The bones are united by serrated *sutures*, the jagged, saw-like edges of the bones interlocking with each other [*sutura* = a seam]. If the skull is that of a young adult the sutures are seen distinctly as irregular lines between the bones. If the skull is that of an old person the sutures are more or less obliterated and the bones are fused, but the positions of the sutures are usually indicated by narrow, irregular linear depressions. In many skulls there are small circumscribed pieces of bone, like islands, interposed in the sutures in certain places; those islands are called **sutural bones.**

The suture that unites the frontal bone to the two parietal bones arches across the skull from side to side, and is called the **coronal suture** [*corona* = a curved line, circle, crown]. The suture that unites the occipital bone to the two parietal bones is called the **lambdoidal suture**, because it is shaped like the Greek capital letter

Lambda [Λ = L]. The suture between the two parietal bones is called the **sagittal suture**; that name is given because in an infant's skull the sagittal suture, the lambdoidal suture, and an unossified region, called the frontal fonticulus or antero-median fontanelle, together, resemble a heraldic arrow [*sagitta* = an arrow].

The point where the sagittal suture meets the coronal suture is called the **bregma** [*βρέγμα* = the front part of the head]. At birth the parts of the frontal and parietal bones around the bregma are not fully ossified, and leave a large, lozenge-shaped membranous area which is yielding to the touch and is called the *antero-median fontanelle*, because it rises and falls with every beat of the heart; in a healthy child the bones have ossified and closed the fontanelle by the end of the second year. The coronal suture slopes downwards and forwards from the top of the skull, so that the bregma is the furthest back point on the suture, and it lies just in front of the mid point of a line drawn from one external acoustic meatus to the other in the vertical transverse plane, and is occasionally felt as a depression in the living head.

The point at which the sagittal suture meets the lambdoid suture is called the **lambda**.

The **vertex** or highest point of a skull held in proper position is on the sagittal suture near its middle, but varies slightly in different skulls. The **parietal foramen** is a small hole present in many skulls in the parietal bone near the sagittal suture about 35 mm. from the lambda. It is usually only big enough to admit a pin; a small artery and vein pass through it; the vein connects the veins of the scalp with the superior sagittal venous sinus which lies along the middle line on the inside of the skull cap, and infection can travel along the vein from a wound in the scalp and attack the sinus.

The *sagittal fontanelle* is an unossified space in the region of the parietal foramina; it is usually closed at birth. If it is not closed at birth, the parietal foramen in the adult skull will probably be larger than usual, *i.e.*, large enough to admit a match. The point on the sagittal suture between the two parietal foramina is called the **obelion** [*ὀβελός* (obelos) = ÷, a mark used by literary commentators].

The **parietal eminence** or **tuberosity** is the most convex point of the parietal bone and is the region where the top of the skull and the side and the back merge into each other; its position varies with the shape of the skull, but none the less it is used as a landmark, for it is fairly easily identified in the living head. It overlies the part of the brain called the supramarginal gyrus.

The frontal eminences anteriorly and the temporal lines at the sides are visible, but will be dealt with later. In some specimens the zygomatic arches can be seen when the skull is looked at from above.

Norma Frontalis.

The **front of the skull** (Fig. 134) is uneven in contour and outline, and its two halves are seldom quite symmetrical, though nearly so. Almost more than any other aspect of the skull it varies with age, race, and sex, besides displaying individual variations in the details of its configuration.

The front of the skull is made up of: the frontal region or forehead; the two orbits; the bony external nose, between and in front of the orbits; the apertura piriformis; the two maxillæ, forming the upper jaw; the zygomatic bone or cheek bone, below the lateral part of the orbit; and the mandible, when it is in place.

Frontal Region.—The forehead is formed by the frontal bone, and is convex. Superiorly it merges into the top of the skull; inferiorly it is limited by the orbits and the root of the nose. The **nasion** is the point in the median plane at the root of the nose where the two nasal bones articulate with the frontal bone; it is opposite the anterior extremity of the brain. The **glabella** is the small region immediately above the nasion, between the two eyebrows [*glabellus* = without hair]. The **superciliary arch** is the smooth elevation that arches upwards and in a lateral direction from the glabella, a little above the margin of the orbit. Behind it, in the interior of the frontal bone, there is usually a large air-space called the **frontal sinus** (Figs. 145, 148, pp. 168, 175), from which a short channel

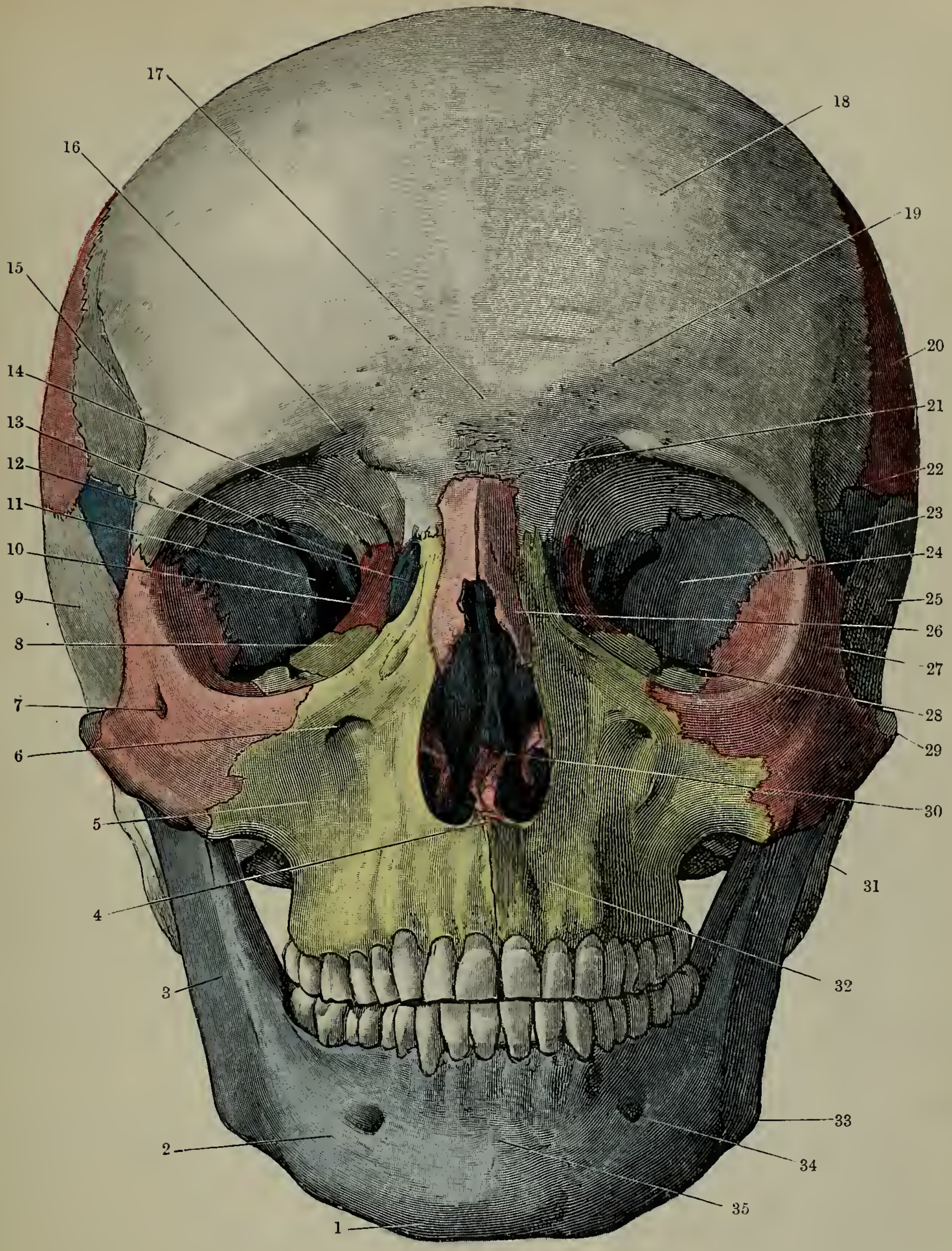


FIG. 134.—THE FRONT OF THE SKULL.

The nasal bones, lateral surface of the ethmoid, vomer, inferior conchæ, zygomatic, and parietal bones are coloured red. The sphenoid, lacrimal, perpendicular part of the ethmoid and middle conchæ and mandible are coloured blue. The maxillæ are coloured yellow. The frontal and temporal bones are left uncoloured.

1. Mental tubercle.
2. Body of mandible.
3. Ramus of mandible.
4. Anterior nasal spine.
5. Canine fossa.
6. Infra-orbital foramen.
7. Zygomatico-facial foramen.
8. Orbital surface of maxilla.
9. Temporal fossa.
10. Lateral surface of ethmoid.
11. Superior orbital fissure.
12. Lacrimal bone and groove.
13. Optic foramen.
14. Ethmoidal foramina.
15. Temporal line.
16. Supra-orbital notch.
17. Glabella.
18. Frontal tuberosity.
19. Superciliary arch.
20. Parietal bone.
21. Naso-frontal suture.
22. Pterion.
23. Great wing of sphenoid.
24. Orbital surface of great wing of sphenoid.
25. Squamous part of temporal.
26. Left nasal bone.
27. Zygomatic bone.
28. Inferior orbital fissure.
29. Zygomatic arch.
30. Apertura piriformis, displaying nasal septum and inferior and middle conchæ.
31. Mastoid process.
32. Incisive fossa.
33. Angle of mandible.
34. Mental foramen.
35. Symphysis menti.

leads down into the cavity of the nose. The **frontal eminence** or **tuberosity** is the most convex part of each half of the frontal bone; it is situated about two finger-breadths above the lateral end of the superciliary arch.

The **supra-orbital margin** or upper margin of the orbital opening is a curved border. At the highest point of the curve, about two finger-breadths from the median plane, there is usually a small notch called the **supra-orbital notch**; the notch can be felt in the living head by the thumb nail pressed on the margin *from below.* Laterally, the supra-orbital margin ends in a prominent projection which is named the **zygomatic process** of the frontal bone because it curves downwards and articulates with the upstanding frontal process of the zygomatic bone. The zygomatic process (external angular process) is easily felt at the lateral end of the eyebrow hairs and is one of the most serviceable landmarks in the head. The ridge that curves upwards and backwards from it is the anterior part of the **temporal line**, and can be both felt and seen in thin people between the brow and the temple.

The two halves of the **frontal bone** are separable at birth and are not fused together completely till some period between the sixth and the tenth year. The suture between the halves is called the *frontal suture.* Remains of the suture can often be seen in the adult skull at and above the glabella, and in some cases, especially in the more civilised races, the whole suture persists till late in life; it is sometimes called the *metopic suture* [μετόπη (metopē) = the interstice between two beam ends (in Doric architecture)]. The point in the middle of the forehead, on the shortest diameter between the two temporal lines, is usually a little above the glabella and is called the **ophryon** [ὀφρύς (ophrys) = the brow].

The **superciliary arch** is more prominent in men than in boys and women; the lower part of the forehead therefore protrudes more in a man, and the forehead is less vertical. Though the arch overlies the frontal sinus it is not produced by the sinus, for in a skull in which the sinus is small or absent the arch may be prominent. The upper part of the orbicularis oculi (corrugator supercilii) arises from the medial end of the arch. The **frontal eminence** is the region where the views of the skull from the front, from above, and from the side overlap; it is more conspicuous in the more vertical foreheads of boys and women than in men; it overlies the part of the brain called the middle frontal gyrus.

The **supra-orbital margin** is the lower limit of the forehead. Its lateral two-thirds is thin and sharp and bends down to the zygomatic process. The medial third is rounded; it bends down into the medial margin of the orbit, and its end is sometimes called the *medial angular process.* The **supra-orbital notch** is situated at the junction of the medial third and lateral two-thirds of the margin; the supra-orbital vessels and nerves lie in it as they pass out of the orbit and turn upwards on to the forehead to reach the scalp. In the floor of the notch there is a minute foramen through which the frontal diploic vein passes to join the supra-orbital vein. In some skulls there are two shallow notches instead of one; in others the notch is converted into a **supra-orbital foramen** by a bridge of bone.

Nasus Externus.—The bony part of the **external nose** is formed by the two *nasal bones* in the bridge of the nose, and, on each side, by the *frontal process of the maxilla,* which lies behind the nasal bone in the side of the nose, and forms also the medial margin of the orbital opening.

Apertura Piriformis.—The **apertura piriformis** is bounded above by the lower margins of the two nasal bones, and at the sides and below by the sharp anterior margins of the frontal processes and bodies of the two maxillæ. It is the anterior opening into the **cavity of the nose**, and one can look through it into the cavity and out through the choanæ at the far end. The cavity is divided by a thin median partition or **septum** into a right and a left half. Each half is called a cavity of the nose or nasal cavity, and the term may mean, according to the context, either the whole cavity or one of the halves. Most of the anterior part of the septum is composed of a plate of cartilage; the septum is therefore always incomplete in a macerated and dried skull, and considerable parts of the bony septum may have been broken away. If the bony septum has not been broken the principal part seen through the apertura piriformis is the *perpendicular lamina of the ethmoid* bone, which forms the upper part of the septum; it is usually slightly bent to one or other side.

The side wall of the nasal cavity is very uneven, because the three rough curled plates of bone called the *conchæ* project from the side wall and hang down into the cavity like curtains. The portions of the cavity which lie below the conchæ and lateral to them are called the *meatuses* of the nose—superior, middle, and inferior. The superior concha is too far back to be seen through the apertura piriformis, but the inferior and middle conchæ and meatuses can be seen if the conchæ have not been broken away. The middle concha is on a level with the medial wall of the orbit, and is rather less liable to be broken off. The inferior concha is situated about half an inch above the floor of the nose, and even should it be broken away the ridge on the side wall of the cavity to which it was attached can be seen.

Maxillary Region.—A sharp spur of bone, called the **anterior nasal spine**, projects forwards from the two maxillæ at the lower margin of the apertura piriformis in the middle line; it is imbedded in the lower part of the septum of the nose immediately above the upper lip. In a much-handled skull it is usually broken off.

If the walls of the alveoli for the teeth have not been absorbed, smooth vertical ridges, produced by the roots or fangs of the teeth, are seen above the alveolar margin. The largest of those ridges corresponds to the root of the canine tooth and is called the **canine eminence**. (The *canine* tooth is the third tooth, counting from the middle in front; and the first two teeth are called *incisors*.) The **canine fossa** is the wide shallow depression above and lateral to the canine eminence, reaching up almost to the lower margin of the orbit. The *infra-orbital foramen* is the opening just above the canine fossa, about 5 mm. below the lower margin of the orbit; in the living person it is about a finger's-breadth lateral to the side of the nose, and may be felt indistinctly if pressure is made there with the finger-tip. It transmits the infra-orbital vessels and nerve.

Between the medial ends of the two supra-orbital margins there is a horseshoe-shaped suture uniting the frontal bone to the upper ends of the two nasal bones and frontal processes of the maxillæ. The middle of the suture is the **nasion**, from which a suture runs down the middle of the bridge of the nose between the two nasal bones; the most prominent point on the suture is called the **rhinion** [ῥίς (rhis) = the nose]. On each side of the bony external nose there is a linear suture between the nasal bone and the frontal process of the maxilla. On the nasal bone, at a varying point, there is often a minute foramen through which a vein passes from the skin to the interior of the nose and thence upwards to join the commencement of the superior sagittal sinus in the cranial cavity; infection can pass along the vein and attack the sinus. Some fibres of the procerus are attached to the nasal bone. The angular head of the quadratus labii superioris arises from the upper part of the frontal process of the maxilla; the nasalis arises from the bone near the lower boundary of the apertura piriformis.

The pliable, lower part of the external nose has a framework of cartilage united to the sharp margins of the apertura piriformis by fibrous tissue. The **apertura piriformis** is oblique, and is ovoid in outline with the narrow end above and in front. It measures about 30-35 mm. in height, and about 25 mm. across its widest part; it is shorter, wider, and more vertical in flat-nosed races. Parts of the septum and side walls of the **nasal cavity** can be seen through it, and also the floor and part of the roof when the skull is tilted.

If the bony **septum** is complete, its anterior edge forms an angle into which the septal cartilage fits. The upper limb of the angle is the perpendicular lamina of the ethmoid. The lower limb is formed *anteriorly* by the *incisor crest* of the maxillæ, a rough ridge which stands up from the junction of the palatine processes of the two maxillæ and is continuous with the anterior nasal spine; and *posteriorly* by the lower and anterior part of the vomer. On the **side wall** note again the inferior and middle conchæ. The inferior concha reaches the apertura piriformis. The middle concha is shorter than the inferior and does not reach so far forwards; the interval between it and the septum is very narrow, and also the part of the middle meatus that lies lateral to it is very narrow because a part of the labyrinth of the ethmoid, called the *bulla ethmoidalis*, bulges into the meatus; the lower part of the middle meatus is roomier, and in its side wall the opening of the maxillary sinus can be seen. Identify the floor of the fossa for the lacrimal sac in the orbit and locate it in the side wall of the nasal cavity, just in front of the middle meatus. The part of the **roof** visible is only the anterior, sloping part, which is formed by the nasal bone and the nasal part of the frontal bone and its frontal spine—a projection that juts down into the roof of the nose and is hidden from the exterior by the nasal bone. The whole **floor** can be seen. While the upper part of the nasal cavity is very narrow and the roof a mere groove, the floor is half an inch in width; it is made of the palatine process of the maxilla and the horizontal part of the palatine bone, which, at the same time, constitute the hard palate and are better seen on the lower surface of the skull.

The **anterior nasal spine** consists of a spicule from each maxilla; its apex is called the **akanthion** [ἄκανθα (akantha) = a thorn]. Running downwards from it there is the *intermaxillary suture*, the lower end of which, in the front of the alveolar margin, is called the **prosthion** [πρόσθιος = foremost]. On each side of the suture, immediately below the apertura piriformis, there is a shallow depression called the **incisive fossa**. The **canine fossa** lies below the infra-orbital foramen on the anterior wall of the maxillary sinus; the caninus muscle arises from its floor. The infra-orbital head of the quadratus labii superioris arises from the infra-orbital margin above the infra-orbital foramen; the incisive slips of the orbicularis oris arise from the incisive fossa and the canine eminence.

Lateral to the canine fossa, the suture between the maxilla and the zygomatic bone can be seen. It begins at the middle of the lower margin of the orbit and ends at the lower border of the zygomatic arch in line with the lateral margin of the orbit. The **zygomatico-facial foramen** is a small hole on the zygomatic bone about 5 mm. below the lateral part of the lower margin of the orbit; it is only big enough to admit a pin; it transmits the zygomatico-facial branch of the zygomatic nerve and a small branch of the lacrimal artery; sometimes it is represented by two openings instead of one. Below the foramen there is a smooth low eminence, called the *malar tuberosity*, which gives origin to the zygomaticus; the eminence is conspicuous in some thin people.

Orbita (Figs. 134, 147, pp. 131, 172).—The **orbit** is a cavity of a shape not unlike a four-sided pyramid laid on one side. The sides are called the *roof*, the *floor*, the *medial wall* and the *lateral wall*. The *base* of the pyramid is the opening on to the face, and the boundaries of the base are the **margins of the orbit**. At the *apex* there is a large aperture; it is the medial and lower part of a cleft called the **superior orbital fissure** (Fig. 148, p. 175); the rest of the fissure extends forwards, upwards, and in a lateral direction *between the roof and the lateral wall* of the orbit, becoming narrower as it does so. The fissure leads back into the middle cranial fossa, and its size varies in different skulls.

Between the roof and the medial wall there are three foramina, the optic and two ethmoidal. The **optic foramen** is the round aperture just above and medial to the apex of the orbit; it leads back into the middle cranial fossa. The **anterior** and **posterior ethmoidal foramina** are further forward; they are about half an inch apart and the anterior is the larger. They lead into canals that open into the median part of the anterior cranial fossa, but their openings there are difficult to find.

The **fossa for the lacrimal gland** [*lacrima* = a tear] is a broad, smooth depression of varying depth, in the anterior and lateral part of the roof of the orbit, under shelter of the zygomatic process of the frontal bone. The **fossa for the lacrimal sac** (Fig. 135, p. 137) is on the medial wall just within the orbital margin. If the lacrimal bone is broken away, only part of the fossa will be seen, for it is a fairly broad vertical groove partly on the lacrimal bone and partly on the frontal process of the maxilla. The fossa becomes continuous with the **naso-lacrimal canal**, the upper opening of which is seen at the *junction of the medial wall and floor* of the orbit; the canal is a short tunnel that leads down into the inferior meatus of the nose under cover of the anterior part of the inferior concha—a fact which one can demonstrate by pushing a match down through the canal from the orbit. The lacrimal sac is a wide tube, blind at its upper end, and its lower end is continuous with the naso-lacrimal duct which goes down through the canal into the nose. The lacrimal gland produces the lacrimal fluid, most of which evaporates, while the remainder passes into the sac and thence into the nose, any excess of fluid overflowing the eyelids as tears. The gland is at the upper, lateral part of the orbit, and the sac is at the lower, medial part; that arrangement ensures that the front of the eye shall be well washed.

Between the floor and the lateral wall of the orbit there is a long cleft, called the **inferior orbital fissure**, which opens into a space behind the maxilla called the infra-temporal fossa. The **infra-orbital groove** is in the floor of the orbit. It begins about the middle of the inferior orbital fissure and runs nearly straight forwards. The anterior part of it has a thin roof of bone and is called the **infra-orbital canal**, and the canal opens on the face as the infra-orbital foramen. In one or both orbits the groove may be roofed over in all its length; in that case one can locate it by passing a pointer back through the infra-orbital foramen.

The chief **relations** (Figs. 147, 148, pp. 172, 175) of the orbit are the following: *Superiorly*—The frontal sinus to a varying extent; the anterior cranial fossa, containing the frontal lobe of the brain. *Inferiorly*—The maxillary sinus in the body of the maxilla; the anterior part of the infra-temporal fossa. *Medially*—Near the apex, the sphenoidal air sinus in the body of the sphenoid; further forward, the ethmoidal air sinuses, which separate the orbit from the cavity of the nose; within the orbital margin, the thin floor of the fossa for the lacrimal sac intervenes between the orbit and the nasal cavity, and an operator can reach the lacrimal sac by passing from the nose through the thin floor of the fossa, if he wants to avoid a scar at the medial corner of the eye. *Laterally*—The posterior part of the orbit is related to the middle cranial fossa, which lodges the temporal lobe of the brain; the anterior part is related to the anterior part of the temporal fossa (p. 138)

The two **orbits** are placed so that their medial walls are almost parallel, while their lateral walls are nearly at right angles to each other; therefore the axis of each orbit is directed forwards and in a lateral direction; none the less, the axes of the two eyeballs are antero-posterior and parallel. Each orbit is about 50 mm. long.

The **orbital opening** or base of the orbit is more or less four-square, measuring about 40 mm. each way; it is directed forwards and slightly in a lateral direction, and it is tilted so that the upper and lower margins slope slightly downwards from medial to lateral side. The *lower margin* of the opening is formed by the maxilla and the zygomatic bone. *The lateral margin* is formed by the frontal process of the zygomatic bone and the zygomatic process of the frontal bone; the suture between the processes, near the upper angle of the opening, can usually be felt in the living person; just within the middle of the margin, about 10 mm. below the suture, there is a slight eminence felt by the finger tip rather than seen, for the attachment of the lateral palpebral raphe and the check and suspensory ligaments of the eye. The *upper margin* is the supra-orbital margin of the frontal bone, and has the supra-orbital notch or foramen at the junction of the rounded medial third and sharp lateral two-thirds; the supra-trochlear nerve and the frontal vessels, passing out of the orbit on to the forehead, cross the margin about 5 mm. medial to the supra-orbital notch and may produce a shallow groove. The *medial* margin is formed by the medial angular process of the frontal bone and the frontal process of the maxilla; the medial palpebral ligament and orbicularis oculi are attached to the margin just in front of the groove for the lacrimal sac.

The orbit being pyramidal, its walls are more or less triangular in outline. The *roof* is concave; it is formed by the orbital plate of the frontal bone, complemented posteriorly by the small wing of the sphenoid. The frontal sinus extends for a variable distance backwards *in* the roof of the orbit between the two tables of the orbital plate. At the lateral angle of the roof there is the wide **fossa for the lacrimal gland**, part of which protrudes beyond the fossa into the upper eyelid. At the medial angle the trochlea is attached; the attachment may be marked by a very small pit or by a spicule of bone, the **fovea vel spina trochlearis**, or by both; the trochlea is a small fibro-cartilaginous ring through which the tendon of the superior oblique muscle of the eyeball passes.

The *lateral wall*, in the greater part of its extent, is formed by the great wing of the sphenoid, but the anterior part is formed by the fronto-sphenoidal process of the zygomatic bone. On the anterior part there is a small aperture called the **zygomatic foramen**, through which the zygomatic nerve leaves the orbit, accompanied by a small branch of the lacrimal artery; sometimes there are two apertures instead of one. A great part of the lateral wall is separated posteriorly from the roof by the **superior orbital fissure**, which is bounded medially by the body of the sphenoid, above by the small wing, below and laterally by the great wing. The two heads of the lateral rectus muscle of the eyeball lie across the wide, lower and medial part of the fissure. Some of the structures transmitted by the fissure pass between the two heads; the others pass above both heads. They are:—

(*a*) *Between the Heads.*—The ophthalmic vein or veins, passing backwards to join the cavernous sinus [ὀφθαλμός (ophthalmos) = *oculus* = the eye]; the abducent nerve, the naso-ciliary nerve, and the two divisions of the oculomotor nerve, all passing forwards.

(*b*) *Above the Heads.*—The trochlear nerve, the frontal nerve, and the lacrimal nerve, all passing forwards, in that order from medial to lateral side; a small branch of the lacrimal artery passing backwards to the dura mater; occasionally a small branch of the middle meningeal artery passing into the orbit; and sympathetic twigs from the carotid plexus [μῆνιγξ (mēninx) = any membrane, but especially a membrane around the brain].

The *floor* is formed chiefly by the orbital surface of the body of the maxilla, which is, at the same time, the roof of the maxillary sinus. But the antero-lateral corner of the floor is formed by the zygomatic bone; and the posterior corner is formed by the orbital process of the palatine bone—that is, the anterior of the two projections on the upper end of the perpendicular part of the palatine bone.

A great part of the floor is separated from the lateral wall posteriorly by the **inferior orbital fissure**, which is bounded *above* by the great wing of the sphenoid, *below* by the orbital surface of maxilla and the orbital process of the palatine bone, while its anterior end is closed either by the zygomatic bone or by an articulation between the great wing and the maxilla. The fissure *transmits*: the maxillary nerve, as it changes its name to infra-orbital nerve; the infra-orbital vessels; the zygomatic nerve; small twigs from the spheno-palatine ganglion to the periosteum of the orbit; a vein connecting the ophthalmic veins with the pterygoid venous plexus in the infra-temporal fossa.

The **infra-orbital groove** and canal lie in the floor of the orbit and in the roof of the maxillary sinus. The infra-orbital nerve (the continuation of the maxillary nerve), accompanied by the infra-orbital vessels, traverses the groove and canal, sends down branches through the facial wall of the sinus to the incisor, canine, and premolar teeth, and enters the face through the infra-orbital foramen.

The upper end of the **naso-lacrimal canal** separates the anterior part of the floor from the medial wall; and at the medial corner of the floor, just lateral to the canal, there is a shallow depression for the origin of the inferior oblique muscle of the eyeball.

The *medial wall* of the orbit is formed, from behind forwards, by: the anterior part of the side of the body of the sphenoid; the lateral surface of the labyrinth of the ethmoid; the lacrimal bone; the posterior part of the frontal process of the maxilla. The optic foramen and the ethmoidal foramina lie between the medial wall and the roof. The **optic foramen** lies between the body of the sphenoid and the roots of the small wing; it transmits the optic nerve and the ophthalmic artery; note that the ophthalmic vein and artery pass through different apertures. The **anterior** and **posterior ethmoidal foramina** are the orbital ends of the anterior and posterior ethmoidal canals, which transmit vessels and nerves of the same name.

The **fossa for the lacrimal sac** is formed by the anterior part of the lacrimal bone and the posterior part of the frontal process of the maxilla; its margins are called the **lacrimal crests**; the anterior crest is part of the medial margin of the orbit; the posterior crest gives attachment to the pars lacrimalis of the orbicularis oculi muscle. The upper end of the suture between the two bones is called the **dacryon** [δάκρυον (dakryon) = *lacrima* = a tear].

Norma Occipitalis.

The **back of the skull** is markedly convex and has the outline of a wide arch; the arch is widest usually at the level of the parietal eminences. The bones seen are portions of the two parietal bones, and a portion of the occipital, while the mastoid portion of the temporal bone and its mastoid process are visible at the lower corner on each side. The parts already seen on the top of the skull but seen again in the back are the parietal eminences, the posterior part of the sagittal suture, the parietal foramina, the lambda, and the lambdoid suture, which is now seen in the whole of its extent.

From the lower end of the lambdoid suture, on each side, the *occipito-mastoid suture* descends between the occipital bone and the mastoid temporal. The **mastoid foramen** is the aperture situated in the suture or on the mastoid temporal near the suture, and it varies in size from a pin point to a match; it passes through the skull wall and opens internally in the posterior cranial fossa into the groove for the sigmoid part of the transverse venous sinus; it transmits an emissary vein that connects the sinus with the veins on the outside of the head, and a small branch of the occipital artery; it is on a level with the external acoustic meatus and about three finger-breadths behind it.

The **external occipital protuberance** or **inion** is the projection, usually well marked, in the median plane, at the lower part of the back of the skull, about midway between the lambda and the foramen magnum. It is easily felt in the living person just above the nape of the neck, and is a useful landmark. If two protuberances are felt there, one below the other, the lower one is the normal protuberance. The **superior nuchal line** is the blunt, curved ridge that arches laterally from the protuberance. The protuberance and the right and left superior nuchal lines mark the boundary between the back of the head and the back of the neck [ἰνίον (inion), used indifferently for back of head or nape of neck; *nucha* = nape of neck]. The part of the skull seen in perspective below the protuberance and the superior nuchal lines belongs to the lower surface of the skull.

In many skulls there is a curved ridge, called the *highest nuchal line*, immediately above the superior nuchal line; it gives attachment to the tendinous sheet in the scalp called the galea aponeurotica [*galea* = a helmet].

In most skulls the boss or most posterior part of the back of the head is not at the protuberance, but is a little distance above it.

The **lambda** is situated between two and three inches above the protuberance. In many heads it can be felt by the finger tip as an apparent depression, owing to the prominence of the apical part of the occipital bone; it overlies the interval between the two halves of the brain a little behind the cleft in the brain called the parieto-occipital fissure.

Norma Lateralis.

The **side of the skull** is divisible into two parts: a larger part above and behind; a smaller part below and in front. The smaller part belongs to the face, and is very uneven. The larger part is the brain-case; it is convex, and is ovoid in outline.

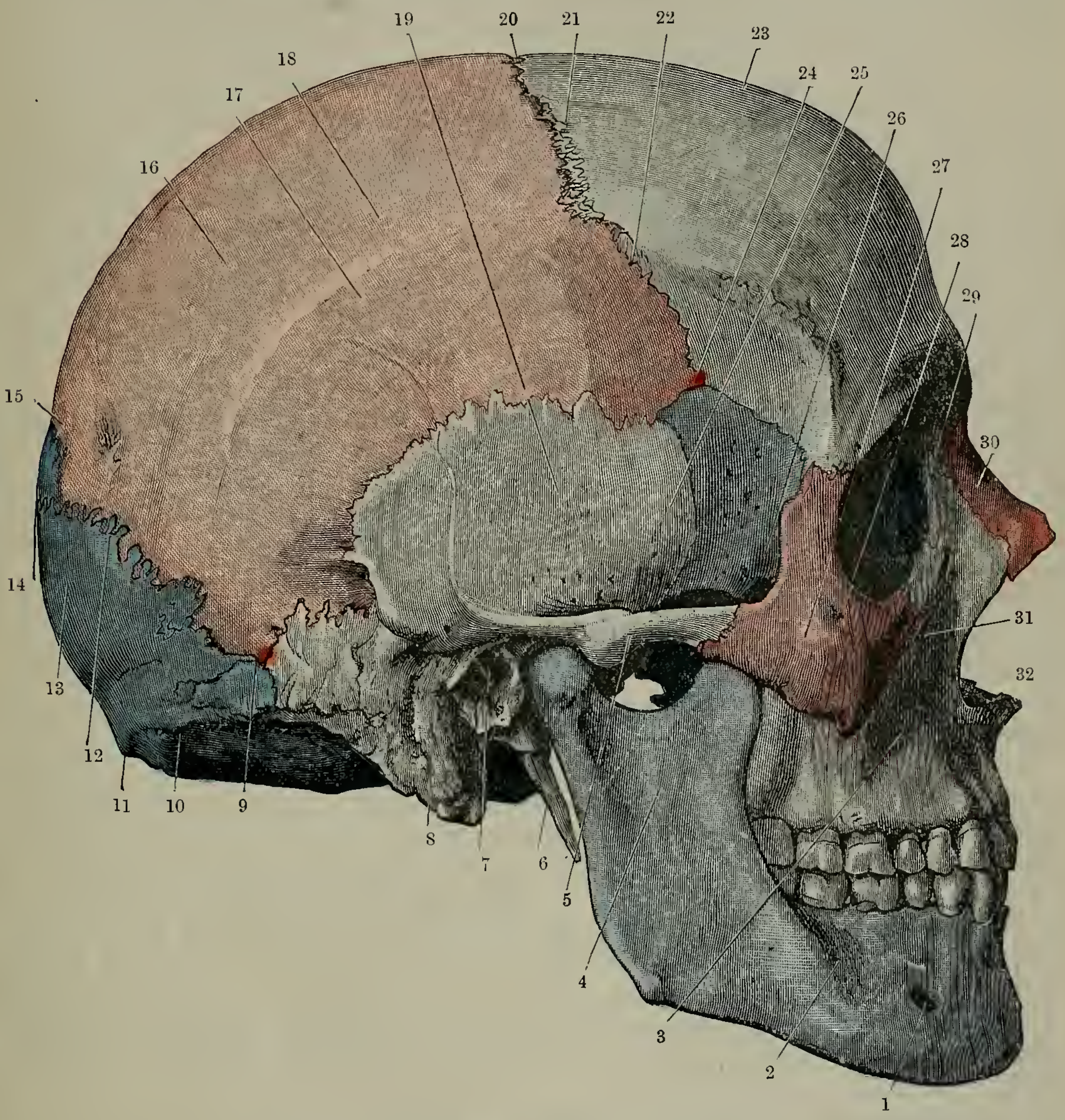


Fig. 135.—Norma Lateralis of the Skull

The occipital, sphenoid, and lacrimal bones and the mandible are coloured blue. The parietal, zygomatic, and nasal bones are coloured red. The temporal, frontal, ethmoid, and maxillary bones are left uncoloured.

1. Mental foramen.
2. Body of the mandible.
3. Maxilla.
4. Ramus of mandible.
5. Zygomatic arch.
6. Styloid process.
7. External acoustic meatus.
8. Mastoid process.
9. Asterion.
10. Superior nuchal line.
11. External occipital protuberance.
12. Lambdoid suture.
13. Occipital bone.
14. Lambda.
15. Obelion.
16. Parietal bone.
17. Lower temporal line.
18. Upper temporal line.
19. Squamous temporal.
20. Bregma.
21. Coronal suture.
22. Stephanion.
23. Frontal bone.
24. Pterion.
25. Temporal fossa.
26. Great wing of sphenoid.
27. Zygomatic bone.
28. Zygomatico-facial foramen.
29. Fossa sacci lacrimalis.
30. Nasal bone.
31. Infra-orbital foramen.
32. Anterior nasal spine.

Many of the parts seen already when the posterior and the upper and the anterior aspects of the skull were examined, are seen again in the lateral aspect, such as the superior nuchal line, the lambdoid suture, the occipito-mastoid suture, the mastoid foramen, the parietal eminence, the coronal suture, the frontal eminence, the superciliary arch, the bony external nose, the maxilla, the zygomatic bone, the margins of the orbit, and the zygomatic process of the frontal bone. Those are to be identified again, and the following parts looked for.

Linea Temporalis.—The **temporal line** is a long, curved ridge which begins at the zygomatic process of the frontal bone. From there it arches upwards and backwards across the frontal bone along the lateral margin of the forehead; then backwards over the parietal bone, passing just below the parietal eminence; having passed the parietal eminence it bends downwards and slightly forwards, and it ends by joining a blunt, prominent ridge, called the **supra-mastoid crest**, which is situated near the junction of the mastoid and squamous portions of the temporal bones. The anterior part of the temporal line is easily felt in the living head, above the zygomatic process of the frontal bone, between the forehead and the temple. Its middle part is usually represented by two lines, an upper and a lower, about half an inch apart; the bone between those lines is often more polished than that above and below, and if the lines are indistinct they can often be identified as the margins of a smooth strip along the upper part of the side of the skull. The posterior part of the line is frequently very indistinct. [*Tempora* = the temples, from *tempus* = time: grey hairs appear first in the temples.]

Fossa Temporalis.—The **temporal fossa** is the wide space outlined by the temporal line and the zygomatic arch. Parts of four bones are seen in the medial wall or **floor** of the fossa: (1) the lower part of the *parietal* bone; (2) the *squamous* part of the *temporal* bone, below the parietal bone and united to it by a curved suture called the *squamous suture*; (3) a small part of the *frontal* bone, in the upper and anterior part of the fossa; (4) a part of the *great wing of the sphenoid*, below the frontal and in front of the squamous temporal. In the anterior part of the fossa the four bones are so close together that a small circle, the size of a sixpence or a shilling, would include portions of them all; the region enclosed by such a circle is called the **pterion**, because one of the pairs of Hermes' wings was attached to the corresponding part of his head-piece [πτέρυξ (pteryx) = a wing].

In an adult male skull, the centre of the pterion is 30 mm. behind the zygomatic process of the frontal bone and at a rather higher level (10 mm.). It is a region made much use of as a guiding point when the position of deeper structures and their relations to the surface of the head are being explained. In many skulls sutural bones are present in the region of the pterion.

The part of the great wing of the sphenoid which is seen in the temporal fossa is called its *temporal surface*. The surface is limited below by a horizontal, antero-posterior ridge called the **infra-temporal line**. The ridge may be smooth and blunt or rough and prominent; it separates the temporal surface of the great wing from the infra-temporal surface, which is seen on the lower surface of the skull (Fig. 137, p. 143).

Arcus Zygomaticus.—The **zygomatic arch** is formed by the zygomatic bone and its temporal process and the zygoma of the temporal bone; it can be felt from end to end, and in thin people it stands out prominently between the temple and the side of the face. About an inch in front of the acoustic meatus the arch divides into two parts, called the **anterior** and **posterior roots** of the zygoma, which diverge from one another, the posterior root extending backwards, the anterior root turning medially towards the side of the skull.

The **anterior root** is easily found if one traces the lower border of the arch backwards; it is broad and its two surfaces look upwards and downwards; its lower surface is convex and is continuous, at the side of the skull, with a smooth, convex eminence, called the **articular tubercle**, which is seen on the lower surface of the skull in the front of a smooth concavity called the **mandibular fossa** (Fig. 137, p. 143). The lateral end of the lower surface of the root is rather prominent and is called the **tubercle of the root of the zygoma**; the tubercle is made use of as a landmark; it is felt just in front of and above the head of the lower jaw bone when the mouth is shut, and immediately above the head when the mouth is opened.

The **posterior root** is continuous with the upper border of the zygomatic arch. It joins the side of the skull and is continued backwards as a ridge immediately above the external acoustic meatus, and can be felt through the skin of the ear; it ends by joining the supra-mastoid crest just behind the level of the meatus. The posterior root and the upper border of the arch are opposite the lower border of the brain.

From the lower aspect of the posterior root a smooth triangular prominence, called the **post-glenoid tubercle**, juts downwards immediately in front of the acoustic meatus, and extends medially for some distance, forming the posterior boundary of the lateral part of the mandibular fossa.

The **temporal line** gives attachment to the galea aponeurotica, to the temporal fascia, and to the uppermost fibres of the temporalis muscle; where the line is divided, the fascia is attached to the upper line, while the muscle fibres reach only the lower. The point where the temporal line crosses the coronal suture is called the **stephanion** [στέφανος (stephanos) = a circle or crown].

The **temporal fossa** contains the temporalis muscle, the middle and deep temporal vessels, the deep temporal nerves, the zygomatico-temporal branch of the zygomatic nerve, and a quantity of fat—all under cover of the temporal fascia; and the chief structures on the surface of the fascia are the superficial temporal vessels, the auriculo-temporal nerve, and the temporal branches of the facial nerve.

The depth and width of the fossa depend, in a measure, on the size of the temporal muscle, which is proportional to the size and weight of the mandible. The anterior and lower part of the fossa is much the deepest part and has an *anterior wall*, which separates it from the orbit; the anterior wall is formed by the zygomatic process of frontal, the frontal-sphenoidal process of zygomatic, and sometimes by the great wing of the sphenoid, where it articulates with that process of the zygomatic bone. On the part of the wall formed by the zygomatic bone there is a small aperture, called the **zygomatico-temporal foramen**, which transmits the zygomatico-temporal nerve, accompanied by a small branch of the lacrimal artery. The posterior border of the frontal process of the zygomatic bone gives attachment to the temporal fascia, and it shows a slight fulness or tubercle called the *marginal process*; the point where the posterior border of the frontal process joins the upper border of the zygomatic arch is called the **jugal point**.

The *floor* or medial wall of the fossa gives origin to the temporalis muscle, and is limited below by the infra-temporal line of the sphenoid, by the roots of the zygoma, and by a short ridge on the squamous temporal between the anterior root and the infra-temporal line. The part of the floor formed by the great wing sometimes shows grooves for the deep temporal arteries; and the part of the floor above the acoustic meatus shows a long and narrow vertical groove for the middle temporal artery.

The centre of the **pterion** is found in the living head, held in the proper horizontal position (p. 125) by drawing (1) a line horizontally backwards from the zygomatic process of the frontal bone for 30 mm., and (2) a line straight upwards from the posterior end of the first line for 10 mm. The pterion is opposite the point where the anterior branch of the middle meningeal artery is deeply imbedded in a groove on the inner side of the skull wall and is most liable to injury, and it is opposite the point on the brain where the stem of the lateral fissure breaks up into its three rami.

The suture between the two constituent bones of the **zygomatic arch** runs obliquely from above downwards and backwards.

The *upper* border of the arch, thin, sharp, and nearly horizontal, is formed chiefly by the zygoma, and gives attachment to the temporal fascia. The *lower* border, formed chiefly by the zygomatic bone, is thicker and rougher and extends much further forwards, but not so far back; it slopes downwards as it is traced forwards, for the arch is much deeper in front than behind; the lower border gives origin to the masseter muscle, which arises also from the *deep* surface of the arch, while the *superficial* surface is subcutaneous. The **tubercle at root of the zygoma** gives attachment to the temporo-mandibular ligament. The **anterior root** is not only continuous with the articular tubercle but also forms part of it. The **posterior root** and the **supra-mastoid crest** give attachment to the temporal fascia.

The *post-glenoid tubercle* is sometimes called the *middle root* of the zygoma; it corresponds to a prominent process developed in some mammals to prevent backward displacement of the mandible.

The **supra-meatal triangle** is a small, and often inconspicuous, depression below the posterior root of the zygoma, just behind the upper margin of the external acoustic meatus. Although small, it is very important, for the tympanic antrum lies about half an inch directly medial to it. The tympanic antrum is a cavity in the temporal bone, and often has to be opened into when diseased; the road to it is through the supra-meatal triangle, the position of which, therefore, has to be accurately known. If the depression of the triangle is fairly well marked, one may be able to feel it in the living head by pulling the ear vigorously forwards and downwards, and pressing with the finger tip immediately above and behind the meatus.

Meatus Acusticus Externus.—The entire **external acoustic meatus** is about 25 mm. long, but only the medial, bony part of it is left in a dried skull; the lateral part is made of cartilage, and has been removed during maceration. The bony part is a tunnel about 15 mm. long. Its *inferior wall* and the greater part of the *anterior* and *posterior walls* are formed by the curled, lateral half of the *tympanic plate*; the *upper wall* and small adjoining parts of the anterior and posterior walls are formed by the squamous temporal. The *medial end* of the meatus is closed up during life with a tense vibratile membrane, called the **tympanic membrane**, which separates the meatus from the tympanic cavity or **middle ear** and forms the greater part of the lateral wall of the middle ear. The tympanic cavity or middle ear or drum of the ear [τύμπανον (tympanon) = a kettledrum] is a cavity in the temporal bone, and is narrow from side to side. The membrane is the drum head, and it, along with the contents of the middle ear, has been removed during maceration, so that, when one looks into the meatus, the bony surface seen at the far end is the medial wall of the middle ear (Figs. 139, 144, pp. 160, 167).

Processus Styloideus.—The styloid process, a slender process about an inch long, projects downwards, forwards, and slightly medially from behind the lower edge of the tympanic plate; it is situated deeply in the interval between the mastoid process and the mandible. It is dealt with more fully when the lower surface of the skull is examined.

Pars Mastoidea Ossis Temporalis.—The **mastoid temporal** lies behind the external meatus, wedged in between the parietal bone, the occipital bone, and the squamous temporal; it is united with the parietal and occipital by sutures, but is continuous with the squamous temporal; the line of fusion is a little below and behind the supra-mastoid crest (Fig. 165), but the crest roughly indicates the position of the junction of the two parts. The lower part of the mastoid temporal juts downwards as the thick, prominent *mastoid process*.

There may be no triangular depression to mark the **supra-meatal triangle** in the skull the student is using, and even a well-marked triangle measures only a few millimetres. The triangle is above and behind the opening of the meatus, close to the meatus, at the meeting of tangents drawn to the upper and posterior margins of the meatus. The *supra-meatal spine*, described as a spicule of bone on the antero-inferior side of the triangle, is seldom present.

The **external acoustic meatus** is barely wide enough to admit an ordinary pencil. It passes in a medial direction and slightly forwards; its opening into the middle ear is very oblique, so that the tympanic membrane, which closes the opening, looks downwards and forwards as well as in a lateral direction.

The parts of the outer orifice formed by the lateral margin of the curved tympanic plate are rough for the attachment of the cartilage of the auricle; the auricularis posterior muscle arises from the bone behind the meatus. In the child the meatus is very short, for the tympanic plate, which forms so much of the meatus, is at birth not a curved *plate* but an incomplete slender *ring*; in a child, therefore, the tympanic membrane is quite near the surface of the head.

The meatus as a whole is described in the chapter on Organs of Sense; the student is apt to get misleading ideas about the meatus if he studies the osseous portion apart from the cartilaginous portion.

The **medial wall of the tympanic cavity**, seen when one looks into the meatus, is uneven, and has about its middle a white bulging called the **promontory**. If the meatus is fairly wide, and the skull is tilted this way and that, a little hole may be seen above the posterior part of the promontory; it is called the **fenestra vestibuli**, because it leads into a part of the internal ear named the *vestibule*. During life the footpiece of the auditory ossicle called the *stapes* or stirrup fits into it. [*Fenestra* = a window.]

The **tympano-mastoid fissure**, which transmits the auricular branch of the vagus nerve, is a narrow slit between the posterior part of the lateral margin of the tympanic plate and the front of the mastoid temporal. In many skulls the tympanic plate is so closely applied to the mastoid that the fissure is represented by a minute foramen just large enough to emit the nerve.

The mastoid portion of the temporal bone or **mastoid temporal** is more or less triangular in outline, the apical part being the mastoid process. Anteriorly it fuses with the squamous temporal a little behind and below the *supra-mastoid crest*, and, below that, it is closely related to the tympanic plate. Posteriorly it articulates with the occipital bone. Its upper border or base articulates with the truncated postero-inferior angle of the parietal bone. The point, at the lateral angle of the occipital bone, where the lambdoidal, parieto-mastoid, and occipito-mastoid sutures meet together, is called the **asterion** [ἀστήρ (astēr) = a star]; the superior nuchal line of the occipital bone, when well marked, reaches the asterion. In skulls in which the supra-mastoid crest is not a mere curved ridge but is a broad, blunt, prominent elevation, there is a depression behind the crest in the angle between the squamous temporal and the base of the mastoid temporal. Note that, in the living head, the depression is just behind the top of the root of the ear, a full inch away from the meatus, and is not to be mistaken for the supra-meatal triangle; it is directly opposite the transverse venous sinus, just below the point where the sinus begins to bend downwards.

The **mastoid process** juts down from the mastoid temporal, and is felt as a prominence behind the lower part of the ear. It is opposite the foramen magnum, so that a line drawn from one mastoid process to the other passes just below the foramen. It is absent at birth, small in a child, variable in size in the adult, and is usually larger in men than in women.

The sterno-mastoid muscle is inserted into a strip which extends from the tip of the mastoid process to the asterion and then includes the lateral third of the superior nuchal line; the splenius capitis into a strip immediately below that for the sterno-mastoid; the longissimus capitis into the back of the root of the mastoid process; and the posterior belly of the digastric from the well-marked groove, called the **mastoid notch**, at the medial side of the root of the mastoid process.

Fossa Infratemporalis (Fig. 137, p. 143).—The **infra-temporal fossa** is the open space behind the maxilla; it communicates with the temporal fossa through a wide opening under cover of the zygomatic arch. Its *anterior wall* is the full, rounded posterior surface of the maxilla. The lowest part of that surface, behind the last molar tooth, is the **tuberosity of the maxilla.** (The *molar* teeth or grinders are the hindermost three teeth in a full set of eight a side.) Above the posterior surface of the maxilla, between it and the great wing of the sphenoid, there is the horizontal cleft, called the **inferior orbital fissure**, by which the infra-temporal fossa communicates with the orbit, where the fissure has been seen already (pp. 134 and 135).

The greater part of the *roof* of the fossa is a large, fairly flat surface of bone already pointed out as the *infra-temporal surface* of the great wing of the sphenoid; the lateral margin of the surface is the **infra-temporal line**, which also has been referred to already (p. 138).

The *medial wall* of the fossa is the *lateral lamina* of the pterygoid process. The lamina is a thin broad plate of bone set nearly perpendicularly behind the maxilla. Between its upper part and the upper part of the maxilla there is a narrow V-shaped cleft, called the **pterygo-maxillary fissure**, the upper end of which joins the inferior orbital fissure at almost a right angle. A large artery called the internal maxillary artery passes out of the infra-temporal fossa through the pterygo-maxillary fissure into the *pterygo-palatine fossa.*

Fossa Pterygo-palatina.—The **pterygo-palatine fossa** is the small confined space one sees immediately beyond the pterygo-maxillary fissure. If a pin or a match is passed through the upper part of the fissure into the fossa, and onwards through the fossa, it appears in the nasal cavity. The hole in the medial wall of the fossa through which the pin enters the nose is called the **spheno-palatine foramen.**

The **infra-temporal fossa** is a roomy space containing the two pterygoid muscles, the spheno-mandibular ligament, the pterygoid venous plexus, the internal maxillary artery (first and second parts) and its branches, the mandibular nerve and its branches, and the chorda tympani nerve—all imbedded in a quantity of fat and lying under cover of the tendon of the temporalis, the coronoid process, and the ramus of the mandible and the masseter muscle. The coronoid process and the ramus constitute a *lateral wall* of the fossa; the temporalis tendon is inserted into the process; the masseter lies on the lateral surface of the process and the ramus, being inserted into the lateral surface of the ramus. [μασητήρ (masētēr) = a chewer.]

The *anterior wall* of the fossa (*i.e.* the posterior or infra-temporal surface of the maxilla, ending inferiorly in the maxillary tuberosity) presents, about its middle, two or three small holes which are the upper ends of the **alveolar canals** through which vessels and nerves descend to the molar teeth of the upper jaw.

The *roof* of the fossa is formed chiefly by the infra-temporal surface of the great wing of the sphenoid, and partly also by a small triangular area that lies in front of the medial part of the articular tubercle and belongs to the squamous temporal. In the infra-temporal surface, close to its posterior border, there are two holes, called the **foramen ovale** and **foramen spinosum**, which will be considered with the lower surface of the skull (pp. 146 and 147).

The *medial wall* is formed by the lateral lamina of the pterygoid process and a narrow strip of bone, belonging to the pyramidal process of the palatine bone, which is wedged in between the lower part of the lamina and the maxilla; very often, however, the strip is so closely united to the bones between which it lies that it cannot be distinguished, and the lower part of the lamina appears to be fused with the maxilla.

The **pterygo-palatine fossa** is a small space situated *below* the apex of the orbit, bounded *anteriorly* by the maxilla, *posteriorly* by the combined root of the pterygoid process and great wing of the sphenoid bone, and *medially* by the perpendicular part of the palatine bone, which separates it from the cavity of the nose. The fossa is filled with fat in which there lie the third part of the internal maxillary artery and its branches, corresponding veins, the maxillary nerve the spheno-palatine ganglion and its branches.

The fossa communicates with the infra-temporal fossa by the **pterygo-maxillary fissure**, through which the internal maxillary artery enters it and the maxillary nerve leaves it. It is on a level with the zygomatic arch just below the jugal point, about two inches distant from the side of the head. In intractable neuralgia of the branches of the maxillary nerve a needle conveying analgesic fluid may be passed through the contents of the infra-temporal fossa into the pterygo-palatine fossa to reach the maxillary nerve.

The following apertures, several of which will be referred to more fully later, open into or out of the pterygo-palatine fossa: (1) the pterygo-maxillary fissure; (2) the inferior orbital fissure; (3) the greater palatine canal (canalis pterygo-palatinus), descending to the posterior corner of the hard palate; (4) the foramen rotundum, passing backwards into the middle cranial fossa; (5) the pterygoid canal, passing backwards through the root of the pterygoid process; (6) the pharyngeal canal, passing backwards and medially in the roof of the nose; (7) the **spheno-palatine foramen** is in the medial wall of the fossa and is bounded by the spheno-palatine notch and the lower surface of the body of the sphenoid. It opens into the superior meatus of the cavity of the nose immediately above the posterior end of the middle concha, but during life is closed up by the mucous membrane. It transmits the spheno-palatine vessels, the naso-palatine nerve, and one or more superior nasal branches of the spheno-palatine ganglion. The foramen can be identified in the dried skull if a match is pushed onwards through the pterygo-palatine fossa into the nose, where one can see it by looking through the choana of that side; the foramen is large and round, but by frequent examination the thin bone around it may have been broken down, so that it may be a large jagged opening.

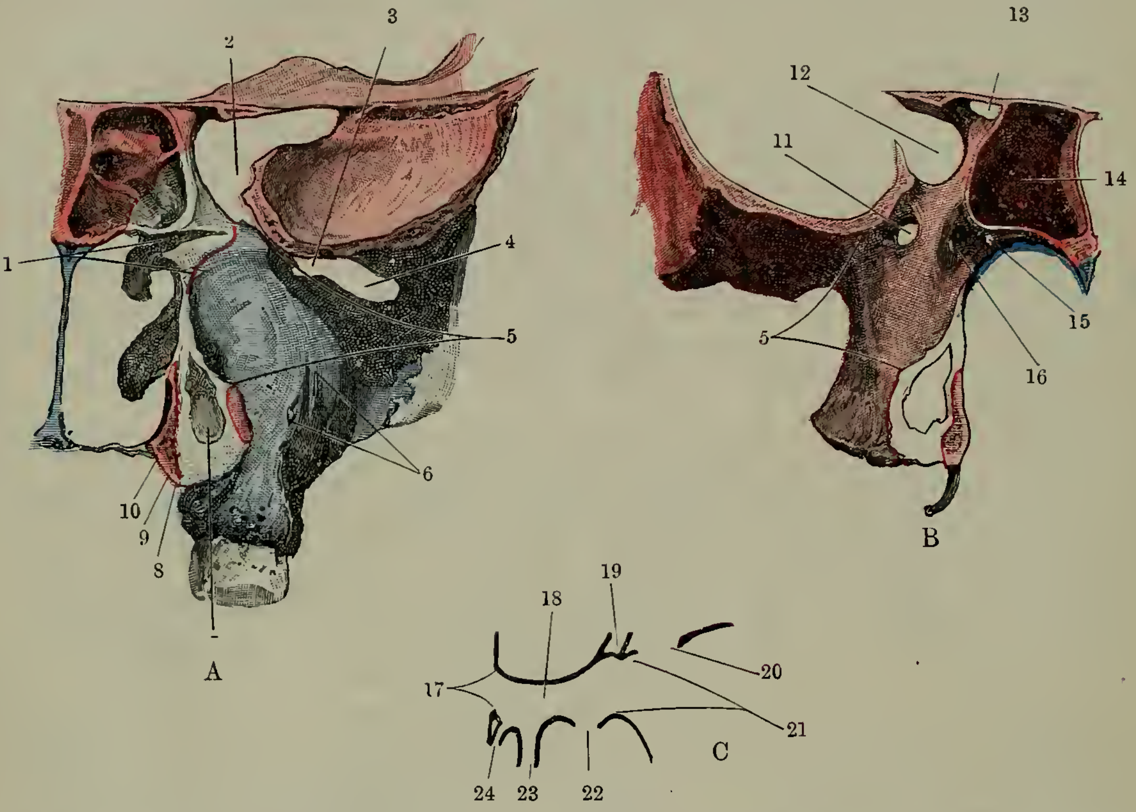


Fig. 136.—Frontal Section through the Pterygo-palatine Fossa and Nasal Cavity of the Right Side.

The sphenoid is coloured red. The maxilla and vomer are coloured blue. The palate bone and middle and inferior conchæ are left uncoloured.

A. Anterior Wall. B. Posterior Wall. C. Diagrammatic representation of a horizontal section across the fossa.

1. Spheno-palatine foramen.
2. Apex of orbital cavity.
3. Inferior orbital fissure.
4. Inferior orbital fissure.
5. Pterygo-maxillary fissure.
6. Alveolar foramina.
7. Part of pterygoid fossa.

8, 9, 10. Greater and lesser palatine canals.
11. Foramen rotundum.
12. Superior orbital fissure.
13. Optic foramen.
14. Sphenoidal sinus.
15. Pharyngeal canal.
16. Pterygoid canal.

17. Spheno-palatine foramen.
18. Pterygo-palatine fossa.
19. Infra-orbital groove.
20. Inferior orbital fissure.
21. Pterygo-maxillary fissure.
22. Foramen rotundum.
23. Pterygoid canal.
24. Pharyngeal canal.

Norma Basalis.

When the skull is turned upside down for the examination of the **lower surface** or *basis cranii externa*, many of the parts seen already from the other aspects or noted in connexion with the individual bones of the skull are seen again, and those parts should be identified at once:—

The *foramen magnum*; the *basilar part* of the occipital bone in front, and the

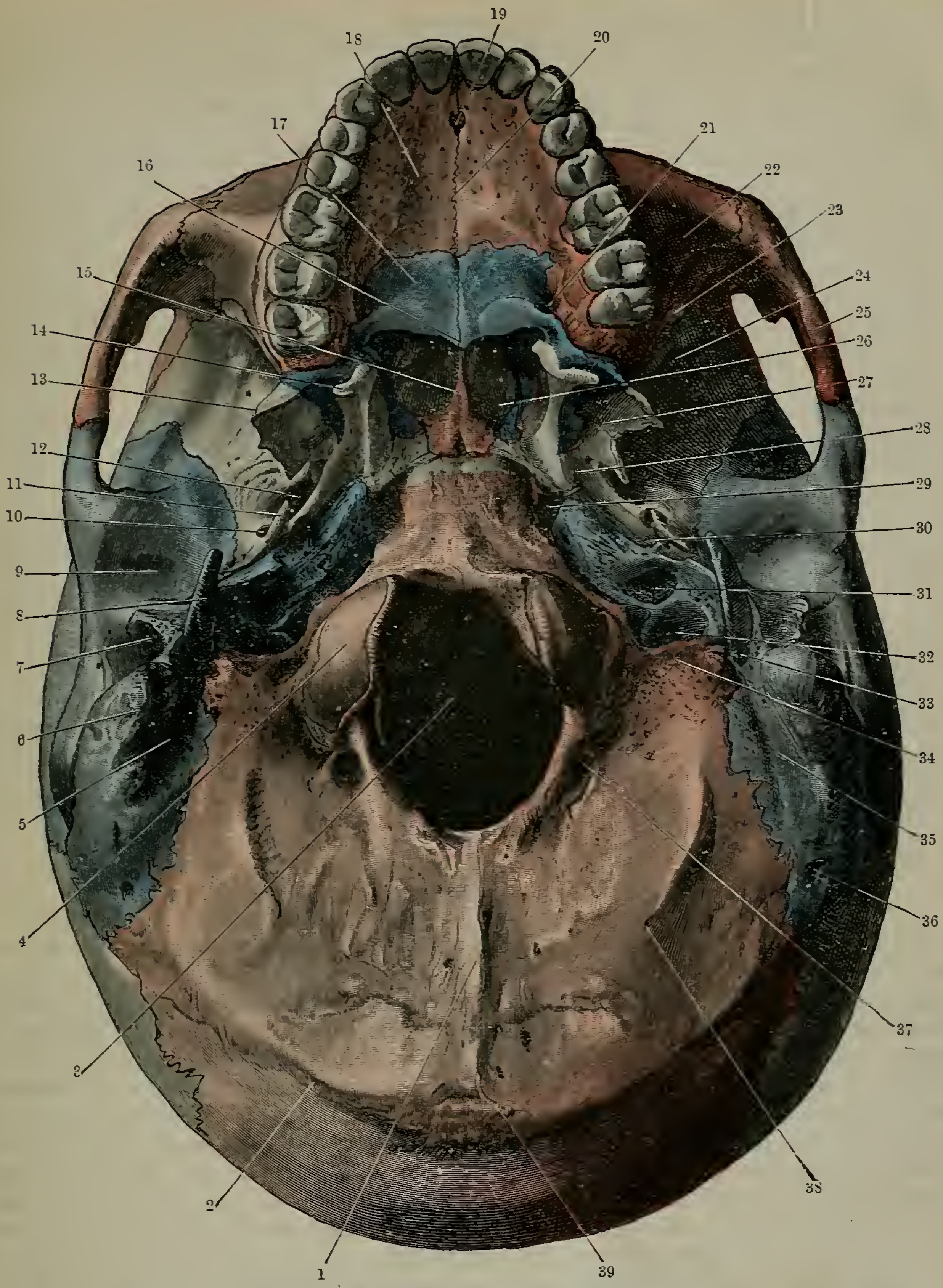


FIG. 137.—INFERIOR SURFACE OF BASE OF SKULL.

The occipital, vomer, maxillary, and zygomatic bones are coloured red. The temporal and palate bones, blue. The sphenoid and parietal bones, and the teeth, are left uncoloured.

1. External occipital crest.
2. Superior nuchal line of the occipital bone.
3. Foramen magnum.
4. Occipital condyle.
5. Mastoid notch.
6. Mastoid process.
7. External acoustic meatus.
8. Styloid process.
9. Mandibular fossa.
10. Foramen spinosum.
11. Angular spine of the sphenoid.
12. Foramen ovale.
13. Lateral pterygoid lamina.
14. Hamulus of medial pterygoid lamina.
15. Vomer.
16. Posterior nasal spine.
17. Horizontal part of palate bone.
18. Palatine process of maxilla.
19. Incisive foramen.
20. Intermaxillary suture.
21. Greater palatine foramen.
22. Zygomatic process of maxilla.
23. Inferior orbital fissure.
24. Infra-temporal fossa.
25. Zygomatic arch.
26. Left choana.
27. Pterygoid fossa.
28. Scaphoid fossa.
29. Foramen lacerum.
30. Opening of osseous part of auditory tube.
31. Carotid canal.
32. Jugular fossa.
33. Stylo-mastoid foramen.
34. Jugular process of occipital bone.
35. Groove for occipital artery.
36. Mastoid foramen.
37. Canalis condyloideus.
38. Inferior nuchal line of occipital bone.
39. External occipital protuberance.

occipital condyles at the sides of the foramen. The *mastoid process*; the *styloid process,* in front of and medial to the mastoid process, may be broken off and only its root remain; the *tympanic plate,* in front of and above the styloid process, and forming a great part of the walls of the external acoustic meatus. (The skull under examination is upside down, but in whatever position the skull is held all the terms, *above, upper,* etc., are used as if it was in its proper upright position.) The *zygomatic arch*; the *posterior root* of the zygoma extending backwards; the *anterior root* bent in a medial direction and continuous with the smooth *articular tubercle,* which is the anterior boundary of the *mandibular fossa.* The *infra-temporal surface* of the great wing of the sphenoid, forming the greater part of the area in front of and medial to the articular tubercle; the *infra-temporal line* or ridge at the lateral margin of the infra-temporal surface; the *inferior orbital fissure* at the anterior margin of that surface; the *pterygoid process,* consisting of a *lateral* and a *medial lamina,* projecting downwards from the medial side of that surface. The *choana,* the large oval opening at the medial side of the pterygoid process, separated from the choana of the other side by the *vomer.* The *hard palate,* the large area of bone below and in front of the two choanæ, bounded in front and at the sides by the *alveolar processes* of the two maxillæ.

Besides the parts named in the foregoing paragraph, which are fairly large and easily identified, the lower surface of the skull abounds with smaller foramina, processes, etc., so that it is more difficult to learn than any other aspect of the skull. The surface is so uneven and its component bones so interlock with one another that it does not lend itself readily to a natural subdivision into well-defined areas which would simplify description, and an attempt to subdivide it may only add new elements to the puzzle. The surface is naturally subdivided into a right and a left half; and a line drawn between the right and left articular tubercles divides it into an anterior and a posterior part, though it is convenient to describe one or two points that lie behind that line along with points that lie in front of it, and *vice versa.*

Anterior Region of Lower Surface of Skull.

In the middle in front there is the *hard palate,* surrounded anteriorly and at the sides by the *alveolar processes.*

Processus Alveolares.—The **alveolar processes** of the two maxillæ form a thick horseshoe-shaped ridge which carries the upper or maxillary teeth. The lower border of each alveolar process is called the **alveolar margin,** and if the teeth have fallen out after death it exhibits a row of pits or **alveoli** which are the sockets for the roots of the teeth. The part of the alveolar margin behind the last molar tooth is called the **maxillary tuberosity**; it is not well developed till the third molar (the wisdom tooth) has erupted. If the teeth are all in place there are sixteen of them; on each side, beginning in front, there are two incisors, one canine, two premolars and three molars. If the teeth have fallen out after death there is a row of sockets, all single except those for the molar teeth (see p. 182). The walls of the alveoli for teeth that have been removed some time before death are absorbed, so that the corresponding part of the alveolar process is nearly flush with the hard palate.

Palatum Durum.—The **hard palate** is the skeleton of the roof of the mouth and the floor of the nose. It is formed of the palatine processes of the two maxillæ anteriorly, and the horizontal parts of the two palatine bones posteriorly. Those four subdivisions are united by a transverse suture and a median longitudinal suture. At the anterior end of the longitudinal suture, behind the incisor teeth, there is a small pit called the **incisive foramen.**

The posterior margin of the hard palate is free and sharp, and the soft palate is attached to it; from its middle a pointed process, called the **posterior nasal spine,** juts backwards. At each of the posterior corners of the hard palate, opposite the root of the last molar tooth, there is a hole almost wide enough to admit a match; it is called the **greater palatine foramen** and is the lower end of the greater palatine canal (canalis pterygo-palatinus), the upper end of which opens into the pterygo-palatine fossa (pp. 141 and 142).

The sides of the **alveolar processes** are covered with mucous membrane, and their **alveolar margins** give attachment to the gums.

The **hard palate** is covered with the muco-periosteum of the roof of the mouth; it is rough and pitted, especially anteriorly, by the numerous palatine glands that lie under cover of the mucous lining. The **incisive foramen**, situated behind the incisor teeth, is a pit into which four small foramina or canals open. Those openings are not always easily seen, especially if the incisive foramen is narrow and deep. They all lead up into the cavity of the nose (p. 169). Two of them are in the median plane, one in front of the other, and are called the *foramina of Scarpa*; the other two, one on each side of the median plane, are called the *foramina of Stensen*. The right and left naso-palatine nerves descend from the nose through the foramina of Scarpa, the left nerve in front of the right. The terminal branch of the greater palatine artery ascends to the nose through a foramen of Stensen.

If the skull is that of a young person, a faint irregular suture may be seen extending from the back of the incisive foramen towards the interval between the canine tooth and the lateral incisor tooth. That suture cuts off a part of the maxilla called the **pre-maxilla**; the pre-maxilla carries the incisor teeth; originally it is separate from the maxilla, and in some animals it remains a separate bone.

The palatine aponeurosis and part of the pharyngo-palatinus muscle are attached to the *posterior border* of the hard palate, and the musculus uvulæ arises from the **posterior nasal spine.** A millimetre or two in front of the posterior border there is a ridge, called the **palatine crest,** into which part of the outspread tendon of the tensor palati is inserted; the crest may be blunt or sharp, and its lateral part is immediately behind the greater palatine foramen.

The **greater palatine foramen** is the lower end of the **greater palatine canal.** If a pin is pushed up through the foramen and canal, its point appears in the pterygo-palatine fossa, where the canal begins. The canal lies in the posterior part of the side wall of the nasal cavity, between the maxilla and the perpendicular part of the palatine bone. The greater palatine vessels from the third part of the internal maxillary vessels and the greater palatine nerve from the spheno-palatine ganglion descend through the canal and foramen and then run forwards in the poorly marked groove close to the alveolar process; they are the chief supply of the palate.

The **lesser palatine foramina** are the small holes behind the palatine crest and greater palatine foramen; there are usually two, but one of them may be so small that it almost escapes notice. The bone on which they are situated is the *pyramidal process* of the palatine bone. They lead up into the **lesser palatine canals**, which are branches of the greater palatine canal and convey the lesser palatine branches of the greater palatine vessels and nerve to the tissues of the soft palate.

Choanæ.—The **choanæ** are the two oval openings above the posterior edge of the hard palate, each of them large enough to admit the tips of two fingers; they are separated from each other by the posterior edge of the bone called the *vomer*; through them the cavities of the nose open into the uppermost part of the interior of the pharynx.

By looking into a choana one can get a partial view of the walls of a **nasal cavity,** and the following parts should be identified: The posterior part of the *floor,* formed by the horizontal part of the palatine bone. The posterior part of the *septum,* formed by the vomer. The posterior part of the *roof,* formed chiefly by the body of the sphenoid. The posterior part of the *side wall,* formed by the medial lamina of the pterygoid process and, in front of that, the perpendicular part of the palatine bone; the three nasal conchæ are seen projecting into the cavity from the side wall, in front of the pterygoid lamina; the inferior and middle conchæ have been identified already through the apertura piriformis; their posterior parts are seen here, and the **spheno-palatine foramen** opens into the cavity immediately above the posterior end of the middle concha; the superior concha lies only a little distance above the posterior part of the middle concha, and is very much smaller—may, indeed, be no more than a sharp ridge of bone.

Each **choana** is bounded inferiorly by the hard palate, medially by the vomer, laterally by the medial lamina of the pterygoid process, and superiorly by the lower surface of the body of the sphenoid, which is, however, concealed by two thin pieces of bones, called the ala of the vomer and the vaginal process of the medial pterygoid process, and they form the actual boundary. The upper boundary of the choana is the junction of the roof of the nasal cavity with the roof of the nasal part of the pharynx.

The *ala of the vomer* spreads in a lateral direction from the upper end of the vomer and covers the part of the lower surface of the body of the sphenoid near the median plane. The *vaginal process* is a thin sheet of bone that extends in a medial direction from the upper end of the medial pterygoid lamina; near the lamina it is fused with the lower surface of the body of the sphenoid, but its medial part is free and its medial edge articulates with the edge of the ala of the vomer. Anteriorly the vaginal process is overlapped by the *sphenoidal process of the palatine bone*, which bends in a medial direction, covering part of the lower surface of the body of the sphenoid in the roof of the nasal cavity, and reaching the edge of the ala of the vomer. On the lower surface of the vaginal process, near the pterygoid lamina, there is a narrow, but fairly well marked, antero-posterior groove; the groove, when traced forwards, leads to a small foramen, which is the posterior end of the pharyngeal canal.

Canalis Pharyngeus.—The **pharyngeal canal** is a narrow, unimportant canal situated in the roof of the nasal cavity between the body of the sphenoid and the sphenoidal process of the palatine bone. Its anterior end opens into the pterygo-palatine fossa; its posterior end opens on the vaginal process in the roof of the choana. The pharyngeal branches of the spheno-palatine ganglion and of the third part of the internal maxillary vessels pass backwards through the canal and along the groove on the vaginal process to supply the mucous membrane of the roof of the pharynx. In a much-handled skull the sphenoidal process is often broken away and the canal is destroyed.

Processus Pterygoidei.—The **pterygoid processes** are two large processes, a right and a left, which project downwards from the roots of the great wings of the sphenoid bone. Each of them stands at the side of a choana, behind the maxilla, and separates the choana from the infra-temporal fossa. It consists of two plates or laminæ, a lateral and a medial, between which there is an interval, open posteriorly and nearly half an inch wide, called the **pterygoid fossa**.

The **lateral lamina** forms the medial wall of the infra-temporal fossa. The **medial lamina** is the lateral boundary of the choana and forms the most posterior part of the side wall of the nasal cavity. The lower end of its posterior border is continued into a slender process, called the **hamulus**, which curves downwards, backwards, and in a lateral direction. The hamulus [= a hook] may be a mere stump or may be 5 or 6 mm. long; if long it is very liable to be broken off in the dried skull; it can be felt, in the living head, by the thumb pressed against the lateral part of the roof of the mouth at the junction of hard palate and soft palate, rather behind the gum. The upper part of the posterior border of the medial lamina splits into two ridges which enclose a shallow oblong depression, about 3 mm. wide, called the **scaphoid fossa** [*σκάφη* (scaphē) = anything dug out, a trough, a boat].

The **infra-temporal surface** of the great wing of the sphenoid is the wide, spreading horizontal surface of bone lateral to the upper end or root of the lateral pterygoid lamina. Posteriorly, it extends backwards beyond the level of the lateral lamina, and close to its posterior edge there are two holes, a larger and a smaller, set close together and called the foramen ovale and the foramen spinosum; both foramina lead directly up into the middle cranial fossa. The **foramen ovale** is the larger opening and is named from its shape; it lies behind and lateral to the upper end of the lateral pterygoid lamina, and is opposite, and an inch and a half medial to, the tubercle of the root of the zygoma. The **foramen spinosum** is behind and lateral to the foramen ovale.

Behind and lateral to the foramen spinosum there is a sharp spur of bone which projects downwards from the posterior angle of the great wing of the sphenoid. It is called the **spine of the sphenoid**, and gives its name to the foramen spinosum; it is situated close to the medial end of the articular tubercle and mandibular fossa, and varies much in prominence in different skulls; in a few skulls a thin bar of bone stretches from the spine to the lateral pterygoid lamina, converting the interval between them into a foramen.

The two **laminæ** of the **pterygoid process** extend downwards to a level rather lower than that of the hard palate. Their posterior margins are free and sharp; the upper halves of their anterior borders are united together, the anterior aspect of their junction forming the posterior wall of the pterygo-palatine fossa, while the posterior aspect forms the upper part of the floor or anterior wall of the **pterygoid fossa**; the lower halves of the laminæ are quite separate from each other, but that is not apparent in the skull, for the pyramidal process of the palatine bone is wedged in between the maxilla and the lower part of the pterygoid process, filling in the interval between the lower halves of the anterior borders of the laminæ; if the skull is that of a young adult, the Λ-shaped suture between the pyramidal process and the two laminæ can be seen in the lower part of the floor of the pterygoid fossa.

The **pyramidal process** of the palatine bone, though so frequently mentioned, is not of outstanding importance, but the origin of the internal pterygoid muscle cannot be fully understood unless the relations of the process to the pterygoid laminæ are understood. Three aspects of the process have now been seen: (1) the uneven surface, showing the lesser palatine foramina, behind the greater palatine foramen and between the lower extremities of the two pterygoid laminæ; (2) an uneven Δ-shaped surface in the floor of the pterygoid fossa, between the lower halves of the two laminæ; (3) a narrow strip in the infra-temporal fossa, between the lower part of the maxilla and the lower part of the lateral pterygoid lamina (p. 141).

The **medial lamina** of the pterygoid process is the most posterior bone in the side wall of the nasal cavity; inferiorly a portion of it stands also in the side wall of the nasal part of the pharynx or naso-pharynx, *i.e.* the uppermost subdivision of the interior of the pharynx; its medial surface is clothed with mucous membrane. The posterior border is thin and sharp, and rather more than half-way up a sharp spur of bone, called the **tubal process** (processus tubarius), sometimes juts backwards from it; above that spur, the border divides into two ridges which bound the **scaphoid fossa**, the medial margin of which is looked on as the real upper part of the border. The end of the auditory tube, as it opens on the side wall of the naso-pharynx, is closely related to the medial margin of the scaphoid fossa and is supported inferiorly by the tubal process. The lower or palatine end of the posterior border is continued into the hooklet or **hamulus**, the concavity of which is directed backwards and upwards towards the base of the skull; the *lower* surface of the root of the hamulus is crossed by a groove. The anterior part of the tensor palati or tensor veli palatini muscle arises from the scaphoid fossa, descends along the lateral surface of the medial pterygoid lamina, and the slender tendon of the muscle turns at a right angle in a medial direction and forwards, in the groove below the hamulus, and spreads out as it enters the soft palate. The posterior border of the lamina, in its whole length, gives attachment to the pharyngeal aponeurosis; its lower half or third, together with the hamulus, gives origin to the upper part of the superior constrictor of the pharynx; the tip of the hamulus gives attachment to a fibrous band, called the pterygo-mandibular raphe, which extends to the posterior end of the mylo-hyoid ridge of the mandible and gives origin to most of the remaining fibres of the superior constrictor.

The **lateral lamina** of the pterygoid process is wider than the medial lamina, and is turned slightly in a lateral direction. Its posterior border is sharp and very uneven; its surfaces give origin to the pterygoid muscles. The pterygoideus externus muscle has two heads, an upper and a lower. The lower head arises from the lateral surface of the lateral pterygoid lamina; the upper head from the infra-temporal surface and infra-temporal line of the sphenoid. The two heads pass backwards, join together, and are inserted chiefly into the front of the neck of the mandible (the mandible should now be placed in position). The pterygoideus internus also has two heads, a superficial and a deep. The small, superficial head arises from the tuberosity of the maxilla and the strip of the pyramidal process of the palatine bone that appears between the maxilla and the lateral pterygoid lamina; the large, deep head arises from the medial surface of the lateral pterygoid lamina and the surface of the pyramidal process that appears in the pterygoid fossa; the two heads join and pass downwards and backwards to be inserted into the medial surface of the mandible above and in front of the angle.

The **infra-temporal surface** of the great wing of the sphenoid is limited in front by the inferior orbital fissure, laterally by the infra-temporal line, while posteriorly it extends backwards and ends as the spine of the sphenoid, at the medial side of the mandibular fossa. The **spine of the sphenoid** is grooved on its medial side by the chorda tympani nerve, and it gives attachment to (1) the posterior part of the tensor veli palatini muscle, (2) the spheno-mandibular ligament, which stretches to the margin of the mandibular foramen, and (3) the pterygo-spinous ligament, a weak fibrous band which stretches to the posterior border of the lateral pterygoid lamina, but may, however, be transformed into a bar of bone.

The **foramen spinosum** is antero-medial to the spine of the sphenoid. It transmits the middle meningeal vessels, an unimportant nerve filament called the nervus spinosus, and lymph vessels from the meninges.

The **foramen ovale** is antero-medial to the foramen spinosum. The only important structure it transmits is the mandibular nerve, including the motor root of the trigeminal nerve; but there pass through it also the accessory meningeal artery, small veins connecting the cavernous venous sinus with the pterygoid venous plexus, lymph vessels from the meninges, and, sometimes, the lesser superficial petrosal nerve.

Very frequently there is a small aperture called the **foramen of Vesalius**, situated antero-medial to the foramen ovale and close to the scaphoid fossa. It opens directly into the middle cranial fossa and transmits a small vein that connects the cavernous sinus with the pterygoid plexus. And occasionally there is a very small hole called the **canaliculus innominatus**, behind the foramen ovale, for the transmission of the lesser superficial petrosal nerve.

Posterior Region of Lower Surface of Skull.

There are only three bones in the posterior part of the base of the skull—the occipital bone, and the right and left temporal bones. The **occipital** bone occupies a large part of the region in the middle and posteriorly; the **temporal** bone is wedged in at the side, between the occipital bone and the great wing of the sphenoid, and the details of its surface present more difficulties than those of the occipital bone.

The **occipital bone** is divided into four parts which surround the foramen magnum—the *basilar part* in front, a *lateral part* at each side, and a large, expanded *squamous part* behind. The four parts are separate at birth, but are usually fused together by the sixth year.

Foramen Occipitale Magnum.—The **foramen magnum** is the large opening in which the medulla oblongata, or lowest subdivision of the brain, becomes continuous with the spinal medulla (spinal cord). It is on a level with the mastoid process at the side of the head, while posteriorly it is on a level with a point midway between the external occipital protuberance and the spine of the second cervical vertebra.

The **foramen magnum** is usually ovoid in outline with the narrower part in front, and its antero-posterior diameter varies from 30 to 40 mm. It *contains* the upper end of the spinal medulla with its membranes and blood-vessels, the spinal roots of the accessory nerves, the vertebral arteries surrounded by plexuses of sympathetic nerves derived from the inferior cervical ganglion, lymph vessels from the meninges of the brain; the lowest part of the cerebellum lies in it; and the membrana tectoria and upper band of the cruciate ligament pass upwards through it to be attached to the upper surface of the basi-occiput in front of the foramen magnum. The posterior atlanto-occipital membrane is attached to the posterior margin of the foramen magnum; the anterior atlanto-occipital membrane and the lig. apicis dentis (suspensory ligament), to the anterior margin; the alar or check ligament, to the low tubercle on the medial surface of the occipital condyle on the side of the foramen magnum. The vertebral artery enters the foramen just behind the condyle, and sometimes grooves the margin of the foramen. The point in the middle of the anterior margin of the foramen magnum is called the **basion**, and the point in the middle of the posterior margin is the **opisthion** [ὀπίσθιος (opisthios) = posterior].

Pars Basilaris Ossis Occipitalis.—The **basilar part** of the occipital bone, or **basi-occiput**, is a wide bar of bone, thin at the margin of the foramen magnum, but thick at its anterior end, where it joins the body of the sphenoid. In youth it is united to the sphenoid by a plate of cartilage, and is fused with the sphenoid after the twenty-fifth year, but the position of their fusion may be indicated by an interrupted transverse depression. At the centre of the lower surface of the basi-occiput, about half an inch in front of the foramen magnum, there is a small elevation called the **pharyngeal tubercle**; the surface of bone in front of the tubercle is clothed with the mucous membrane of the roof of the pharynx, and is opposite and almost on a level with the mandibular fossa or lower jaw joint on the side of the head.

The hole, with jagged edges, seen alongside the anterior part of the basi-occiput is called the **foramen lacerum**; it leads directly up into the middle cranial fossa. On its anterior margin, as seen from below, there is a small rounded elevation, called the *pterygoid tubercle,* at the extreme upper end of the medial pterygoid lamina; and on the anterior margin of the foramen, above the tubercle, and rather hidden by it, there is an opening large enough to admit a thick pin. That opening is the posterior end of the **pterygoid canal**, the anterior end of which opens into the pterygo-palatine fossa; in some skulls it is so hidden that it cannot be seen, but a hook or a bent pin enables one to find it. (See also pp. 159 and 161.)

The **pharyngeal tubercle**, in an articulated skeleton, lies directly above the tubercle on the anterior arch of the atlas. It gives insertion to the uppermost bundle of fibres of the superior constrictor of the pharynx, and attachment to a median, fibrous longitudinal band, called the *pharyngeal raphe,* that lies in the posterior wall of the pharynx. The rectus capitis anterior is inserted into an impression on the basi-occiput in front of the occipital condyle, and the longus capitis into an impression lateral to and in front of the pharyngeal tubercle, so that the back of the upper end of the pharynx is recessed in between the longus capitis muscles of the two sides, and the prevertebral fascia is attached to a line which curves forwards from behind the pharyngeal tubercle to the front and lateral margins of the impression for the longus capitis.

The position of the junction of the basilar part of the occipital bone or basi-occiput with the body of the sphenoid bone corresponds to a line drawn between the tips of the pterygoid tubercles.

Partes Laterales Ossis Occipitalis.—The **lateral parts** of the occipital bone lie at the sides of the anterior half of the foramen magnum; they are named also the **condylar parts** because they bear the occipital condyles.

Condyli Occipitales.—The **occipital condyles** are the large, smooth, oblong protuberances that lie at the margins of the foramen magnum. They articulate with the lateral masses of the atlas vertebra and through them the weight of the head is transmitted to the vertebral column. The nodding movements of the head take place at the joints between the condyles and the atlas. The condyles and the joints are on a level with, and almost directly opposite, the mastoid process on each side. The articular surface of each condyle is often notched at the sides, and in some skulls the notches meet and divide the articular surface into two parts.

Fossa Condyloidea et Canalis Condyloideus.—The **condyloid fossa** is the depression behind the condyle. In many skulls there is a **condyloid canal** which begins in the fossa, and passes obliquely forwards and upwards into the cranial cavity. The bony wall of the fossa is thin and may have an artificial perforation in it which may be mistaken for the canal, but the artificial opening leads directly up into the cranial cavity, and not obliquely.

The **occipital condyles** lie alongside the anterior part of the foramen magnum. They are placed obliquely, their anterior ends being nearer each other than the posterior ends. The articular surface of each is convex from before backwards and slopes downwards from lateral to medial side. The articular capsule is attached to the margins of the articular surface, and the check ligament is attached to the medial surface of the condyle.

The **condyloid fossa** accommodates the upper part of the back of the lateral mass of the atlas when the head is bent backwards.

The **condyloid canal**, when present, passes above the posterior part of the condyle and opens, in the posterior cranial fossa, into or near the groove on the upper surface of the jugular process that lodges the lower end of the sigmoid part of the transverse venous sinus. The canal transmits a vein that connects the sinus with the sub-occipital venous plexus.

Canalis Nervi Hypoglossi.—The external opening of the canal for the hypoglossal nerve, or **hypoglossal canal**, lies above the lateral margin of the anterior part of the condyle, and is usually largely hidden by it, so that the skull has to be tilted before the opening is seen. The beginner should not mistake the jugular foramen for it because the foramen chances to catch his eye first. The jugular foramen is a large irregular opening nearly half an inch away from the condyle, and through it one can see into the cranial cavity. The hypoglossal canal is only wide enough to admit a match; it is medial to the jugular foramen and quite close to the condyle; internally, it opens into the cranial cavity a little above the margin of the foramen magnum (p. 164).

Processus Jugularis.—The **jugular process** is the part of the occipital bone—about half an inch square—which lies lateral to the posterior half of the condyle. Its anterior border forms the posterior margin of the jugular foramen; the border is concave from side to side and the concavity is called the **jugular notch.**

The **hypoglossal canal** passes in a medial direction and backwards above the anterior part of the condyle. The important structure that passes through it is the hypoglossal nerve; but it transmits also a meningeal branch of the ascending pharyngeal artery, veins connecting the meningeal veins and the veins of the medulla oblongata with the pharyngeal venous plexus, and lymph vessels from the meninges.

The **jugular process** is the homologue of the transverse process of a vertebra. It blends medially and posteriorly with the rest of the occipital bone; its anterior margin is free and forms the floor of the **jugular notch**; its lateral margin is united to the petrous temporal by a plate of cartilage which ossifies about the twenty-fifth year; its rough lower surface gives insertion to the rectus capitis lateralis; and the prevertebral fascia is attached to the anterior margin in front of the rectus; its upper surface, in the floor of the posterior cranial fossa, has a broad shallow groove which lodges a part of a large venous sinus called the sigmoid sinus.

In some skulls a curved process, called the *intra-jugular process*, projects from the jugular notch and partially or completely divides the jugular foramen into two parts. Occasionally a tubercle or a process, called the par-occipital or *para-mastoid process*, projects downwards from the lateral part of the jugular process, and may be long enough to articulate with the transverse process of the atlas.

Squama Occipitalis.—The **squamous part** is by far the largest subdivision of the occipital bone. It lies partly in the base and partly in the back of the skull. The *external occipital protuberance* and the superior nuchal lines, already examined (p. 136), are the boundary between the base and the back.

Crista Occipitalis Externa.—The **external occipital crest** is a median ridge which extends from the protuberance to the posterior margin of the foramen magnum; in some skulls it is very poorly marked.

Lineæ Nuchæ Inferiores.—The **inferior nuchal lines** are two faint curved ridges, one on each side, situated about midway between the foramen magnum and the superior nuchal line. Each begins about the middle of the external occipital crest and arches in a lateral direction and forwards and downwards towards the side of the occipital bone.

The upper end or border of the ligamentum nuchæ is attached to the **external occipital crest** and **external occipital protuberance**; the protuberance and the medial part of the **superior nuchal line** give attachment to the galea aponeurotica and origin to the uppermost fibres of trapezius; the lateral part of the line gives origin to the occipitalis and insertion to part of the sterno-mastoid and of the splenius capitis. The semispinalis capitis (complexus) is inserted into the medial half of the area between the superior and **inferior nuchal lines**; the obliquus capitis superior, into the lateral half; the rectus capitis posterior minor, into the medial part of the area below or in front of the inferior nuchal line; the rectus posterior major, into the lateral part. Though the oblique muscle and the two recti are small, their insertions are wide and in many skulls are mapped out by ridges.

All the subdivisions of the **temporal bone** appear in the lower surface of the skull: the lower end of the *mastoid temporal*; the *tympanic plate*; the lower surface of the *petrous temporal,* medial to the tympanic plate; the *styloid process,* emerging from behind the lower part of the tympanic plate; and the portion of the *squamous temporal* bearing the articular tubercle and mandibular fossa, in front of the tympanic plate.

Certain parts belonging to the temporal bone or placed close alongside it have been noted already, and are easily identified again. (1) The **articular tubercle,** medial to the posterior part of the zygomatic arch and continuous with its anterior root; (2) the **mandibular fossa,** behind the articular tubercle; the head of the mandible is in relation with the fossa when the mouth is shut, and is pulled forwards and downwards into relation with the tubercle as the mouth is opened; (3) the **spine of the sphenoid,** medial to the tubercle or medial to the fossa; (4) the **post-glenoid tubercle,** in the posterior boundary of the fossa immediately in front of the opening of the external acoustic meatus; (5) the **tympanic plate,** behind and below the fossa; (6) the **mastoid process,** behind and below the external acoustic meatus; (7) the **mastoid notch,** at the medial side of the root of the mastoid process; (8) the **foramen lacerum,** alongside the anterior part of the basi-occiput, between it and the petrous temporal.

The **mastoid notch** gives origin to the posterior belly of the digastric muscle. Close to the medial side of the notch and parallel with it, the occipital artery runs backwards and in a lateral direction, in contact with the mastoid temporal or with the suture between it and the occipital bone, and may produce a groove on the bone.

The following structures lie opposite the mastoid process, *i.e.*, a line connecting the two mastoid processes would pass through or near them: The posterior belly of the digastric, the occipital artery, the posterior part of the rectus lateralis, the posterior part of the atlanto-occipital joint, and the upper end of the spinal medulla—in that order latero-medially. The vertebral artery, as it enters the foramen magnum, lies just behind the line.

The **styloid process** lies deeply in the interval between the mastoid process and the mandible, and intervenes between the parotid gland and the internal jugular vein. It projects downwards, forwards, and medially from the petrous temporal, behind the lower part of the tympanic plate, which partly ensheathes its basal portion. Two ligaments and three muscles are attached to it. The stylo-hyoid ligament stretches from its tip to the hyoid bone; the stylo-mandibular ligament, which is a thickened part of the fascia covering the antero-medial surface of the parotid gland, extends from its anterior aspect to the posterior border of the mandible. The stylo-glossus arises from the anterior aspect near the tip; the stylo-hyoideus, from the postero-lateral aspect of the middle third; the stylo-pharyngeus, from the medial aspect near the root.

The following parts are now to be looked for:—

Foramen Stylo-mastoideum.—The **stylo-mastoid foramen** is the aperture immediately behind the root of the styloid process, between it and the mastoid process, in front of the mastoid notch. It is the lower end of a canal, in the substance of the temporal bone, through which the facial nerve travels on its way from the brain to the exterior of the skull; besides the facial nerve, it transmits the stylo-mastoid branches of the posterior auricular vessels, which pass upwards through it into the temporal bone.

Foramen Jugulare.—The jugular foramen is a large opening with uneven margins situated a little to the medial side of the root of the styloid process, and it leads into the posterior cranial fossa. It is bounded anteriorly by the petrous temporal and posteriorly by the jugular notch of the occipital bone.

The largest structure in the jugular foramen is the internal jugular vein, which begins in it as a continuation of the sigmoid part of the transverse venous sinus. The vein is dilated at its commencement and the dilatation is called the *bulb* of the internal jugular vein. To accommodate the bulb there is a concavity, called the **jugular fossa**, on the petrous temporal where it forms the antero-lateral wall of the jugular foramen.

The jugular foramen is opposite and almost on a level with the lower margin of the external acoustic meatus. A portion of the bone forming the jugular fossa forms also the floor of the tympanic cavity or middle ear. That relationship can be verified if one looks at the medial wall of the tympanic cavity through the external meatus, and gauges the position of the floor of the cavity. In middle-ear disease, infection may pass through the bone, and attack the internal jugular vein.

The following parts lie opposite the external acoustic meatus, *i.e.*, a line drawn from one meatus to the other would pass through them or near them: the root of the styloid process, the jugular foramen, the hypoglossal canal, the anterior end of the occipital condyle, and the anterior margin of the foramen magnum, in that order latero-medially.

The **jugular foramen** leads upwards and backwards into the cranial cavity, and the structures it transmits will be enumerated more intelligibly when it is examined from inside the skull (p. 166). Sometimes spicules of bone project across the foramen from its margins, and may divide it into compartments.

The right internal jugular vein is usually larger than the left, and therefore the right jugular foramen and fossa are larger than the left. When the fossa is large there may be a very small amount of bony substance between it and the tympanic antrum, which lies above it.

On the lateral wall of the foramen, in the floor of the jugular fossa, there is a small "pin-point" aperture: it is the medial end of a narrow, horizontal canal, called the **mastoid canaliculus**, which passes through the temporal bone and opens laterally in the tympano-mastoid fissure. The canal is traversed by a slender but not unimportant nerve filament called the auricular branch of the vagus.

Canalis Caroticus.—Directly in front of the jugular foramen and fossa, in the lower surface of the petrous temporal, there is a circular or oval opening, wide enough to admit a thin pencil; it is the lower end of the **carotid canal**, through which the internal carotid artery travels to reach the cranial cavity. The carotid canal is in the petrous temporal; it leads upwards for a short distance and then, bending to become horizontal, it runs in a medial direction and forwards to open into the middle cranial fossa at the foramen lacerum. Since the lower end of the canal is anterior to the jugular foramen, the internal carotid artery, as it enters the bone, is in front of the internal jugular vein. The lower end of the canal is opposite the anterior margin of the orifice of the external acoustic meatus, and the ascending part of the canal lies below and in front of the middle ear and the internal ear; the thudding sound that one hears in the head during moments of excitement or after a spurt of violent exertion is due to the beating of the carotid artery against the bone which separates it from the internal ear.

The anterior margin of the jugular foramen and fossa is separated from the lower opening of the carotid canal by a ridge of bone on which there may be more than one small hole for small vessels that enter the bone. But one of those foramina is the lower end of the **tympanic canaliculus**, through which a small nerve, called the tympanic branch of the glosso-pharyngeal nerve, passes up to enter the tympanic cavity and form the tympanic plexus on its medial wall.

The **carotid canal** transmits the internal carotid artery, the internal carotid plexus of sympathetic nerves derived from the superior cervical ganglion, small veins connecting the cavernous venous sinus with the pharyngeal venous plexus, and lymph vessels from the meninges. On the postero-lateral wall of the canal, just above its lower aperture, there are the openings of the very narrow **carotico-tympanic canaliculi** for the tympanic branches of the carotid artery and of the carotid sympathetic plexus.

The **quadrate area** of the petrous temporal is the rough, nearly four-square area medial to and in front of the lower opening of the carotid canal, between that opening and the foramen lacerum. The *antero-lateral border* of the area lies against the posterior border of the great wing of the sphenoid, *i.e.*, the border immediately behind the foramen ovale and foramen spinosum; the two borders may touch one another or there may be a narrow fissure between them.

The *cartilaginous part* of the *auditory tube* (Eustachian tube) lies along the fissure, or the line of contact, in a shallow groove shared by both the bones. The postero-lateral end of the groove is at the medial side of the spine of the sphenoid, and it is continuous there with a canal in the interior of the temporal bone. The canal is called the **musculo-tubal canal**; it is divided by a thin bony septum into an upper canal and a lower; the *upper canal* lodges a tiny muscle called the tensor tympani; the *lower canal* is the **osseous part** of the **auditory tube.** If a pin or a hook is run along the groove to its postero-lateral end and pushed onwards, it will pass, usually without difficulty, into the canal; and, if one looks through the external acoustic meatus, the point of the hook will be seen in the tympanic cavity, for the auditory tube opens into the cavity and the tensor tympani muscle enters the cavity and is inserted into one of the auditory ossicles, namely, the *malleus.*

The **foramen lacerum** can be seen between the petrous temporal and the basi-occiput, and the posterior end of the **pterygoid canal** is situated on the anterior margin of the foramen, above and lateral to the **pterygoid tubercle**; they will be dealt with more fully when the floor of the cranial cavity is examined (p. 161).

The **quadrate area** gives origin to the levator palati or levator veli palatini muscle. Cartilage, or dense fibrous tissue, unites the *postero-medial border* of the area to the basi-occiput, and its *antero-medial border* to the posterior border of the great wing of the sphenoid; the cartilaginous part of the auditory (Eustachian) tube lies along its line of union with the great wing. The levator palati at its origin is therefore postero-medial to the tube. The tensor palati is a thin muscle with a triangular outline, the apex of the triangle being the tendon as it turns round the lower surface of the pterygoid hamulus, while the base is the origin of the muscle from the skull. It arises from the spine of the sphenoid and from the scaphoid fossa, and, between those points, from the cartilage of the tube; the upper part of the muscle therefore lies on the antero-lateral aspect of the tube and separates it from the mandibular nerve descending from the foramen ovale and the middle meningeal artery ascending to the foramen spinosum.

The **osseous part of the auditory tube** is about 10 mm. long. It is situated in the temporal bone, between the tympanic plate and the petrous temporal; and a thin bony septum separates it from the semi-canal for the tensor tympani, which lies above it. One end opens into the anterior part of the tympanic cavity; from there the tube passes medially, forwards and slightly downwards, and opens on the lateral end of the groove for the cartilaginous part, at the medial side of the spine of the sphenoid, where the opening is easily found. Push a pin through the opening and along the tube to the tympanic cavity, and note that the tube has the ascending part of the carotid canal on its postero-medial side, and the mandibular joint on the antero-lateral side.

Fissura Petro-tympanica.—The name **petro-tympanic fissure** is given usually to the whole length of the narrow slit seen between the mandibular fossa and the upper edge of the tympanic plate. The lateral end of the slit is directly in front of the opening of the external acoustic meatus; the medial end is directly behind the spine of the sphenoid.

The **tympanic plate** has three surfaces. The **posterior surface** is for the most part fused with the petrous and mastoid temporal. The curved **upper surface** forms the anterior wall, lower wall, and greater part of the posterior wall of the **external acoustic meatus**; its rough curved *lateral margin* gives attachment to the cartilage of the auricle. The **anterior surface** is concave and is related to the upper part of the parotid gland, which separates it from the back of the head and neck of the mandible; its uneven, sharp *lower border* gives attachment to the fascia covering the postero-medial surface of the parotid gland; its *upper border* forms the posterior boundary of the petro-tympanic fissure, and gives attachment to the fascia covering the antero-medial surface of the parotid gland.

The *lateral part* of the **petro-tympanic fissure** may be obliterated by fusion of the tympanic plate with the back of the post-glenoid tubercle. The *middle part* leads up into the tympanic cavity; the anterior process of the malleus is stuck into it; and the tympanic branch of the middle meningeal artery passes upwards through it. The chorda tympani nerve, having traversed the tympanic cavity, enters the *medial part* of the fissure, issues through its medial end, runs downwards, forwards, and in a medial direction, grooving the medial side of the spine of the sphenoid, and joins the lingual nerve below the foramen ovale. In some skulls a thin strip of bone is seen between the lips of the medial part of the fissure; that strip is the lower edge of the tegmen tympani (a part of the surface of the petrous temporal seen in the floor of the cranial cavity), which is continued downwards to form the antero-lateral wall of the bony part of the auditory tube. The slit below the tube, between that edge and the posterior lip of the fissure, is the cleft to which the name "petro-tympanic" properly applies, and through it the chorda tympani nerve makes its exit.

The **mandibular fossa** and the **articular tubercle** are for articulation with the head of the mandible, and their margins give attachment to the articular capsule, the thickened lateral part of which, called the temporo-mandibular ligament, is attached to the **tubercle at the root of the zygoma**; but the fossa and articular tubercle are separated from actual contact with the head of the mandible by an articular disc of fibro-cartilage, which is attached by its circumference to the capsule, and divides the cavity of the joint into an upper and a lower part.

CRANIAL CAVITY.

The **cranial cavity** is the large cavity which lodges the brain. The bones which share in its formation are the frontal, the ethmoid, the sphenoid, the occipital, the two parietal, and the two temporal bones. The cavity is lined with the outermost of the three membranes or meninges of the brain, namely, the **dura mater**, which consists of two closely adherent layers, the *outer* of which clothes the bone, serving the purpose of periosteum, and is called the *endocranium.* The periosteum on the outside of the skull is called the *pericranium.* The pericranium and the endocranium are both continuous with the fibrous ribbons, called *sutural ligaments,* that lie between the articulating edges of the bones, and are continuous with each other round the lips of the various foramina and fissures that lead from the cranial cavity to the exterior.

Section of Skull.—The cranial cavity can be exposed for examination either by a median section which splits the skull into a right and a left half, or by a horizontal section which removes the skull-cap. The second method is the more common; the saw-cut is usually made to pass through the *frontal* bone just above the superciliary arches, through the two inferior angles of the *parietal* bone and the upper part of the *squamous temporal* on each side, and through the *occipital* bone just above the external occipital protuberance. The two parts are then examined separately: the skull-cap shows the roof of the cranial cavity; the lower part of the skull shows its floor; the front, the sides, and the back of the cavity are included partly with the roof and partly with the floor.

The advantage of the median section is that it not only exposes the cranial cavity but also lays open the nasal cavity and the sphenoidal sinus. If the skull which the student has procured for himself has had the skull-cap removed, the lower part of the skull should then be divided into a right and a left half. If the student has an uncut specimen of skull he should remove the skull-cap by the saw-cuts indicated above, and then split the lower part of the skull into halves.

In making the sagittal section he should use a very fine saw, and should make the cut a little to one or other side of the median plane in order to avoid injury to the septum of the nose, but, at the same time, he must be careful not to injure the conchæ, which project from the side wall of the nasal cavity. The first cut should be made through the hard palate and the alveolar process of the maxilla; if they are not cut first they will break when the thicker parts of the skull are divided. The two halves can be tied together or hinged together with improvised pins and hooks when the student wants to examine both halves at once.

Thickness of Skull.—In cutting the skull the student will note that the thickness of the walls of the cranial cavity varies in different areas. The thicker and thinner parts are not all constant in position in different skulls, but the parts well covered with muscles are always thinner than the more exposed parts, *e.g.*, the floor of the temporal fossa and the floor of the posterior cranial fossa on each side of the median plane.

The bone of the skull as a whole is thicker in some races than in others, the more primitive races usually having the advantage of thicker skull bones; but in all races the skull bones are thinner in women and children than in men. The skull of a child is very thin, but it is more yielding and elastic than that of an adult and is less liable to fracture. There are, however, great differences in thickness in the skulls of adults of the same race and sex. About a quarter of an inch is an average thickness, but variations occur ranging from less than one-eighth of an inch to almost half an inch. There is no known relation between the thickness of the skull bones and the quality of the intelligence, but a thick skull obviously protects the brain more efficiently from injury by violence. It is not possible to gauge the thickness of the skull with any certainty during life, except during the course of an operation; and in the early steps of an operation on the skull it is safer to assume that the skull is thin.

Roof of Cranial Cavity.

The **skull-cap** is the **roof** of the cranial cavity or **vault** of the skull. If the horizontal saw-cut has been made as indicated, the skull-cap includes part of the *frontal* bone in front, part of the *occipital* bone behind, nearly the whole of both *parietal* bones in the middle, and a very small part of the *squamous* portion of the *temporal* bone on each side, at the lower border of the parietal bone.

The internal or **cerebral surface** of the vault is highly concave in every direction. The dura mater is only loosely attached to the skull vault, except along the lines of the sutures, where, in a young adult skull, it is continuous with the sutural membranes or ligaments.

The **sutures** between the bones may be indistinct, for if their obliteration had commenced it will be more advanced on the inner surface than on the outer; and if the skull is that of an old person the sutures may have disappeared. The sutures are: The **sagittal suture**, uniting the two parietal bones; the **coronal suture**, uniting them to the frontal bone; the **lambdoidal suture**, uniting them to the occipital bone; and the **squamous suture**, on each side, uniting the parietal bone to the squamous temporal. The squamous suture is at a lower level on the inside of the skull than on the outside, because the squamous temporal overlaps the parietal bone on the outside, and the saw-cut may have been at such a level that the suture is seen only on the outside.

The following additional parts are to be noted on the cerebral surface of the vault:—

Crista Frontalis (Fig. 138, 41, p. 156).—The **frontal crest** is a median ridge on the anterior wall of the cranial cavity, on the lower part of the cerebral surface of the frontal bone, and it may extend far enough up to be seen on the skull-cap.

Sulcus Sagittalis.—The **sagittal groove** is a shallow median furrow on the cerebral surface of the vault, extending from above the root of the nose to the occipital protuberance. It begins on the frontal crest, passes upward and backwards on the frontal bone, backwards along the sagittal suture, and downwards on to the occipital bone, widening progressively during its course. The superior sagittal venous sinus lies along it, in the upper border of the falx cerebri, which is attached to its lips. (The falx cerebri is a fold of the inner layer of the dura mater, projected downwards from the cranial vault as a tense, median partition, to keep the two halves of the cerebrum apart and prevent friction between them in sudden movements of the head.)

Foveolæ Granulares.—The **granular pits** are small irregular depressions that are placed here and there alongside the sagittal groove. They are more numerous and larger in the skull of an old person than in a young skull, and the bone in their floors may be thin enough to be translucent. They lodge arachnoid granulations, which are small bud-like growths that protrude from the arachnoid. (The arachnoid is the middle and the thinnest of the three membranes that enclose the brain) [ἀράχνιον (arachnion) = a spider's web].

Foramen Parietale.—The **parietal foramen** (p. 130), when present, is situated in the parietal bone, close to the sagittal groove, about an inch or an inch and a half above the lambdoid suture.

Sulci Arteriosi (Fig. 146, 3, p. 170).—The **arterial grooves** are narrow branching grooves seen extending from the cut edges of the vault towards the top. They are grooves for meningeal vessels; the largest grooves are seen on the part of the vault formed by the parietal bone; those are for the branches of the middle meningeal artery and vein, and their direction is upwards and backwards.

Impressiones Digitatæ. — The **digital impressions** are the broad, shallow, ill-defined depressions, like finger-marks, found all over the vault. They correspond to the gyri or convolutions on the surface of the brain.

Floor of Cranial Cavity.

The **basis cranii interna**, or upper surface of the base of the skull, is the floor of the cranial cavity. Grooves for meningeal vessels are seen on it; and the digital impressions are better marked than on the vault. The dura mater is more firmly attached to the bone of the base than to that of the vault.

The floor is divided into three main districts, one behind the other and at different levels, corresponding to the anterior, middle, and posterior **cranial fossæ**, of which the anterior is at the highest level and the posterior at the lowest.

Fossa Cranii Anterior.

The **anterior cranial fossa** contains the lower part of the frontal lobes of the brain. It is bounded in front and at the sides by the frontal bone, while its floor is divided into (1) a median part, which lies above the nasal cavity and is formed by the ethmoid bone and the body of the sphenoid, and (2) a right and a left lateral part, each of which lies above the orbit and is made up of the orbital plate of the frontal bone and the small wing of the sphenoid.

In the **median subdivision** the chief parts to be looked for are the following:—

Crista Galli.—The **crista galli** is the upstanding process seen in the median plane in front.

Foramen Cæcum.—The **foramen cæcum** is the small pit in front of the crista galli [*cæcum* = blind]. The foramen, however, is not blind: there is a small aperture at its bottom which transmits a vein.

Crista Frontalis.—The **frontal crest** is the median ridge seen above the foramen cæcum, in the anterior boundary of the fossa; it extends upwards on to the vault and fades away there.

Lamina Cribrosa.—At each side of the crista galli there is a narrow, horizontal plate of bone, called the lamina cribrosa or *cribriform plate* of the ethmoid because it is full of little holes; it separates the cranial cavity from the nasal cavity (Fig. 146, 10, p. 170; Fig. 147, 4, p. 172).

Behind the two cribriform plates there is a broad, fairly flat area of bone; that is the anterior part of the upper surface of the body of the sphenoid, and it is limited behind by the anterior lip of a groove called the sulcus chiasmatis or *optic groove*, which leads laterally on each side into an aperture called the *optic foramen.* The optic groove and foramen are, however, included in the middle cranial fossa.

By far the greater part of the **lateral subdivision** is formed by the orbital plate; only a small part posteriorly is formed by the small wing. The **orbital plate** separates the cranial cavity not only from the orbit, but also from the ethmoidal air-cells; for the medial part of the plate overlies the labyrinth of the ethmoid, roofing in the air-cells. The *frontal sinus* extends backwards for a variable distance between the two tables of bone of which the plate is composed; and the upper table therefore separates the cranial cavity from part of the frontal sinus.

In an old adult skull the suture between the plate and the **small wing** may be obliterated, but if the suture is visible the outline of the wing can be made out—fairly broad at its medial end and tapering to a point at the lateral end. The posterior border of the small wing is the free, sharp margin of the floor of the lateral part of the fossa, and it ends *medially* in a prominent process, called the **anterior clinoid process**, that juts backwards behind the optic foramen.

Each lateral part of the floor of the anterior cranial fossa is convex, rather uneven, and slopes downwards towards the median portion, more so anteriorly than posteriorly, where both parts are smoother and more nearly horizontal. Together with the corresponding half of the median portion it supports the frontal lobe of the brain; the ridges and **digital impressions** on the lateral part correspond to the sulci and gyri on the orbital surface of the lobe, and therefore vary in the pattern they make; they are much better marked in some skulls than others.

The antero-lateral margin of the orbital surface of the frontal lobe, *i.e.* the superciliary margin of the brain, fits into the angle between the floor and the antero-lateral wall of the fossa, which corresponds, on the exterior, to a line drawn from the root of the nose upwards and then laterally along the superciliary arch and onwards to the root of the zygomatic process of the

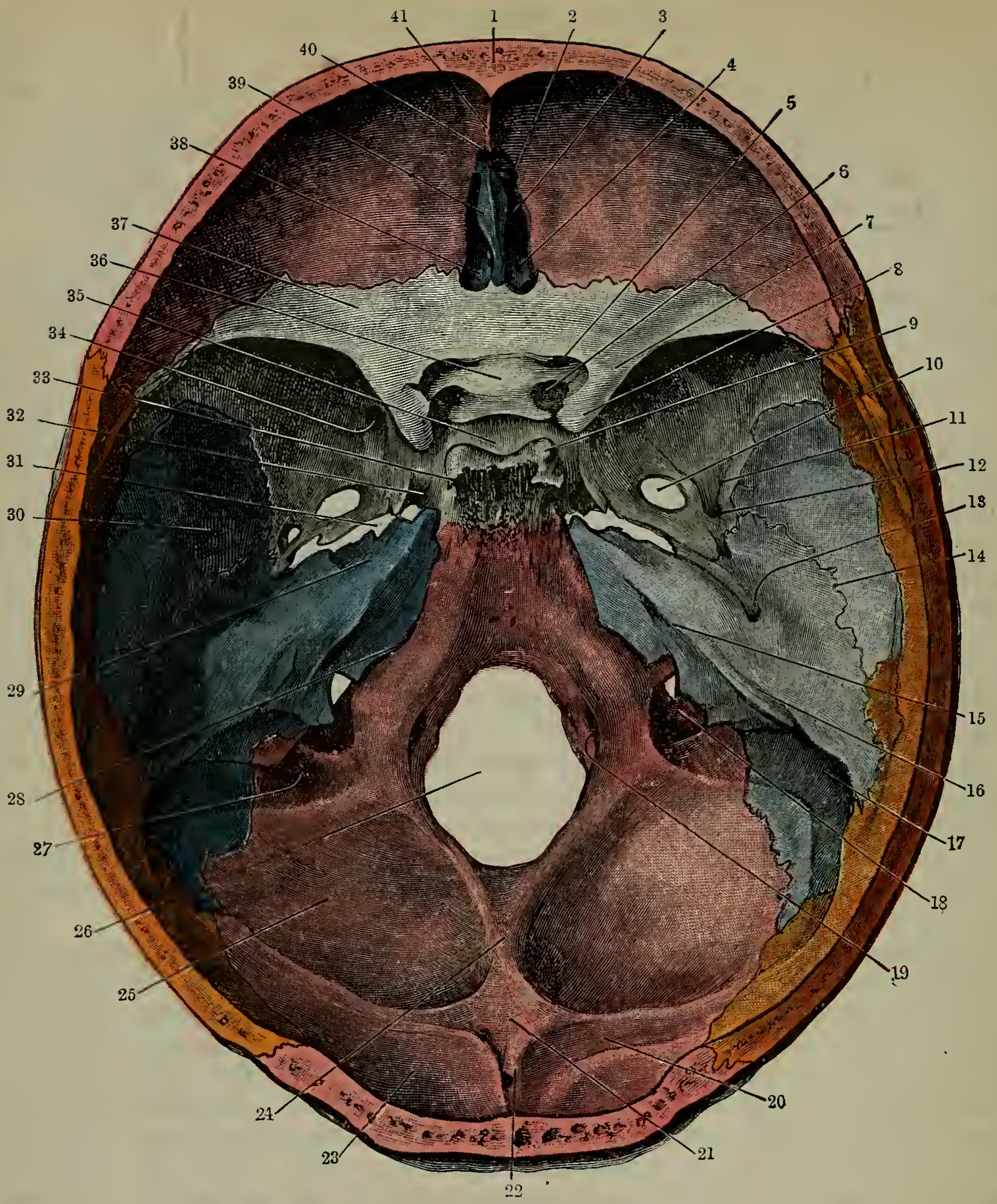


Fig. 138.—Floor of Cranial Cavity.

The frontal and occipital bones are coloured red ; the ethmoid and temporal bones, blue ; the parietal, orange ; and the sphenoid is left uncoloured.

1. Frontal bone.
2. Slit for anterior ethmoidal nerve.
3. Anterior ethmoidal foramen.
4. Lamina cribrosa of ethmoid.
5. Optic foramen.
6. Foramen for internal carotid artery formed by anterior and middle clinoid process.
7. Small wing of sphenoid.
8. Anterior clinoid process, in this case united on its medial side to the middle clinoid processes.
9. Posterior clinoid process.
10. Foramen ovale.
11. Groove for middle meningeal artery.
12. Foramen spinosum.
13. Hiatus canalis facialis.
14. Line of petro-squamosal suture.
15. Internal acoustic meatus.
16. Groove for superior petrosal sinus.
17. Groove for sigmoid part of transverse sinus.
18. Jugular foramen.
19. Canalis hypoglossi.
20. Groove for transverse sinus.
21. Internal occipital protuberance.
22. Ridge for attachment of falx cerebri.
23. Fossa for lodgment of left occipital lobe of brain.
24. Internal occipital crest.
25. Fossa for the lodgment of the left cerebellar hemisphere.
26. Foramen occipitale magnum.
27. Groove for the sigmoid sinus turning into the jugular foramen.
28. Groove for the inferior petrosal sinus between petrous temporal and basi-occipital.
29. Trigeminal impression for the semilunar ganglion.
30. Middle cranial fossa for lodgment of the temporal lobe of the brain.
31. Cleft between petrous temporal and great wing near foramen lacerum.
32. Carotid groove in front of foramen lacerum.
33. Dorsum sellæ of sphenoid.
34. Leads into foramen rotundum.
35. Fossa hypophyseos.
36. Tuberculum sellæ of the sphenoid.
37. Anterior cranial fossa for lodgment of frontal lobes of the brain.
38. Cribriform plate of ethmoid.
39. Crista galli of ethmoid.
40. Foramen cæcum.
41. Frontal crest for attachment of falx cerebri.

frontal bone, and then backwards to the pterion. The gyrus rectus, which is the most medial gyrus of the orbital surface, lies on the cribriform plate and the body of the sphenoid behind that; the olfactory tract and bulb, immediately lateral to the gyrus rectus, lie on the sphenoid and on the orbital plate at the edge of the cribriform plate; the nerve filaments, twenty or so, which constitute the olfactory nerve, come up from the nose through the small **foramina in the cribriform plate** (which are arranged in two irregular rows) and end in the olfactory bulb.

In the lateral part of the fossa, especially in front and at the side, there are narrow branching *grooves for the anterior meningeal vessels* derived from the middle meningeal and ethmoidal vessels.

The **crista galli** is the upper anterior part of the perpendicular lamina of the ethmoid projected upward into the cranial cavity. It is highest and thickest in front, where it may contain either spongy bone or an air cavity which opens directly into the nose or into the frontal sinus; and from its anterior part two processes, called *alar processes*, project forwards to articulate with the frontal bone and form the side boundaries of the **foramen cæcum**, which lies between the frontal bone and the crista galli.

The anterior end and anterior part of the convex border of the falx cerebri are attached to the sharp sloping border of the crista galli and to the frontal crest. The anterior part of the superior sagittal venous sinus lies on the frontal crest in the convex border of the falx, and its commencement is connected with the veins of the nose by the vein which passes through the foramen cæcum.

The **nasal slit** is a short and narrow cleft, often difficult to find, situated between the anterior part of the root of the crista galli and the anterior part of the cribriform plate; it leads down into the nasal cavity.

The **anterior** and **posterior ethmoidal canals** are narrow tunnels which begin at foramina of the same name between the roof and medial wall of the orbit, where they have been seen already, and run in a medial direction, between the labyrinth of the ethmoid and the medial part of the orbital plate of the frontal bone, to open into the cranial cavity; their openings are often hidden by overhanging lips of bone. The *posterior* canal transmits the posterior ethmoidal vessels and opens at the junction of the cribriform plate with the front of the sphenoid. The posterior ethmoidal nerve, also contained in the canal, does not reach its cranial end, being distributed to the mucous lining of the ethmoidal and sphenoidal sinuses. The *anterior* canal is larger; it opens at the side of the cribriform plate about the middle; it transmits the anterior ethmoidal vessels and the anterior ethmoidal nerve, which is a continuation of the naso-ciliary nerve; the nerve runs forwards on the cribriform plate and descends to the nose through the **nasal slit** or through a foramen alongside the slit.

The **small wing of the sphenoid**, triangular in outline and compressed from above downwards, lies in the roof of the orbit and superior orbital fissure, and in the floor of the anterior cranial fossa; posteriorly, it overhangs the middle cranial fossa. It arises by two roots separated by the optic foramen: the *anterior root*, broad and flat, is continuous with the anterior part of the upper surface of the body of the sphenoid; the *posterior root*, much smaller, springs from the side of the body of the sphenoid and stands between the optic foramen and superior orbital fissure. The spheno-parietal venous sinus lies in the dura mater on the lower surface of the overhanging posterior margin of the wing. The **anterior clinoid process**, projecting backwards from the postero-medial angle of the wing, gives attachment to the anterior end of the free margin of the tentorium cerebelli.

Fossa Cranii Media.

The **middle cranial fossa** is divided into a median part and a right and a left lateral part.

MEDIAN PART OF MIDDLE CRANIAL FOSSA.

The median part is elevated above the level of the lateral parts. Its floor is formed by the body of the sphenoid, and is separated therefore from the cavity of the nose by the sphenoidal sinus enclosed within the bony shell of the body of the sphenoid (Fig. 146, 8, p. 170). The floor presents for examination the optic groove and foramina, the sella turcica, and the carotid grooves.

Sulcus Chiasmatis.—The **optic groove** or sulcus chiasmatis is situated in the most anterior part of the floor, immediately behind the anterior cranial fossa; it may be well defined or very shallow.

Foramen Opticum.—On each side the optic groove ends at the **optic foramen**, which opens into the medial side of the back of the orbit, where it has been seen already (pp. 134 and 136).

Sella Turcica.—**Sella turcica** is the name given to the middle part of the upper surface of the body of the sphenoid, from a resemblance to a Turkish saddle. The pommel is the transverse, oval elevation, called the **tuberculum sellæ**, situated directly behind the optic groove. The seat is the wide, smooth depression behind the tuberculum; it is called the **hypophyseal fossa** (pituitary fossa) because a process of the brain called the hypophysis (pituitary body) lies in it. Behind the hypophyseal fossa there is an upstanding square plate of bone (broken off in many skulls) called the **dorsum sellæ** or back of the saddle. The upper corners of the dorsum sellæ are called the **posterior clinoid processes.** The anterior and posterior clinoid processes get their name from a fancied resemblance to the four posts of a bed [κλίνη (clīnē) = a bed]. Low down on the side of the dorsum sellæ, where its root joins the body of the sphenoid, there is a narrow groove for the passage forwards of the abducent nerve; the groove is only the width of a thick pin, but can usually be seen even when the dorsum sellæ is broken off.

Sulcus Caroticus.—The *carotid groove* is a broad, shallow, ʃ-shaped groove on the upper part of the side of the body of the sphenoid. It begins at the medial side of the foramen lacerum, ascends for a short distance, then runs forwards on the side of the sphenoid body, and finally turns upwards to end medial to the anterior clinoid process. The internal carotid artery lies on it, and its sinuous bends indicate the course of the artery in the cranial cavity.

In many skulls there is a pair of **middle clinoid processes.** Each middle clinoid process, when present, is usually a small tubercle situated a little behind the lateral end of the tuberculum sellæ. In some skulls it is a large process and joins the anterior clinoid process (Fig. 138, 8), converting the termination of the carotid groove into a foramen, called the **carotico-clinoid foramen.** Occasionally it joins the posterior clinoid process instead, or it may branch and join both the anterior and the posterior clinoid process.

The **optic foramen** is a short, wide, nearly circular canal which passes in a lateral direction, forwards and slightly downwards from the cranial cavity into the orbit, and transmits the optic nerve and the ophthalmic artery. It is bounded by the body of the sphenoid and the two roots of the small wing, the thin bone of the body separating it from the sphenoidal sinus.

The **optic groove** or sulcus chiasmatis connects the two optic foramina. The optic chiasma, which connects the two optic nerves, does not, however, lie in the groove, but is situated a little distance above it; therefore "sulcus chiasmatis" is not an appropriate name.

The **hypophyseal fossa** lodges the hypophysis and is roofed over by a fold of dura mater called the diaphragma sellæ, which has a hole in the middle of it for the stalk that connects the hypophysis with the brain. The **posterior clinoid processes** give attachment to the anterior ends of the circumferential margin of the tentorium cerebelli.

The cavernous venous sinus lies at the side of the body of the sphenoid on the horizontal part of the **carotid groove**; its centre is opposite a point on the upper border of the zygomatic arch directly above the tubercle of the root of the zygoma; the carotid artery, lying in the carotid groove, is imbedded in the sinus, together with the carotid plexus, the oculo-motor, trochlear, ophthalmic, and abducent nerves, while the maxillary nerve runs forwards towards the foramen rotundum just below the carotid groove and cavernous sinus. Those structures are therefore all related to the body of the sphenoid—the cavernous sinus, the carotid artery, and the maxillary nerve being closely related to it and to the sphenoidal sinus within it. The two cavernous sinuses are connected by anterior and posterior inter-cavernous sinuses which, respectively, cross the back of the **tuberculum sellæ** and the front of the **dorsum sellæ.** The notch between the tuberculum sellæ and the anterior clinoid process is occupied by the carotid artery as it leaves the carotid groove.

Lateral Part of Middle Cranial Fossa.

Each lateral subdivision of the middle cranial fossa is a wide, deep hollow which sinks to the level of the zygomatic arch and lower surface of the body of the sphenoid; it contains the temporal lobe of the brain. The principal parts on the exterior of the skull to which it is related are the orbit *in front,* the temporal fossa *laterally,* and the infra-temporal fossa and the mandibular joint *below.*

The bones in the lateral part of the middle fossa are: (1) The petrous part of the temporal bone, *i.e.* the pyramidal mass of bone forming its posterior wall or boundary; (2) the squamous temporal, in front of the petrous, in the side wall of the fossa and slightly in the floor; (3) the great wing of the sphenoid, partly in the side wall in front of the squamous temporal and partly in the anterior wall and in the floor in front of the petrous temporal. Beyond the limits of the fossa the lower part of the parietal bone lies in the side wall of the cranial cavity above the squamous temporal, and its antero-inferior angle articulates with the top of the great wing.

The *anterior lip* of the hollow is the overhanging posterior margin of the anterior fossa, and it ends laterally, on the side wall, **opposite the pterion.** The *posterior lip* is the upper margin of the petrous temporal; it is channelled lengthwise by a groove, sometimes well defined, but sometimes poorly marked and interrupted, which lodges the superior petrosal venous sinus; close to its medial end there is a wide, very shallow notch, called the *trigeminal notch*, on which the trigeminal or fifth cerebral nerve lies.

Fissura Orbitalis Superior.—The noteworthy feature in the *anterior boundary* of the fossa is the large, oblique gap between the wings of the sphenoid, called the **superior orbital fissure**, which opens into the orbit, where it has been examined already (pp. 134, 135).

The points to be noted in the *floor* are the foramen rotundum, foramen ovale, foramen lacerum, foramen spinosum, and the grooves for the meningeal vessels.

Foramen Rotundum.—The **foramen rotundum** is the round hole situated almost directly below the medial end of the superior orbital fissure; it leads horizontally forwards into the upper part of the pterygo-palatine fossa, and transmits the maxillary nerve; if a pin is pushed forwards through the foramen, and the skull is looked at from the side, the point of the pin will be seen entering the pterygo-palatine fossa. The foramen is situated in the root of the great wing, close to the body of the sphenoid, and is separated only by thin bone from the sphenoidal sinus.

Foramen Ovale.—The **foramen ovale** is nearly half an inch behind the foramen rotundum, near the posterior border of the great wing of the sphenoid; it transmits the mandibular nerve, and has been seen already in the roof of the infra-temporal fossa (pp. 146, 147).

Foramen Spinosum.—The **foramen spinosum**, behind and lateral to the foramen ovale and quite close to it, also has been seen from the infra-temporal fossa: it transmits the middle meningeal vessels.

Sulci Arteriosi.—The **grooves for the middle meningeal vessels** are usually sufficiently distinct to enable one to trace the course of the main trunk of the artery and its branches on the walls of the cranial cavity; their whole course is seen in a skull split into halves without previous removal of the skull cap (Fig. 146, p. 170). The **main groove** begins at the foramen spinosum, runs forwards and in a lateral direction on the part of the squamous temporal that bears the articular tubercle of the lower surface of the skull; and at a varying point, but usually near the side of the skull opposite a point on the upper margin of the zygomatic arch about midway between the acoustic meatus and the margin of the orbit, it divides into an anterior and a posterior branch. The **anterior groove** extends from that point to the anterior inferior angle of the parietal bone *opposite the pterion*; in that region the groove is usually very deep and often roofed over and converted into a tunnel for a short distance; becoming a groove again, it extends upwards and backwards, branching over the parietal bone, the chief branch of the groove taking a line towards the point on the top of the skull midway between nasion and inion. The **posterior groove** extends backwards and upwards across the squamous temporal on to the parietal bone, branching as it goes, the chief branch taking a line towards the lambda. The meningeal vessels, since they are so closely related to the bone, are liable to be torn when the skull is injured during life, especially the veins, for they lie between the arteries and the bone. The chief point of danger is at the pterion where the anterior branch is lodged in a deep groove and may lie in a tunnel. The grooves are in the inner table of the skull bones, which is more brittle than the outer table, and is sometimes called the *vitreous* table on that account; in an injury to the head the brittle, inner table may be cracked and the vessels torn, though the outer table is not broken [*vitreus* = like glass].

Foramen Lacerum.—The **foramen lacerum** is a large hole, with ragged margins, already seen on the lower surface of the skull. Seen in the floor of the cranial cavity, it is situated between the petrous temporal and the sphenoid. The carotid canal opens into it laterally, and the carotid artery crosses it to reach the carotid groove on the sphenoid. A spur of bone, called the **lingula**, projects obliquely backwards from the lateral margin of the carotid groove. In some skulls the lingula is a mere spicule of bone; in others it is long enough to reach the petrous temporal and form a complete lateral boundary for the foramen lacerum. In many skulls the roof of the carotid canal is deficient in bone, or has been partly broken away; in that case the jagged margins of the incomplete roof of the canal are continuous with the margins of the foramen lacerum. The posterior end of the **pterygoid canal** is found on the anterior margin of the foramen lacerum almost directly below the lingula.

The *posterior wall* or boundary of the lateral part of the middle cranial fossa is formed by the anterior face of the petrous temporal, and is nearly triangular in outline; the parts to be specially looked for in it are the trigeminal impression, the arcuate eminence, the tegmen tympani, and the hiatus of the facial canal.

Impressio N. Trigemini.—The **trigeminal impression** is a shallow depression, barely wide enough to accommodate a finger tip, situated on the anterior surface of the petrous temporal near its apex or medial extremity, below the trigeminal notch. The semilunar ganglion—the chief ganglion of the trigeminal nerve—lies in it.

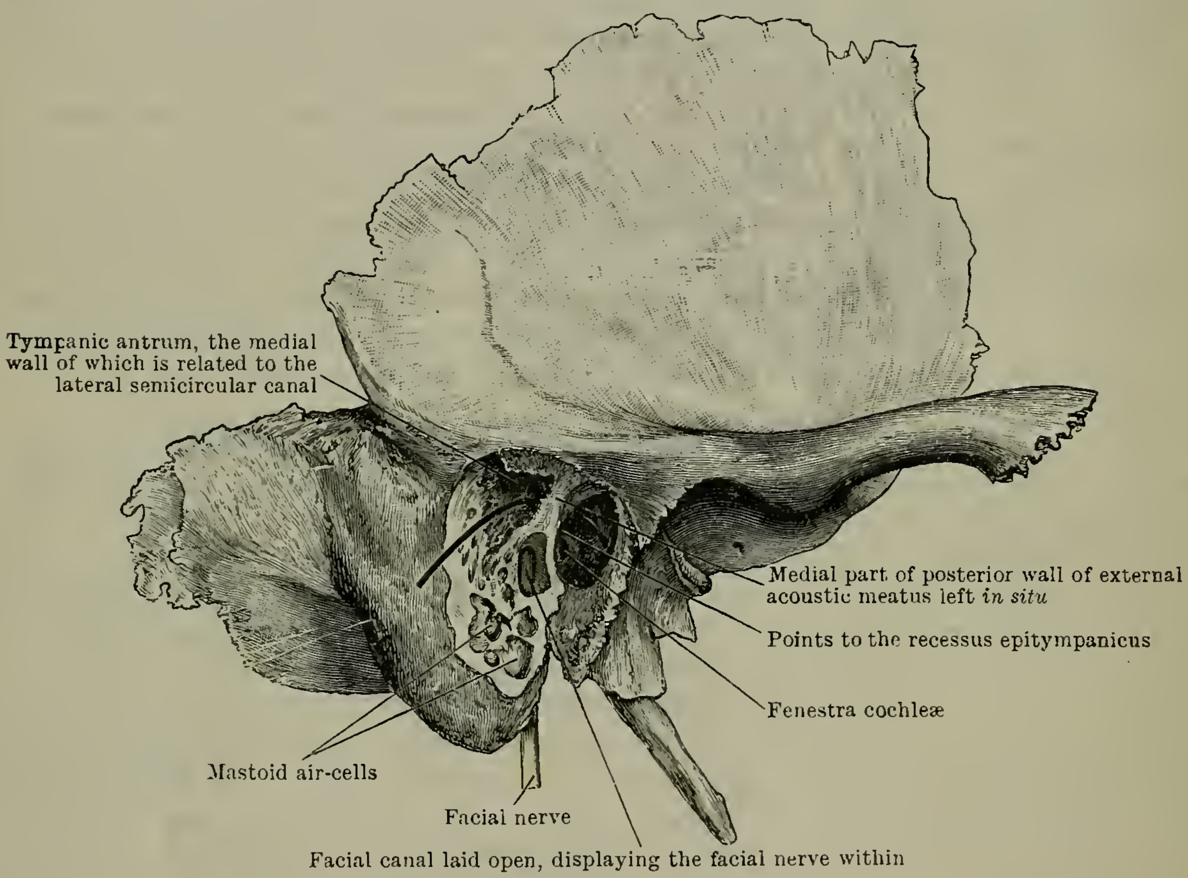

Tympanic antrum, the medial wall of which is related to the lateral semicircular canal
Medial part of posterior wall of external acoustic meatus left *in situ*
Points to the recessus epitympanicus
Fenestra cochleæ
Mastoid air-cells
Facial nerve
Facial canal laid open, displaying the facial nerve within

Fig. 139.

Preparation to display the position and relations of the tympanic antrum. The greater part of the posterior wall of the external acoustic meatus has been removed, leaving only a bridge of bone at its medial extremity; under this a bristle (thick black) is displayed, passing from the tympanic antrum through the iter chordæ posterius to the cavity of the tympanum.

Eminentia Arcuata.—The **arcuate eminence** is a smooth, rounded elevation on the anterior surface of the petrous temporal near its upper margin, a little lateral to a point midway between the apex of the petrous temporal and the side of the skull; sometimes it is diffuse and ill-defined. Underneath it, in the substance of the bone, there is one of the curved canals of the internal ear, called the *superior semicircular canal*, the convexity of whose curve produces the elevation.

Hiatus Canalis Facialis.—The **hiatus of the facial canal** is a small slit situated lower down on the anterior surface, and about midway between the apex of the petrous temporal and the side of the skull. It communicates with the facial canal in the interior of the bone, and transmits a small nerve, called the greater superficial petrosal nerve, which emerges from the hiatus and lies in a groove that runs in a medial direction and downwards and forwards to the foramen lacerum.

Tegmen Tympani.—The **tegmen tympani** is the fairly smooth area of bone forming the lateral part of the anterior surface of the petrous temporal, and is so named because part of it forms the roof of the middle ear or tympanum. It is made of thin bone, and therefore disease in the middle ear has only a short way to travel to attack the membranes of the brain and the brain itself. The tegmen tympani is the roof not only of the tympanum but also of the musculo-tubal canal and the tympanic antrum. The **tympanum** has been seen already at the far end of the external acoustic meatus, and its position relative to the cranial cavity can be gauged from its position as seen through the meatus. The **musculo-tubal canal** runs in a medial direction and downwards and forwards from the tympanum, and it was located when the lower surface of the skull was examined. The **tympanic antrum** is a small but very important cavity, which lies in the substance of the temporal bone behind the tympanum and communicates with the tympanum; it is about half an inch medial to the suprameatal triangle; it communicates posteriorly with the air cells which pervade the mastoid portion of the temporal bone to a greater or lesser extent; the antrum is relatively large at birth; the mastoid cells grow as diverticula from the antrum, commencing at or shortly before birth, but not reaching full development till after puberty. If the student has a specimen of skull of his own, he would not be ill-advised to break through the tegmen tympani carefully and snip it away, in order to see the tympanic antrum and note its relation to the middle ear and to the exterior of the skull.

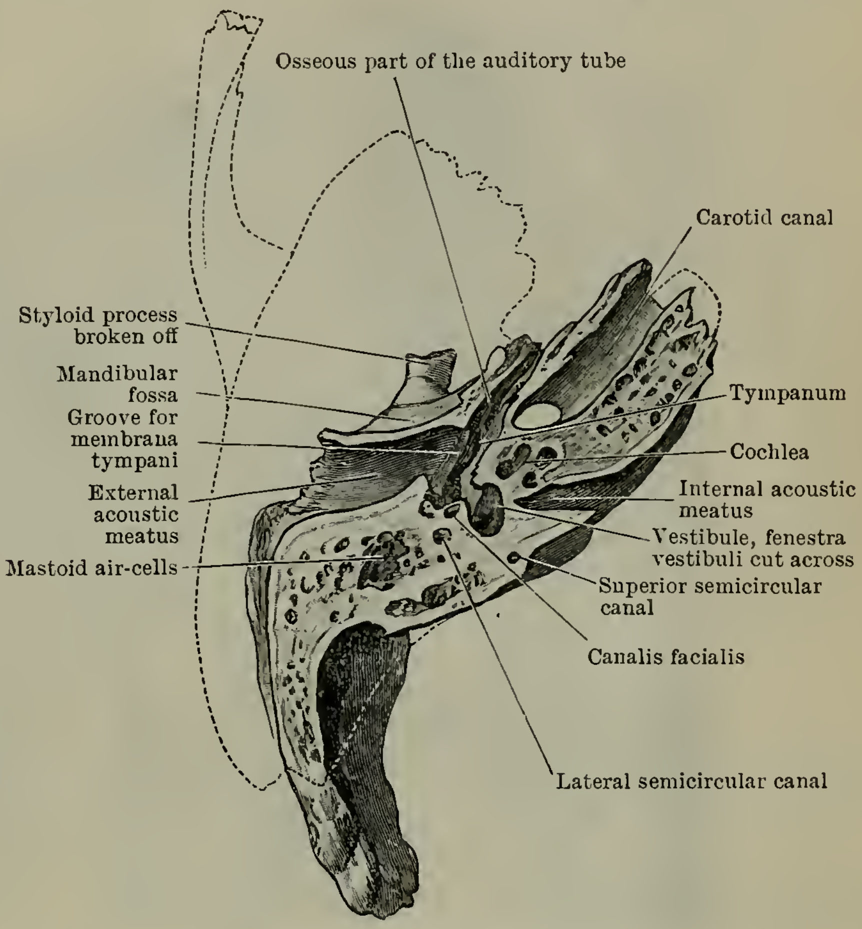

Osseous part of the auditory tube
Carotid canal
Styloid process broken off
Mandibular fossa
Groove for membrana tympani
External acoustic meatus
Mastoid air-cells
Tympanum
Cochlea
Internal acoustic meatus
Vestibule, fenestra vestibuli cut across
Superior semicircular canal
Canalis facialis
Lateral semicircular canal

FIG. 140.—HORIZONTAL SECTION THROUGH THE LEFT TEMPORAL BONE (Lower Half of Section).

The overhanging *anterior lip* of the **lateral part of the middle cranial fossa** has a concave edge which begins medially at the anterior clinoid process and sweeps in a lateral direction and forwards and upwards to end at the side of the skull in the region of the pterion, the groove or tunnel for the anterior branch of the middle meningeal vessels being just behind, or even in, its lateral extremity. The lip is formed chiefly by the small wing of the sphenoid, and is completed laterally by the frontal bone. It fits into the stem of the lateral fissure of the cerebrum, *i.e.* the cleft between the frontal and temporal lobes; therefore the lateral end of the stem, where it breaks up into the rami of the fissure, is opposite the pterion.

The lower margin of the temporal lobe, *i.e.* the anterior part of the infero-lateral margin of the cerebrum, fits into the ill-defined groove that marks the junction of the side wall of the fossa with the floor and posterior boundary; and it corresponds, on the exterior, to a line which begins near the anterior end of the upper border of the zygomatic arch, runs backwards along the upper border of the arch and the posterior root, and is continued backwards a short distance beyond the root to a point which corresponds, in the living head, to the place where the skin of the back of the root of the ear joins the skin of the head.

The **foramen of Vesalius**, when present, is situated a little medial to the foramen ovale.

The **foramen lacerum** is a short wide canal seen both on the lower surface of the skull and in the floor of the middle cranial fossa; the carotid canal opens into it laterally, and the carotid groove begins on its antero-medial boundary. On the **lower surface** it is bounded *postero-laterally* by the petrous temporal, *medially* by the basilar part of the occipital bone and the body of the sphenoid, and *anteriorly* by the root of the great wing and pterygoid process of the sphenoid. **In the cranial cavity** it is bounded *postero-laterally* by the petrous temporal, *medially* and *anteriorly* by the carotid groove on the body and root of great wing of the sphenoid; and the lingula, if long, completes the *lateral* boundary, which is defective if the lingula is short. The foramen *transmits* a meningeal branch of the ascending pharyngeal artery, some meningeal lymph vessels, and small veins connecting the cavernous sinus with the pharyngeal venous plexus. It *contains* (1) some cartilage, (2) the internal carotid artery, surrounded by the internal carotid plexus of sympathetic nerves and a plexus of tiny veins connecting the cavernous sinus and pharyngeal plexus, (3) the great deep petrosal nerve, the termination of the greater superficial petrosal nerve, and the beginning of the nerve of the pterygoid canal. The cartilage fills the lower part of the foramen, and is pierced by the structures transmitted. The internal carotid artery, after it emerges from the carotid canal and as it bends up into the cranial cavity to enter the cavernous sinus, lies on the upper surface of the cartilage. While in the foramen the carotid nerve plexus gives off the great deep petrosal nerve. The greater superficial petrosal nerve, a branch of the facial, runs in a groove on the anterior surface of the petrous temporal from the hiatus canalis facialis to the foramen lacerum, and joins the great deep nerve to form the nerve of the pterygoid canal, which traverses that canal and joins the spheno-palatine ganglion.

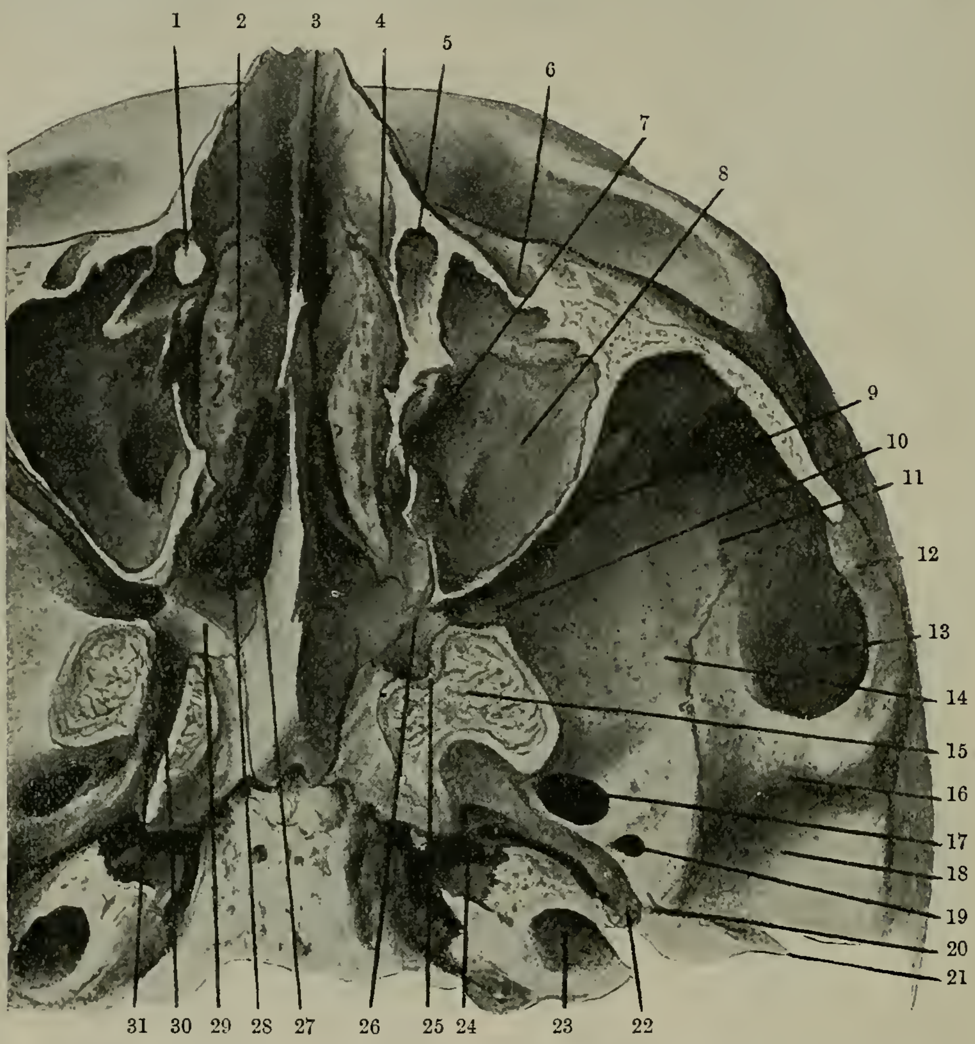


FIG. 141.—HORIZONTAL SECTION A LITTLE BELOW THE LEVEL OF ORBIT.

1. Naso-lacrimal canal.
2. Middle concha.
3. Nasal septum.
4. Middle meatus of nose.
5. Naso-lacrimal canal.
6. Infra-orbital canal.
7. Opening into maxillary sinus from the middle meatus of the nose.
8. Roof of maxillary sinus.
9. Inferior orbital fissure.
10. Passing through pterygo-maxillary fissure into pterygo-palatine fossa and ending opposite opening of foramen rotundum.
11. Infra-temporal crest of great wing of sphenoid.
12. Zygomatic arch.
13. Squamous part of temporal.
14. Infra-temporal surface of great wing of sphenoid.
15. Cut pterygoid process.
16. Tuberculum articulare.
17. Foramen ovale.
18. Mandibular fossa.
19. Foramen spinosum.
20. Spine of sphenoid.
21. Petro-tympanic fissure.
22. Opening of bony canal of auditory tube.
23. Carotid canal.
24. Foramen lacerum.
25. Anterior opening of pterygoid canal.
26. Roof of pterygo-palatine fossa just above spheno-palatine foramen.
27. Superior concha.
28. Superior meatus of the nose.
29. Placed in position of spheno-palatine foramen.
30. Placed in the pterygo-palatine fossa near the upper part of the pterygo-maxillary fissure.
31. Pterygoid canal laid open.

The **pterygoid canal** is a narrow horizontal tunnel, about half an inch long, which traverses the combined root of the pterygoid process and great wing of the sphenoid, and transmits the nerve of the pterygoid canal and an artery of the same name derived from the third part of the internal maxillary artery. The posterior end of the canal opens on the anterior margin of the foramen lacerum below the lingula and above the pterygoid tubercle. The anterior end opens on the posterior wall of the pterygo-palatine fossa below and medial to the foramen rotundum.

The motor and sensory roots of the trigeminal nerve cross the **trigeminal notch** and enter the **trigeminal impression** on the roof of the medial end of the carotid canal, where the sensory root joins the semilunar ganglion; the ganglion also lies partly in the impression and partly overlaps the carotid artery in the foramen lacerum. Three large nerves spring from the ganglion—the ophthalmic, which runs forwards towards the superior orbital fissure but divides into branches before it gets there; the maxillary, which runs forwards to the foramen rotundum; and the mandibular, which descends to the foramen ovale. The motor root runs under cover of the ganglion and is incorporated in the mandibular nerve either at the foramen ovale or just below it.

The **hiatus canalis facialis** transmits the greater superficial petrosal nerve and the petrosal branch of the middle meningeal artery. The nerve runs in a groove medially and forwards, and has to pass under cover of the semilunar ganglion or the mandibular nerve as it approaches the foramen lacerum.

Below the hiatus there is a small aperture through which the lesser superficial petrosal nerve issues from the substance of the temporal bone; continuous with the aperture there is a narrow groove which runs medially, forwards and downwards to the suture between the petrous temporal and the great wing of the sphenoid. The aperture and the groove are often very difficult to identify. The nerve lies in the groove and leaves the skull either through that suture or through the foramen ovale, or through the **canaliculus innominatus**, which, when present, is situated behind the foramen ovale.

Occasionally the remains of the *petro-squamous suture* can be seen in the adult near the side wall of the skull.

The **tympanum**; the **internal ear**, which lies in the substance of the petrous temporal medial to the tympanum; the **musculo-tubal canal**, which opens out of the anterior part of the tympanum and is divided by a septum into an *auditory tube* and a *canal for the tensor tympani* muscle; the **tympanic antrum**, situated behind the tympanum; and the **mastoid air cells**, which communicate with the antrum—are all described fully in the chapter on Sense Organs.

Fossa Cranii Posterior.

The **posterior cranial fossa** lies above the vertebral column and the muscles of the back of the neck. It is the largest and deepest of the cranial fossæ, and it lodges the hind-brain, *i.e.* cerebellum, pons, and medulla oblongata.

The **bones** which form the walls of the fossa are: (1) the posterior part of the body of the **sphenoid**, including the *dorsum sellæ*; (2) the posterior surface of the **petrous temporal**; (3) the cerebral surface of the **mastoid temporal**, in the side wall behind the petrous temporal; (4) the posterior inferior angle of the **parietal bone**, above the mastoid temporal; (5) the whole of the **occipital bone**, except the part of the squama that lies above the level of the external occipital protuberance and the superior nuchal lines: the **basilar part** of the occipital bone is situated in the anterior wall of the fossa, above and in front of the foramen magnum, which occupies the lowest part of the floor; the **lateral part**, including the jugular process, lies in the floor, at the side of the foramen magnum; the lower, larger part of the **squama** lies in the floor, in the side wall, and in the posterior wall, behind the foramen magnum, behind the lateral part and behind the mastoid temporal and inferior angle of the parietal bone. In an adult over 25 years the basilar part is fused with the body of the sphenoid, the line of fusion being barely half an inch below the root of the dorsum sellæ.

The **rim** of the fossa is formed by: (1) the **dorsum sellæ**, in the middle in front; (2) in the middle posteriorly, a prominent elevation, called the **internal occipital protuberance**, which is nearly opposite the external protuberance; (3) the **upper margin of the petrous temporal**, on each side in front; (4) on each side, posteriorly, a broad, shallow, horizontal groove, called the **transverse sulcus**, which begins at the side of the internal occipital protuberance, and passes laterally and forwards to the base or lateral end of the petrous temporal; at that point it leaves the rim to become continuous with a deeper groove, called the sigmoid sulcus, which extends sinuously to the jugular foramen; the horizontal part of a large venous sinus, called the transverse sinus, lies in the transverse groove, and the sigmoid part of that sinus lies in the sigmoid groove.

A wide fold of the inner layer of the dura mater, shaped like a tent and called the **tentorium cerebelli**, roofs over the posterior cranial fossa and keeps the weight of the hinder part of the cerebrum off the cerebellum. The circumferential or basal margin of the tentorium is attached to the lips of the transverse groove and the lips of the groove for the superior petrosal sinus on the upper margin of the petrous temporal.

The fossa is divisible into a median part and a right and a left lateral part.

MEDIAN PART OF POSTERIOR CRANIAL FOSSA.

The parts to be noted in the median subdivision are the foramen magnum, the hypoglossal canals, the jugular tubercles, the clivus, the grooves for the inferior petrosal sinuses, and the internal occipital crest.

Foramen Occipitale Magnum.—The **foramen magnum** is in the lowest part of the fossa. The medial surface of the occipital condyle can be seen at the anterior part of the margin on each side, and in many skulls the condyles encroach upon the foramen and reduce the width of its anterior part. (See also p. 148.)

Canalis Nervi Hypoglossi.—The internal opening of the **canal for the hypoglossal nerve** is situated a little above the part of the margin of the foramen magnum that is formed by the condyle. The opening is rather hidden unless the skull is tilted; and it is often double on one or both sides. The external opening has been seen already on the lower surface of the skull (p. 149).

Tuberculum Jugulare.—The **jugular tubercle** is the smooth rounded elevation situated above and in front of the internal opening of the hypoglossal canal.

Clivus.—The **clivus** is the broad sloping surface between the anterior margin of the foramen magnum and the root of the dorsum sellæ; it is formed by the upper surfaces of the basilar part of the occipital bone and of the posterior part of the body of the sphenoid; it is related to the pons and medulla oblongata of the brain [*clivus* = a slope].

Sulcus Petrosus Inferior.—The **groove for the inferior petrosal sinus** lies along the suture between the basilar part of the occipital bone and the petrous temporal, and is shared by both bones.

Crista Occipitalis Interna.—The **internal occipital crest** is the strong median ridge between the foramen magnum and the internal occipital protuberance.

The hypoglossal nerve pierces the dura mater as two bundles which unite in the **hypoglossal canal.** When the opening of the canal is double, the two bundles may enter the canal separate, or they may both enter through one of the openings, while the other transmits a meningeal artery.

The **jugular tubercle** overlies the hypoglossal canal; immediately behind and lateral to the tubercle there is a short, shallow groove in which the ninth, tenth, and eleventh cerebral nerves lie, as they pass towards the jugular foramen.

The **clivus** is concave from side to side. Its upper part is related to the pons and the basilar artery, its lower part to the medulla oblongata and the vertebral arteries, and, near the foramen magnum, it is roughened by the attachments of the membrana tectoria and the upper limb of the cruciate ligament. Between the two layers of the dura mater that cover the clivus there are some venous channels, called the basilar plexus, which connect the right inferior petrosal sinus with the left. The abducent nerve, on each side, pierces the inner layer of the dura mater near the lateral margin of the clivus, about half an inch below the dorsum sellæ, and runs upwards on the clivus, between the two layers of dura mater, to the groove on the side of the root of the dorsum sellæ, where it enters the cavernous sinus.

The **groove for the inferior petrosal sinus** begins at the apex of the petrous temporal, *i.e.* at the medial end of its upper border, where the sinus is connected with the posterior end of the cavernous sinus; it runs obliquely downwards, backwards, and in a lateral direction along the petro-occipital suture, to the jugular foramen, where the sinus, descending through the antero-medial part of the foramen, joins the commencement of the internal jugular vein.

The **internal occipital crest** gives attachment to a small fold of the inner layer of dura mater, called the falx cerebelli, which intervenes between the two hemispheres of the cerebellum. A small venous sinus, called the occipital sinus, lies along the edge of the crest between the two layers of the falx; sometimes the sinus is paired. The lower or anterior end of the crest sometimes divides into two parts which form the boundaries of a small depression called the **vermian fossa**, because a part of the cerebellum called the vermis is related to it.

The tentorium cerebelli, the falx cerebri, and the falx cerebelli are attached to the **internal occipital protuberance**; in its immediate neighbourhood the superior sagittal sinus and the straight sinus end, and the transverse sinuses and the occipital sinus begin; the posterior end of the cerebrum is immediately above and lateral to it. The internal occipital protuberance is seldom directly opposite the external protuberance, but there is so little difference in their levels that the external protuberance is usually taken as the surface guide to the position of structures near the internal protuberance. Owing to the two protuberances, that region of the occipital bone is one of the thickest parts of the skull.

Lateral Part of Posterior Cranial Fossa.

The chief parts to be noted in each lateral subdivision of the posterior cranial fossa are the cerebellar fossa, the transverse and sigmoid grooves, the jugular foramen, the condyloid canal, the mastoid foramen, and the internal acoustic meatus. Points of less importance are the grooves for the meningeal arteries, the openings of the aqueduct of the cochlea and aqueduct of the vestibule, and the subarcuate fossa.

The **cerebellar fossa** is the wide concavity between the transverse groove and the foramen magnum. Faint grooves produced by meningeal arteries may be seen in its floor.

Sulcus Transversus.—The **transverse groove** begins at the side of the internal occipital protuberance and sweeps round the wall of the cranial cavity to the lateral end of the upper margin of the petrous temporal, where it joins the sigmoid groove.

Sulcus Sigmoideus.—The **sigmoid groove** curves downwards and descends along the side wall of the skull to the floor, extends in a medial direction on the floor for an inch, and, finally, curves forwards to end at the jugular foramen. Its curves resemble those of the letter S; hence the name "sigmoid" [*sigma* is the Greek name for the letter S].

The position of the two grooves corresponds, on the exterior of the skull, to a line (1) which begins at the side of the external occipital protuberance, and is drawn almost horizontally, but with a slight upward convexity, to a point a little behind the place where the posterior root of the zygoma joins the supramastoid crest, and that point, on the living head, is where the skin of the upper part of the back of the root of the auricle joins the skin of the head; (2) from that point the line is drawn almost vertically downwards to a point about a finger's-breadth behind the lower margin of the external acoustic meatus; (3) from there, forwards to the lower border of the meatus. The first or horizontal part of the line is opposite the horizontal part of the transverse sinus and the attachment of the tentorium; the posterior part of the infero-lateral border of the cerebrum is just above it; the margin of the cerebellum is just below it. The second and third parts of the line correspond to the sigmoid part of the transverse sinus.

The sigmoid groove is deeper than the transverse groove; in some skulls its upper part is especially deep, at the expense of the petrous temporal, so that it is quite close to the tympanic antrum, and the sigmoid sinus in such a case is in considerable danger in an operation on the antrum.

The **mastoid foramen** is an aperture of variable size that leads from the exterior of the skull (p. 136) into the sigmoid groove on the side wall of the fossa. The **condyloid canal**, when present, passes from the condyloid fossa (p. 149) into the posterior cranial fossa and opens into or near the sigmoid groove on the floor of the fossa.

Eminentia Cruciata.—The posterior part of each transverse groove is situated on a thick, blunt ridge that extends in a lateral direction from the internal occipital protuberance for some distance. Above that ridge, on the posterior wall of the cranial cavity, there is a wide, well-marked depression, called the *posterior cerebral fossa*, which lodges the posterior end of the occipital lobe of the cerebrum. The right cerebral fossa is separated from the left by a thick vertical ridge which descends to the internal occipital protuberance. Along that ridge the sagittal groove, seen already on the vault of the skull, runs down to the protuberance and becomes continuous with one or other of the transverse grooves, usually the right; occasionally it splits and becomes continuous with both transverse grooves. The transverse ridges, the sagittal ridge, and the internal occipital crest culminate and meet at the protuberance, and together with the protuberance are called the **eminentia cruciata.**

The **transverse groove** begins at the internal occipital protuberance, passes across the occipital squama to its lateral angle, and then passes on to the mastoid temporal and the truncated posterior inferior angle of the parietal, grooving only a small part of the parietal angle. There it becomes the **sigmoid groove**, which turns downwards grooving the mastoid temporal and the petrous temporal, where it is separated by very thin bone from the mastoid air cells and may be very close to the tympanic antrum; reaching the floor, it passes off the mastoid temporal on to the upper surface of the jugular process of the occipital bone, on which it passes first in a medial direction and then forwards to the jugular foramen.

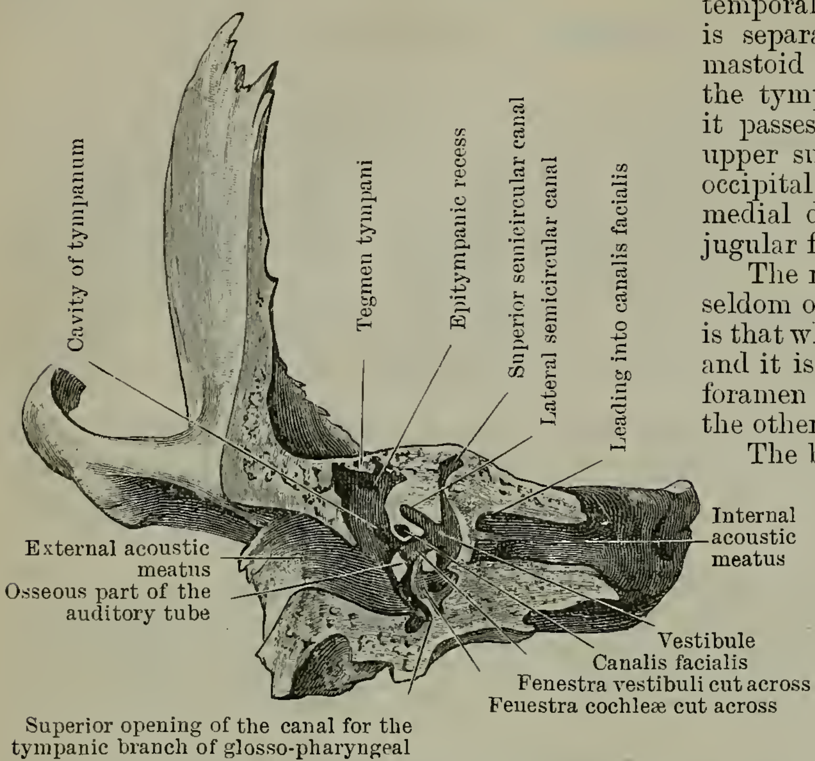

Cavity of tympanum
Tegmen tympani
Epitympanic recess
Superior semicircular canal
Lateral semicircular canal
Leading into canalis facialis
Internal acoustic meatus
External acoustic meatus
Osseous part of the auditory tube
Vestibule
Canalis facialis
Fenestra vestibuli cut across
Fenestra cochleæ cut across
Superior opening of the canal for the tympanic branch of glosso-pharyngeal

Fig. 142.—Vertical Transverse Section through the Left Temporal Bone (Anterior Half of Section).

The right and left transverse grooves are seldom of equal size; the wider of the two is that which is joined by the sagittal groove, and it is usually the right; and the jugular foramen also is wider on that side than on the other.

The basal margin of the **tentorium cerebelli** is attached to the internal occipital protuberance, to the lips of the transverse groove, to the lips of the narrow, ill-marked groove along the upper margin of the petrous temporal, and then is prolonged medially to be attached to the posterior clinoid process. Along the transverse groove it encloses the horizontal part of the transverse sinus; along the margin of the petrous temporal it encloses the superior petrosal sinus, which runs from the cavernous sinus to the transverse sinus; and at the trigeminal notch the trigeminal nerve crosses beneath the sinus and the margin of the tentorium. The internal margin of the tentorium, *i.e.*, the margins of the door of the tentorium, is continued forwards, on each side, across the attached, basal margin at the apex of the petrous temporal, to be fastened to the anterior clinoid process.

Sulci Arteriosi.—Faint narrow grooves are seen here and there in the walls of the posterior cranial fossa for the posterior meningeal vessels, which are derived from the vertebral, the occipital, and the ascending pharyngeal arteries; and some twigs of the posterior branch of the middle meningeal artery may descend into the fossa.

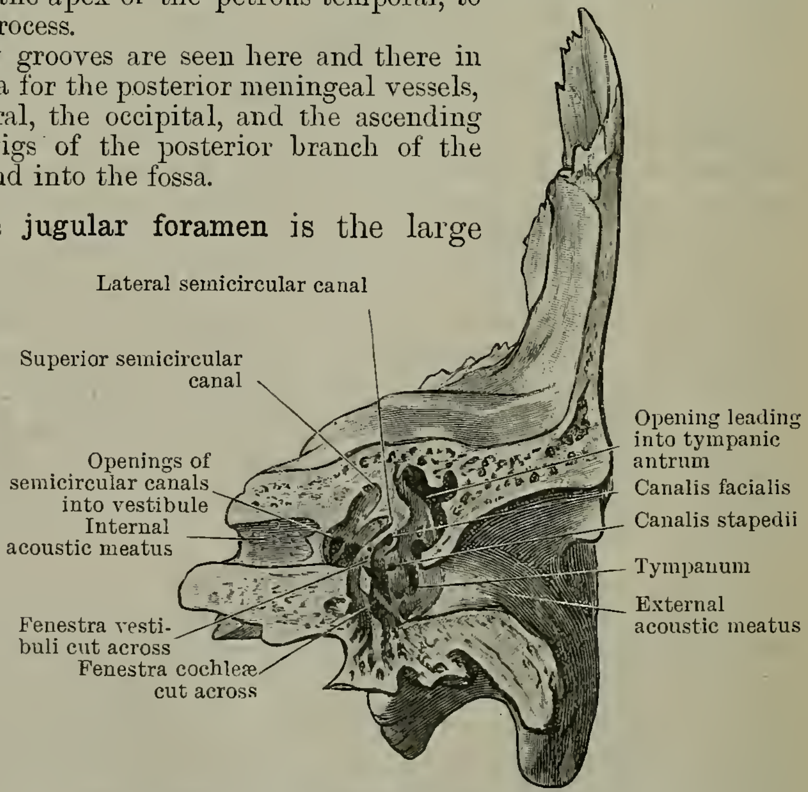

Lateral semicircular canal
Superior semicircular canal
Openings of semicircular canals into vestibule
Internal acoustic meatus
Fenestra vestibuli cut across
Fenestra cochleæ cut across
Opening leading into tympanic antrum
Canalis facialis
Canalis stapedii
Tympanum
External acoustic meatus

Fig. 143.—Vertical Transverse Section through the Left Temporal Bone (Posterior Half of Section).

Foramen Jugulare.—The **jugular foramen** is the large aperture, with irregular margins, situated between the petrous temporal and the jugular process of the occipital bone, in the anterior and medial part of the floor of the lateral subdivision of the fossa. It leads downwards and slightly forwards to the lower surface of the skull, where it is opposite the lower margin of the external acoustic meatus.

The **jugular foramen** transmits three sets of structures, and small spicules of bone projecting from its margins may partly or completely divide it into corresponding compartments. By far the most important structures that pass through the foramen are the transverse sinus and the ninth, tenth, and eleventh cerebral nerves. The *antero-medial compartment* transmits the inferior petrosal sinus and a meningeal branch of the ascending pharyngeal artery. The *middle compartment* transmits the glosso-pharyngeal, vagus, and accessory nerves, in that order from before backwards. The *postero-lateral compartment* is larger than the other two, and transmits the sigmoid part of the transverse sinus as it becomes the internal jugular vein, a meningeal branch of the occipital artery, a meningeal branch of the vagus, and lymph vessels from the meninges. (See also p. 151.)

Meatus Acusticus Internus.—The posterior surface of the petrous temporal forms the anterior wall of the lateral part of the fossa; the only conspicuous aperture in it is the oblique opening of the **internal acoustic meatus** (Fig. 146, 34, p. 170). The meatus is a short canal in the petrous temporal, nearly horizontal and nearly transverse; its lateral end is separated by thin bone from the internal ear.

The **internal acoustic meatus** is about 8 mm. long and 3 to 5 mm. wide. It transmits the motor and sensory parts of the facial nerve, the acoustic nerve, the internal auditory branch of the basilar artery and the internal auditory vein, which joins the inferior petrosal sinus. The lateral end of the meatus is called the **fundus** or bottom. The part of the petrous temporal bone that forms the fundus separates the meatus from the vestibule and cochlea of the internal ear, and is called the **lamina cribrosa**, because there are several apertures in it which transmit the auditory vessels and the facial and acoustic nerves. If the skull has been split into halves so that one can see into the meatus, the lamina cribrosa and the holes in it are visible at the far end. The position of the internal ear can be gauged by an examination of the meatuses. The lamina cribrosa, seen at the bottom of the internal meatus, is the medial wall of the internal ear. The lateral wall of the internal ear is the medial wall of the tympanum or middle ear; that wall can be seen through the external acoustic meatus, and the bulge called the promontory seen there is produced by the basal curve of the cochlea, which is coiled like a snail shell [κοχλίας (cochlias) = a snail, a spiral]. The arcuate eminence of the anterior surface of the petrous temporal also is a guide, for it overlies the superior semicircular canal, which stands up from the posterior part of the vestibule of the inner ear like the handle of a pail. At the bottom of the internal meatus the facial nerve passes through one of the holes in the lamina cribrosa and enters the facial canal, which conducts it through the temporal bone, passing first in a lateral direction, above the vestibule, to the anterior part of the upper border of the medial wall of the tympanum, then backwards along the upper border of the medial wall, and finally downwards behind the tympanum to appear as the stylo-mastoid foramen on the lower surface of the skull.

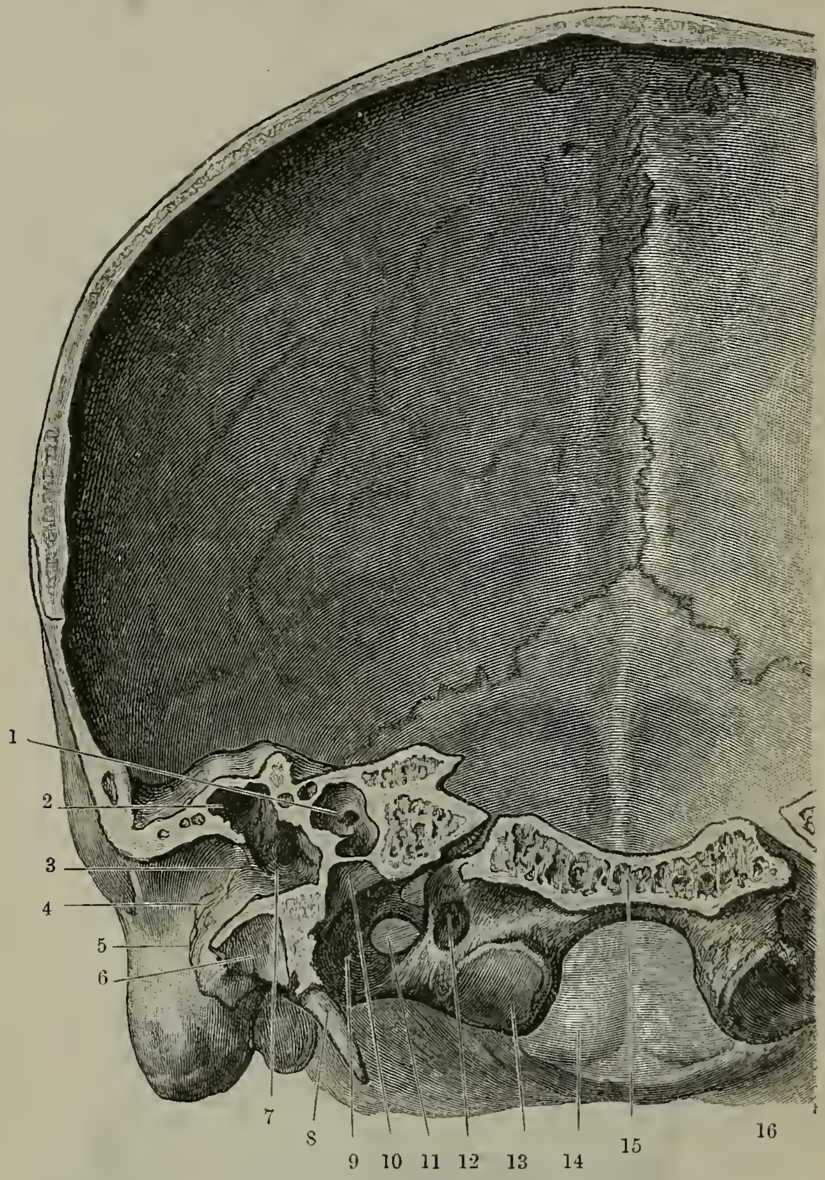


FIG. 144.—VERTICAL SECTION THROUGH THE SKULL IMMEDIATELY IN FRONT OF THE ROOT OF THE STYLOID PROCESS.

1. Cochlea.
2. Entrance to the antrum.
3. Sulcus tympanicus.
4. Tympanic plate.
5. Tympano-mastoid fissure.
6. Tympanic plate.
7. Tympanic cavity (floor).
8. Styloid process.
9. Jugular fossa.
10. Lower end of carotid canal.
11. Jugular foramen.
12. Canalis hypoglossi.
13. Occipital condyle.
14. Foramen magnum.
15. Basi-occipital.
16. Squama of occipital bone.

Apertura Externa Aquæductus Vestibuli.—A narrow canal about 8 mm. long, called the **aqueduct of the vestibule**, passes backwards from the vestibule and opens on the posterior surface of the petrous temporal into a small slit seen about half an inch lateral to the opening of the internal meatus; the slit is overhung by a thin lip of bone. The canal transmits a tiny artery and vein and a delicate membranous tube called the ductus endolymphaticus, which emerges from the external aperture of the canal and dilates to form a blind bag, called the saccus endolymphaticus, which lies under cover of the dura mater.

Fossa Subarcuata.—The **subarcuate fossa** is a small ill-defined depression about midway between the opening of the meatus and the aperture of the aqueduct, but at a higher level than either of them. It is larger and better defined in the skull of a child than of an adult (Fig. 168, c, p. 201). Small vessels pass through its floor into the bone.

Apertura Externa Aquæductus Cochleæ.—On the anterior margin of the jugular foramen, directly below the opening of the internal meatus, there is a small pit hidden under an overhanging lip of bone, but may in some specimens be seen from the lower surface of the skull. At the bottom of the pit there is the external opening of the **aqueduct of the cochlea**, a narrow canal about 15 mm. long, which leads from the cochlea and conducts a small vein to the inferior petrosal sinus and a tubular prolongation from the dura mater to the cochlea.

CAVUM NASI.

The term **Nose** includes not only the **external nose**, which juts from the face, but also the **cavity of the nose**, of which merely a small part lies in the external nose.

The **cavity of the nose** extends from the choanæ on the base of the skull to the apertura piriformis on the front, or to the nostrils, when the soft parts are in place. It lies above the cavity of the mouth, being separated therefrom by the hard palate; and it lies below the anterior and middle cranial fossæ and the frontal and sphenoidal air sinuses. In round numbers of millimetres, its length varies from 50 mm. at the floor to 75 mm. at the roof; its greatest height, about its middle, is 50 mm., and it diminishes to 30 mm. at the apertura piriformis and 25 mm. at the choana.

It is divided into **right** and **left halves** by a median partition or **septum**, and the term "cavity of nose" or "nasal cavity" is applied sometimes to the whole cavity and sometimes to one or other of the halves, the context interpreting which is meant. Each of the two cavities is narrow from side to side, the widest part, near the floor, measuring only about 10 mm., while near the roof, except in its posterior section, it is only 1 or 2 mm.

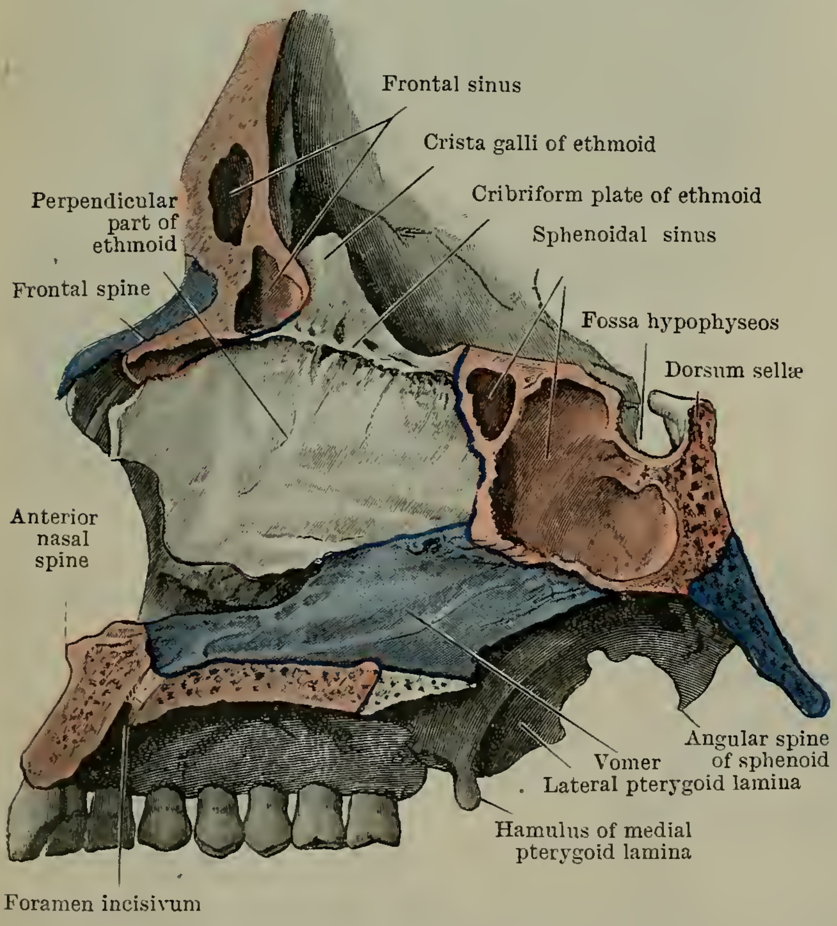


FIG. 145.—ROOF, FLOOR, AND SEPTUM OF NOSE.

The frontal, maxillary, and sphenoid bones are coloured red; the nasal, vomer, and basi-occipital blue; the perpendicular part of the ethmoid and the horizontal part of the palatine bone are left uncoloured.

Boundaries of Nasal Cavity.—Each of the two nasal cavities has a *roof*, a *floor*, a *lateral* wall, and a *medial* wall, which is the septum between the two cavities.

The **roof** is very narrow from side to side except at its posterior end. It is horizontal in the middle, but slopes downwards in front and behind, so that the anterior and posterior parts of the cavity are of lesser vertical depth than the middle part. The **middle**, horizontal part consists of the cribriform plate of the ethmoid. The **anterior** sloping part is formed by a small part of the frontal bone and by the nasal bone below that; and, still lower down, when the soft parts are in place, by the cartilages of the nose. The **posterior** sloping part—a very steep slope—is formed by the anterior and inferior surfaces of the body of the sphenoid.

The **roof of each nasal cavity**, in nearly the whole of its length, is only 1 or 2 mm. in width, but its most posterior part, which is formed by the lower surface of the body of the sphenoid, measures about 10 mm. across; in a dried skull, that is also the lowest part of the roof, being on a level with the zygomatic arch at the side of the skull. Though the anterior part of the lower surface of the body of the sphenoid is reckoned as part of the roof, yet the ala of the vomer and the sphenoidal process of the palatine bone, which are closely applied to it, shut it off from the nasal cavity, and are the actual bones clothed with the muco-periosteum of the posterior part of the roof. The **pharyngeal canal** is situated in that part of the roof, between the sphenoidal process and the body of the sphenoid.

The part of the roof formed by the anterior surface of the body of the sphenoid looks forwards rather than downwards, and diminishes to 2 mm. in width as it is traced upwards and forwards, for the greater part of each half of the front of the body of the sphenoid articulates with the labyrinth of the ethmoid, leaving the smaller part alongside the median plane free to form a boundary for the nasal cavity. In that area there is a round opening of considerable size which leads back into the *sphenoidal sinus*.

The anterior surface and anterior part of the lower surface of each half of the body of the sphenoid is formed by bone which in early life is separate and is called the *sphenoidal concha*.

The part of the nasal cavity which is highest, and also nearest the cranial cavity, is the middle part; it is roofed by the cribriform plate, which is at the level of the nasion, and is perforated by the olfactory nerves; infection from a diseased nose has, at that part, only a very short distance to travel to reach the brain and its membranes.

The small nasal surface of the frontal bone appears in the roof of the nose in front of the cribriform plate and separates the nasal cavity from the frontal sinus; it slopes downwards and forwards to the nasal bone, those two bones forming the anterior sloping part of the roof, along which the anterior ethmoidal nerve, with companion vessels, runs downwards and forwards to emerge between the nasal bone and cartilage, under the name of the external nasal nerve, for the supply of the skin of the lower half of the external nose; the nerve leaves a narrow groove on the surface of bone on which it runs.

The **floor** is smooth, nearly horizontal from before backwards, and slightly concave from side to side. It is considerably wider than the roof, measuring 10-12 mm. across, and is slightly wider in the middle than at either end. It is shorter than the roof, for the choanæ slope from above downwards and forwards, while the apertura piriformis slopes downwards and backwards. Its posterior fourth or third is formed by the horizontal part of the palatine bone, and the remainder by the palatine process of the maxilla. Near the front, close by the septum, is the opening of the incisive canal, which is covered over with mucous membrane before maceration. The **incisive canal** passes downwards through the bone and divides into the foramina of Stensen and Scarpa, which open into the incisive foramen on the hard palate.

The three chief constituents of the **septum** are: (1) the perpendicular lamina of the ethmoid, situated above and behind; (2) the vomer, situated below and behind; (3) the septal cartilage of the nose, which, in a dried skull, is destroyed; it is situated anteriorly, and fills in the wide, angular interval between the other two. The superficial area of the septum is too great for the height of the cavity, and it is therefore bent to one side near its middle, or it is bent first to one side and then to the other.

The **osseous septum** is composed almost entirely of the perpendicular lamina of the ethmoid superiorly and the vomer below and posteriorly, but it is completed by the following small projections: (1) The *sphenoidal crest*, which projects forwards from the median line of the front of the body of the sphenoid to articulate with the perpendicular lamina. (2) The *frontal spine*, which projects from the nasal part of the frontal bone downwards and forwards between the perpendicular lamina and the nasal crest. (3) A *nasal crest* is formed by the lips of the margins of the nasal bones that articulate with each other; that crest articulates, from above downwards, with the frontal spine, the perpendicular lamina, and the septal cartilage. (4) A *nasal crest*, to articulate with the lower edge of the vomer, is formed by sharp ridges that stand up from the horizontal part of the palatine bone and the palatine process of the maxilla, where they articulate with their fellows of the other side. (5) A thicker and higher *incisor crest* stands up from the junction of the alveolar processes of the maxillæ; it articulates posteriorly with the vomer and superiorly with the vomero-nasal cartilage.

The upper part of the perpendicular lamina of the ethmoid shows numerous small branching grooves which lodge olfactory nerves. Indistinct grooves for vessels may be seen on the vomer, and one long groove for the naso-palatine nerve and spheno-palatine vessels, which enter the nose through the spheno-palatine foramen in the lateral wall, cross the roof and run downwards and forwards, grooving the vomer, to reach the incisive canal.

The *cartilaginous septum* is formed almost wholly by the septal cartilage, which, however, is aided by (1) the vomero-nasal cartilage, a small strip along its lower margin; and (2) the medial part of the greater alar cartilage, at the tip of the nose.

The **lateral wall** is very uneven and is composed of several bones, namely, the *nasal*, the *maxilla* and its *frontal process*, the *lacrimal*, the *labyrinth* of the ethmoid and its *conchæ*, the *inferior concha*, the perpendicular part of the *palatine*, and the *medial lamina of the pterygoid process.*

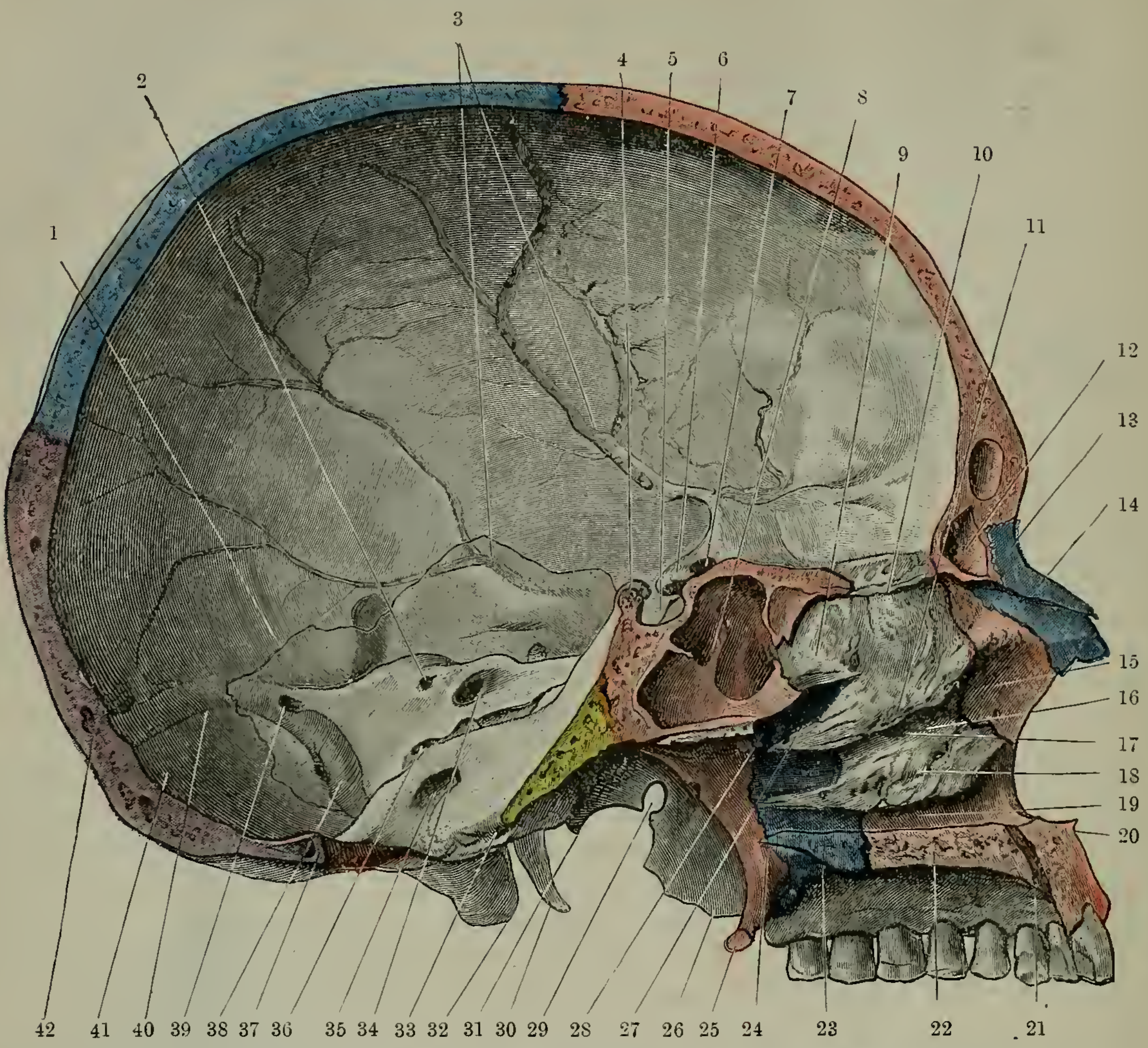


FIG. 146.—MEDIAL ASPECT OF THE LEFT HALF OF THE SKULL SAGITTALLY DIVIDED.

The frontal, maxillary, and sphenoid bones are coloured red; the parietal, nasal, and palatine bones, blue; the basilar part of occipital, yellow, and squama occipitalis, purple. The ethmoid and inferior concha, together with the left ala of the vomer, are left uncoloured.

1. Suture between parietal and temporal bones.
2. Remains of the subarcuate fossa.
3. Grooves for branches of middle meningeal artery.
4. Dorsum sellæ.
5. Hypophyseal fossa.
6. Anterior clinoid process.
7. Optic foramen.
8. Sphenoidal sinus.
9. Nasal surface of superior concha.
10. Cribriform plate of ethmoid.
11. Nasal surface of middle concha.
12. Frontal sinus.
13. Nasal bone near frontal spine.
14. Nasal bone.
15. Frontal process of maxilla in side wall of atrium.
16. Lower part of middle meatus of nose.
17. Directed towards an opening of maxillary sinus.
18. Nasal surface of inferior concha.
19. Inferior meatus of nose.
20. Anterior nasal spine.
21. Foramen incisivum.
22. Palatine process of maxilla.
23. Horizontal part of palatine bone.
24. Posterior nasal spine.
25. Hamulus of medial pterygoid lamina.
26. Lateral pterygoid lamina.
27. Superior meatus of nose.
28. Spheno-palatine foramen.
29. Pterygo-spinous ligament almost completely ossified to enclose a foramen.
30. Styloid process of temporal bone.
31. Angular spine of sphenoid.
32. Mastoid process.
33. Basion (mid-point of anterior border of foramen magnum).
34. Internal acoustic meatus.
35. Canalis hypoglossi.
36. Groove for inferior petrosal sinus leading towards jugular foramen.
37. Opisthion (mid-point of posterior border of foramen magnum).
38. Groove for sigmoid sinus.
39. Opening of mastoid foramen.
40. Groove for transverse sinus and attachment of tentorium cerebelli.
41. Fossa for lodgment of cerebellar hemisphere.
42. Internal occipital protuberance.

The conchæ should be identified at once. The **inferior nasal concha** is the rough plate of bone that projects from the side wall into the lower part of the nasal cavity for a little distance and then curves downwards; it is a separate bone, and if it has been broken away the line along which it was attached is seen as an irregular broken ridge about half an inch above the floor of the nose. The **middle nasal concha** is situated about an inch above the inferior concha, which it resembles; it is not a separate bone, but projects from the ethmoid labyrinth a little way into the nasal cavity and then turns downwards. The **superior nasal concha** also is a projection from the labyrinth. It is much smaller than the other conchæ; it is the small ridge of bone situated a little above the posterior half of the middle concha. If a pair of forceps is passed into the nose and opened vertically, it must be kept close to the septum to prevent the upper leg being intercepted by the conchæ.

The **nasal bone** lies in the anterior and upper part of the lateral wall, as well as in the roof. The **frontal process of the maxilla** lies immediately behind and below the nasal bone. Those two bones form also the bony skeleton of the external nose. The **lacrimal bone**, already seen in the orbit, lies behind the frontal process; only its lower and anterior part appears in the nose.

The **medial lamina of the pterygoid process** is the most posterior bone in the lateral wall of the nose. It forms the lateral boundary of the choana, and has been often referred to already.

The medial surface of the **body of the maxilla** lies in the lower part of the side wall of the nasal cavity, extending from the lower part of the apertura piriformis backwards almost to the medial pterygoid lamina. It is to a large extent concealed by other bones, among which two openings are seen leading into the maxillary sinus.

The **perpendicular part of the palatine bone** lies in the posterior part of the lateral wall in front of the medial pterygoid lamina. The horizontal part is easily identified in the floor. The perpendicular part lies directly above the lateral margin of the horizontal part and extends upwards to the body of the sphenoid in the roof. It is wider, as well as longer, than the horizontal part. It separates the nasal cavity from the pterygo-palatine fossa. Behind that, it overlaps the medial pterygoid lamina; anteriorly, the greater part of it is applied to the posterior part of the medial surface of the maxilla, shutting off that part from the nasal cavity.

The smooth lateral surface of the **labyrinth of the ethmoid** has been seen already in the orbit, behind the lacrimal bone; its rough **medial surface** is now seen in the nose below the cribriform plate, extending from the frontal process of the maxilla to the body of the sphenoid, forming the greater part of the upper half of the lateral wall of the nose. The superior and middle conchæ project from its medial surface; and hidden under cover of the middle concha there is a rounded bulging part of the labyrinth, called the **bulla ethmoidalis**, which can partly be seen when examined from the front [*bulla* = a bubble]. The bulla is bounded in front and below by a curved groove or slit called the **hiatus semilunaris**.

Meatuses of the Nose.—The cavity of the nose is divided into the *common* meatus, the *superior*, *middle*, and *inferior* meatuses, the *naso-pharyngeal* meatus, the *spheno-ethmoidal recess*, and the *atrium* of the middle meatus; and, when the soft parts are in place, the portion above the nostril is called the *vestibule* of the nose.

The **common meatus** is the narrow cleft that separates the septum from the conchæ; it extends from the roof to the floor. The **naso-pharyngeal meatus** is the portion of the cavity behind the conchal region. The **spheno-ethmoidal recess** is the small space above and behind the superior concha. The **superior meatus** is an oblique, cleft-like space in the posterior half of the labyrinth of the ethmoid; its slit-like orifice is below the superior concha and above the middle concha. The **middle meatus** is much larger than the superior; part of it is lateral to the middle concha and part of it is below, extending down to the inferior concha; the lower part is roomy; the part that lies under cover of the middle concha is greatly contracted by the bulging bulla ethmoidalis. The **atrium** of the middle meatus is the wide region in front of the middle meatus [*atrium* = an entrance hall]. The **inferior meatus** is the space lateral to and below the inferior concha.

The **lateral wall** is more uneven and complicated than the other boundaries of the nose;

it is also the most variable and most liable to injury in the dried skull, so that the student may have difficulty in applying any given description to the specimen he is using for study.

The groove made by the anterior ethmoidal nerve may be on the part of the **nasal bone** that lies in the lateral wall, rather than on the part in the roof.

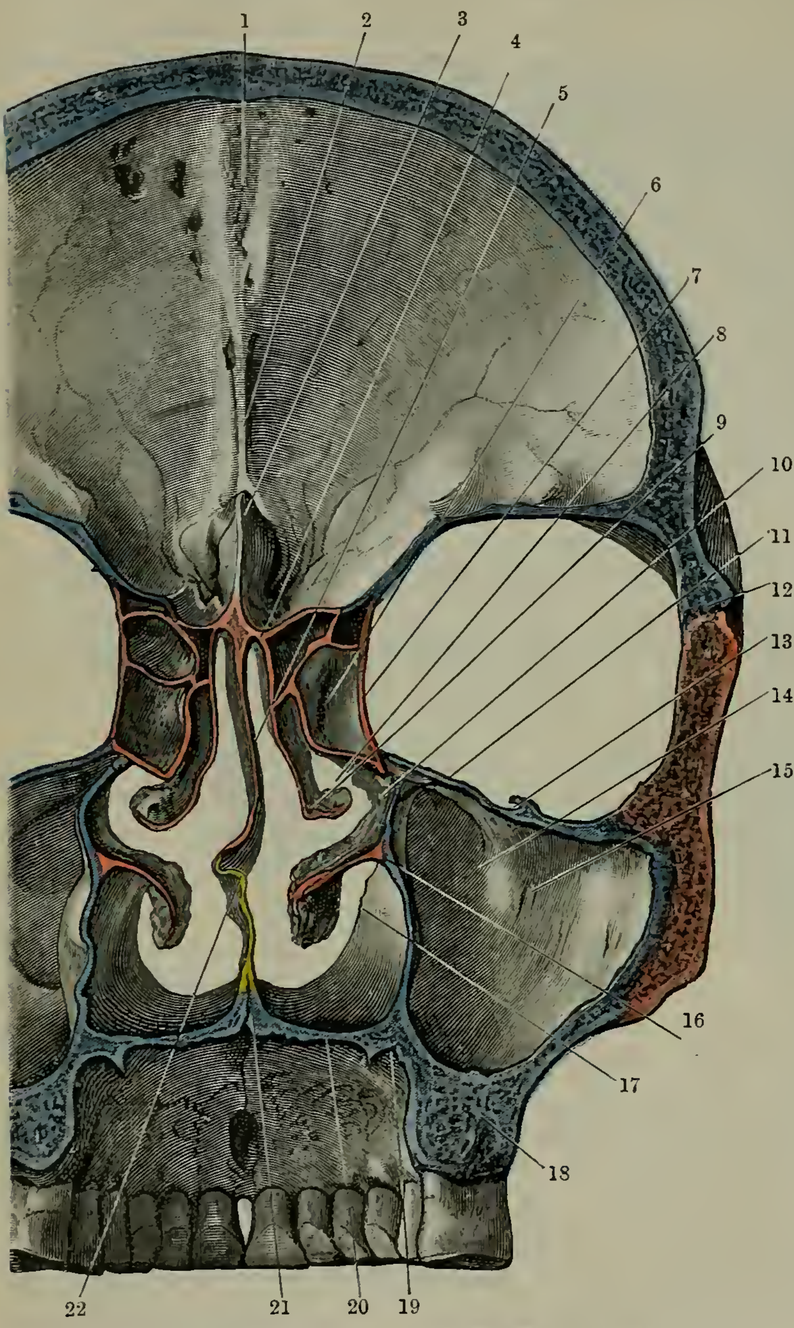


Fig. 147.—Frontal Section passing inferiorly through the Interval between the First and Second Molar Teeth.

The frontal and maxillary bones, where cut, are coloured blue; the ethmoid, inferior conchæ, and zygomatic red; the vomer yellow.

1. Groove for sagittal sinus.
2. Frontal crest.
3. Crista galli of ethmoid.
4. Cribriform plate of ethmoid.
5. Perpendicular part of ethmoid.
6. Labyrinth of ethmoid.
7. Lateral surface of ethmoid.
8. Middle meatus of nose.
9. Middle concha.
10. Opening from middle meatus into maxillary sinus.
11. Orbital surface of maxilla.
12. Zygomatico-frontal suture.
13. Infra-orbital groove.
14. Maxillary sinus.
15. Canal for the anterior alveolar nerve and vessels exposed.
16. Inferior concha.
17. Inferior meatus of nose.
18. Alveolar process of maxilla.
19. Groove for greater palatine nerve and vessels.
20. Palatine process of maxilla.
21. Nasal crest of maxillæ.
22. Vomer.

The **frontal process of the maxilla** presents a wide area which forms the side wall of the *atrium* of the middle meatus. At the lower boundary of that area, where the frontal process joins the body of the maxilla, there is a horizontal ridge, called the *conchal crest*, which articulates with the anterior part of the inferior concha. At the upper boundary of the area there is a ridge called the *ethmoidal crest*. The anterior part of that ridge produces the elevation, called the *agger nasi*, in the un-macerated head. The posterior part articulates with the anterior end of the middle concha; the portion of the frontal process above that articulation is applied to the front of the labyrinth of the ethmoid and helps to close in the anterior ethmoidal cells.

The **lacrimal bone** also is applied to the labyrinth, forming a boundary to anterior ethmoidal cells; but its antero-inferior portion appears in the side wall of the nose, and its lowest part projects downwards and helps to close the large opening of the maxillary sinus.

The **labyrinth of the ethmoid**, situated between the orbit and the nasal cavity, bulges into the cavity and greatly reduces the width of its upper part. It is composed of exceedingly thin, fragile bone. The upper half of its medial aspect is a wide area which, though far from smooth, is relatively even, and shows narrow grooves for the lateral group of olfactory nerves leading up to the holes in the cribriform plate. Inferiorly the posterior half of the area ends in the projecting ridge called the **superior concha**; the anterior half is continuous with the medial surface of the anterior part of the middle concha.

The **spheno-ethmoidal recess** is situated above and behind the posterior part of the superior concha, in front of the body of the sphenoid, and the sphenoidal sinus opens into it.

The **middle concha** forms the roof and medial wall of the upper, narrow part of the middle meatus, and its rough medial surface is the lower and lesser half of the medial aspect of the labyrinth. It extends forwards to the frontal process of the maxilla, and backwards to the perpendicular part of the palatine bone, its anterior end being at a considerably higher level than the posterior end. The lower border is convex from before backwards, its lowest point being about the level of the floor of the orbit, and the border is thickened and curled in a lateral direction, so that the lateral surface of the concha is concave and the medial surface is convex.

The **superior meatus** is bounded inferiorly by the posterior half of the middle concha, and superiorly by the superior concha and the walls of posterior ethmoidal cells, which open into it by two or three orifices in the dried skull, but mucous membrane covers one or two of the openings during life. The **spheno-palatine foramen** also opens into it at its posterior part, but is covered over with mucous membrane before maceration.

The rounded, bulging **bulla ethmoidalis**, which lies in the lateral wall of the upper part of the middle meatus, hidden under cover of the middle concha, varies considerably in size; it encloses some of the middle ethmoidal sinuses.

From the labyrinth, in front of the bulla, there springs a long, thin process, called the **uncinate process**, which curves downwards and backwards, first in front of the bulla and then below it, and has a considerable share in covering the large opening of the maxillary sinus.

The curved interval between the bulla and the uncinate process is the **hiatus semilunaris**, into which the mucous lining dips as it passes from the bulla to the process. In some cases, however, the uncinate process is closely applied to the bulla, and the hiatus is then a gutter-like groove on the process, the margins of which are curled to form the margins of the groove. The **infundibulum** [= a funnel], which leads downwards through the anterior part of the ethmoid labyrinth from the frontal sinus, opens into the hiatus, and the upper or anterior portion of the hiatus is sometimes described as part of the infundibulum.

The **middle meatus** extends from the attached margin of the middle concha down to the inferior concha, and is therefore of considerable height. The middle concha constitutes a medial wall for the upper, narrow part of the meatus, which is at the level of the orbit, and is separated from the orbit by the lower part of the labyrinth, including the bulla. The lower, wide part of the meatus is open medially, and is situated below the labyrinth, opposite the upper part of the maxillary sinus, from which it is separated by the bones that close the opening of the sinus.

The *sinuses* leading into the meatus open into its upper part. The *middle ethmoidal* sinuses open into it on the surface of the bulla; the *maxillary* sinus opens into the lower part of the hiatus semilunaris; the infundibulum, leading from the *frontal* sinus, opens into the upper part of the hiatus; the *anterior ethmoidal* sinuses also open into the upper part of the hiatus and into the infundibulum. In the dried skull there are, in addition, one or more openings into the lower part of the meatus, out of the maxillary sinus, but they are closed with mucous membrane when the soft parts are in place.

The **perpendicular part of the palatine bone** is a very thin plate of bone situated in the posterior part of the side wall of the nose. Its posterior edge articulates with the medial pterygoid process and often overlaps it. Anteriorly, it is applied to the medial surface of the maxilla and takes a considerable share in closing the opening of the maxillary sinus. Between the upper parts of the maxilla and pterygoid process, it forms the medial wall of the pterygo-palatine fossa, from which the **greater palatine canal** descends to the hard palate; the canal is situated in the side wall of the nose between the palatine bone and the maxilla. Two processes project upwards from the upper end or margin of the palatine bone, namely, the sphenoidal and orbital processes; they are separated by the spheno-palatine notch, which, with the body of the sphenoid, forms the **spheno-palatine foramen.** The *sphenoidal process* inclines medially to form part of the roof of the nose. The *orbital process* is wedged in between the body of the sphenoid, the labyrinth of the ethmoid, and the body of the maxilla, and forms the posterior corner of the floor of the orbit; it often contains a cavity, called the palatine sinus, which may open into the sphenoidal sinus or into a posterior ethmoidal sinus. At the root of the orbital process, a ridge called the *ethmoidal crest* articulates with the posterior end of the middle concha; about 10 mm. from the lower end of the palatine bone, a ridge called the *conchal crest* articulates with the posterior end of the inferior concha.

The **inferior concha** extends between the conchal crests of the palatine bone and the maxilla, and its anterior attachment is the higher. It reaches a little further forward and a little further back than the middle concha. Its lower border is slightly thickened, curled laterally, convex from before backwards, and is only a little distance above the level of the lower margin of the apertura piriformis. The inferior concha passes across the lower part of the opening of the maxillary sinus and sends off processes which assist in closing the opening.

The **inferior meatus** extends from the attached margin of the inferior concha to the hard palate; the medial surface of the lower part of the maxilla forms its lateral wall; and the concha provides it with a roof and a partial medial boundary. It is related laterally to the maxillary sinus and inferiorly to the mouth. The **naso-lacrimal canal** opens into it under cover of the anterior part of the inferior concha.

The junction of the middle meatus and its atrium is opposite the fossa for the lacrimal sac in the orbit, and the mucous lining of the nose is separated from the sac by the lacrimal bone and the frontal process of the maxilla. The **naso-lacrimal canal** is situated in the side wall of the nose between the nasal cavity and the maxillary sinus. It is 10 or 12 mm. in length, and is bounded laterally and antero-medially by the walls of a deep groove in the maxilla, while postero-medially it is bounded by the lower part of the lacrimal bone and the inferior concha.

The apertures leading into or out of the nose are the following: The *choana*; the *apertura piriformis*, or, when soft parts are present, the *nostril*; the *naso-lacrimal canal*; and the *openings of the sinuses*, namely, sphenoidal, ethmoidal, frontal, and maxillary. The **sphenoidal sinus** opens into the spheno-ethmoidal recess; the **posterior ethmoidal sinuses** open into the superior meatus; the **middle** and **anterior ethmoidal sinuses**, the **frontal sinus** *via* the infundibulum, and the **maxillary sinus** open into the middle meatus. The *naso-lacrimal canal* opens into the inferior meatus.

Besides the foregoing there are certain apertures in the dried skull which are covered over with mucous membrane before maceration, viz.: The *spheno-palatine foramen* opens out of the pterygo-palatine fossa into the posterior part of the superior meatus; there is an additional opening out of the maxillary sinus into the middle meatus; the *incisive canal* leads down from the anterior part of the floor of the nose into the incisive foramen; and the *foramina in the lamina cribrosa* in the roof transmit the olfactory nerves from the nose to the median part of the anterior cranial fossa.

General Relations of the Nose (Fig. 147, p. 172).—**Superior**, from before backwards: the frontal sinus; the anterior or ethmoidal part of the median subdivision of the anterior cranial fossa; the sphenoidal sinus, separating the nose from the posterior part of that fossa and from the median subdivision of the middle cranial fossa. **Inferior**: the mouth. **Posterior**: the nasal part of the pharynx. **Lateral**: the pterygoid fossa, the pterygo-palatine fossa, and the greater palatine canal (canalis pterygo-palatinus) opposite the posterior section of the cavity; further forward, the ethmoidal sinuses, the infundibulum, and the orbit, opposite the upper half of the middle section of the cavity, while opposite the lower half there are the maxillary sinus and the naso-lacrimal canal; the anterior section is situated in the external nose and is related laterally to the exterior.

SINUS PARANASALES.

The **para-nasal air sinuses** (Figs. 147, 148, pp. 172, 175) are cavities in the interior of certain of the skull bones, namely, the *frontal*, the *ethmoid*, the *sphenoid*, the *palatine*, and the *maxilla*. They all communicate either directly or indirectly with the cavity of the nose. Those communicating directly with the nose are the sphenoidal, ethmoidal, and maxillary; those communicating indirectly are the frontal and the palatine. They are all lined with mucous membrane which is continuous, round the lips of the apertures of communication, with the mucous lining of the nose, and disease can readily spread from the nose to the sinuses. During a severe cold in the head, the inflammation often extends from the nasal mucous lining to the mucous lining of sinuses, giving rise to frontal headaches (frontal sinus), pain in the cheek (maxillary sinus), pain between the eyes (ethmoidal sinuses), deep-seated pain at the back of the eyes (sphenoidal sinus).

The walls of the sinuses are composed of compact bone and are lined with endosteum which is blended with the mucous lining.

At birth the ethmoidal sinuses are present but are very small; the maxillary sinus is a mere groove; the frontal and sphenoidal appear during childhood. They all enlarge gradually till puberty, and rapidly after puberty.

The sinuses act as resonating chambers for the voice; and by means of them the bones containing them, without increase of weight, gain increase of bulk and superficies necessary for the formation of the walls of the cavities of the nose, mouth, and orbits.

Sinus Maxillaris (Figs. 141, 147, 148, pp. 162, 172, 175).—The **maxillary sinus** (Antrum of Highmore) is a large cavity occupying the body of the maxilla. It is situated *lateral* to the lower half of the nasal cavity, *below* the orbit, *in front of* infra-temporal fossa, and *above* the molar and premolar teeth, its deepest part being above the first molar and second premolar tooth. The opening out of it is on the medial side; in a separated maxilla the opening is very wide, but when in position in the skull, that large opening is overlapped by adjoining bones and reduced to two, or perhaps three, small apertures; when the mucous membrane is in place, only the uppermost of those apertures is left uncovered, and it opens out of the **uppermost** part of the sinus into the lower or posterior part of the hiatus semilunaris of the middle meatus.

The **maxillary sinus** is the largest of the sinuses; it is variable in size and may differ in the two sides of the same skull. Average measurements, in round numbers, are 35 mm. in height, 30 mm. in antero-posterior depth, and 25 mm. in width. In shape it resembles a pyramid. The **apex** is situated in the zygomatic process of the maxilla. The **base** or **medial wall** separates it from the inferior meatus and lower, wide part of the middle meatus, and is formed by the medial or nasal surface of the maxilla and the bones which almost completely close the large opening in the upper part of that surface, namely, portions of the uncinate process of the ethmoid, the palatine, the lacrimal, and the inferior concha.

The secretions of the mucous lining of the sinus are swept towards the orifice in the medial wall by the cilia of the epithelium covering the mucous membrane; in inflammatory conditions, when the quality of the secretion clogs the action of the cilia or the quantity is too great for them to cope with, the sinus fills up, since the orifice is at its uppermost part.

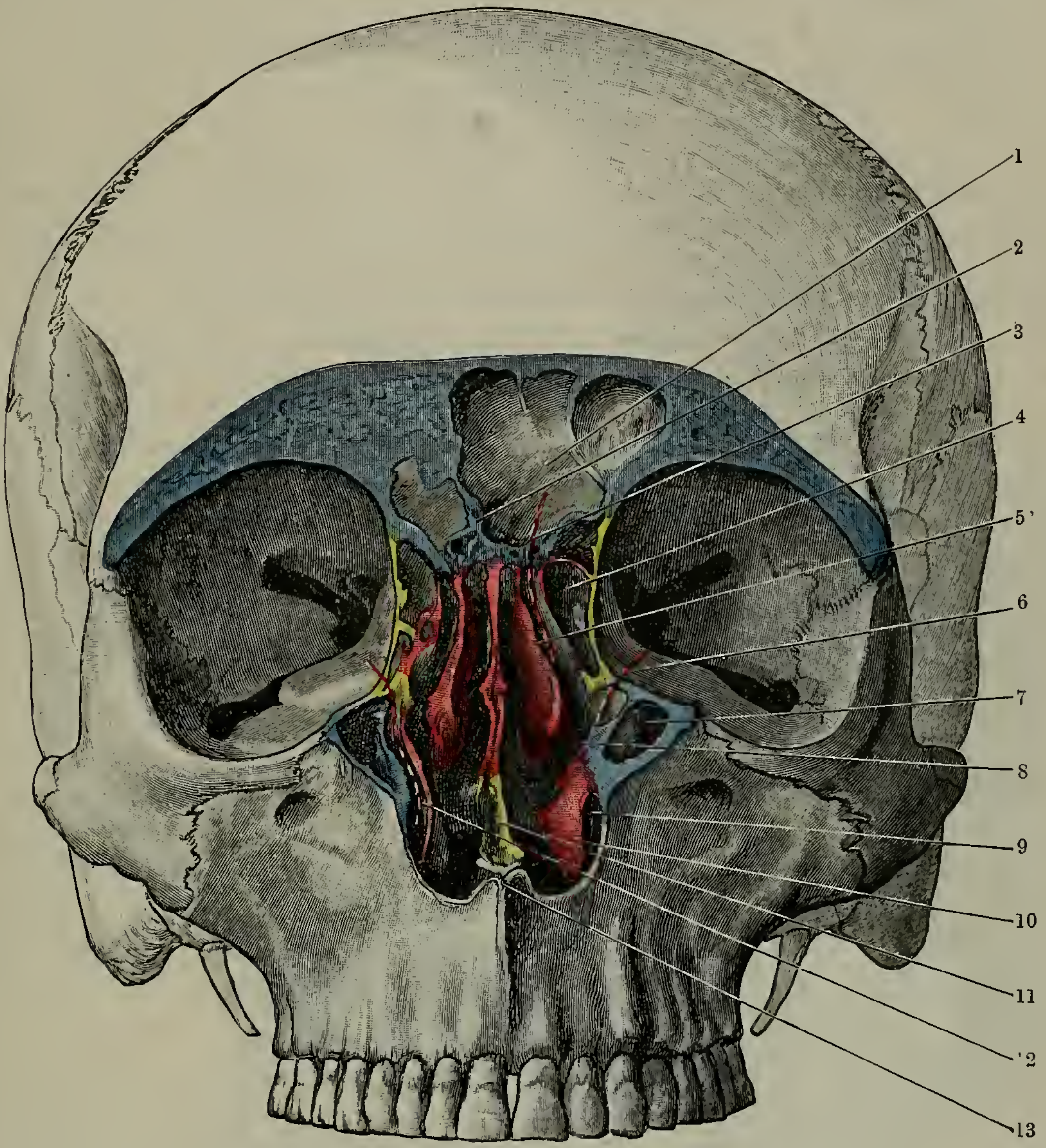


FIG. 148.—PART OF THE FRONTAL, NASAL, AND MAXILLARY BONES REMOVED IN ORDER TO DISPLAY THE RELATION OF THE VARIOUS CAVITIES EXPOSED.

The frontal and maxillary bones, where cut, are coloured blue; the ethmoid and the inferior concha red; the lacrimal and vomer yellow.

1. Frontal sinus.
2. Septum of frontal sinus deflected towards the right.
3. Infundibulum leading from sinus to middle meatus.
4. Anterior ethmoidal air-sinuses.
5. Middle concha.
6. Red line in upper part of naso-lacrimal canal.
7. Cavity of maxillary sinus laid open.
8. Middle meatus of nose.
9. Inferior meatus of nose.
10. Inferior concha.
11. Vomer.
12. Naso-lacrimal canal laid open.
13. Anterior nasal spine.

The **floor** of the sinus is formed by the alveolar process of the maxilla, and is the thickest wall of the sinus, though the process is excavated by the alveoli of the teeth. The teeth whose roots are in relation to the floor vary from the three molars as a minimum to the molars, premolars, and the canine as a maximum. The roots of the first two molars produce eminences in the floor, and, though usually covered with thin bone, they may perforate the floor. Incomplete septa springing from the intervals between teeth may partially divide the sinus into compartments. The floor is below the level of the floor of the nose; the lowest part is about 10 mm. below the level of the nose, and overlies the roots of the first molar and second premolar teeth. The **posterior wall** is formed by the posterior or infra-temporal surface of the maxilla, which separates the sinus from the infra-temporal and pterygo-palatine fossæ. The **posterior alveolar canals**, conveying the vessels and nerves to the molar teeth, are situated in the lower part of the posterior wall. The **roof** is formed by the orbital surface of the maxilla, which separates the sinus from the orbit. The **infra-orbital groove and canal** are situated in the roof and may produce a ridge, especially at the angle between roof and anterior wall. The anterior or **antero-lateral wall** is formed by the facial surface of the maxilla. The branches of the infra-orbital vessels and nerve to the premolar, canine, and incisor teeth descend through canals in the antero-lateral wall, but occasionally one or more of the canals may be defective, so that the corresponding vessels and nerve lie between the bone and the mucous lining. The upper and anterior part of the sinus extends far enough forwards to be in front of the naso-lacrimal canal as well as lateral to it.

Sinus Frontalis.—The **frontal sinus** is a cavity in the frontal bone; it is separated from its fellow by a complete bony septum which is usually bent to one or other side. It is situated immediately above the supra-orbital margin and above the root of the nose. If large, it extends backwards in the roof of the orbit between the two tables of the orbital plate. The frontal sinus may open directly into the nasal cavity through an opening in the nasal part of the frontal bone, but more commonly one of the anterior ethmoidal cells is converted into a passage, called the **infundibulum**, by means of which the sinus drains into the middle meatus, for the upper end of the infundibulum opens into the sinus and its lower end opens into the upper or anterior end of the hiatus semilunaris. The mucous lining of the infundibulum is sometimes called the *fronto-nasal duct.*

Cellulæ Ethmoidales.—The **ethmoidal sinuses** or cells are numerous small thin-walled, intercommunicating cavities occupying the labyrinth of the ethmoid. They are situated between the orbit and the nasal cavity, and below the cranial cavity, from which they are separated by the medial part of the orbital plate of the frontal bone. They are divided into three groups—anterior, middle, and posterior. The **posterior sinuses** open into the superior meatus of the nose by one or more apertures. The **middle sinuses** open into the middle meatus on the surface of the bulla ethmoidalis by one or two apertures. The **anterior sinuses** open into the hiatus semilunaris of the middle meatus.

The **frontal sinus** varies greatly in size in different skulls, and may vary on the two sides of the same skull, the left being usually the larger. Average measurements are 30 mm. in height, 25 mm. in transverse width, and 20 mm. in antero-posterior depth. The configuration of the brow in the living person gives no indication of its size; in a well-formed skull it may be absent, or may extend laterally as far as the temporal fossa and backwards in the roof of the orbit as far as the optic foramen. The septum between the right and left sinuses is usually median inferiorly and bent to one side above. The sinus is related *inferiorly* to the orbit, the nose, and the anterior ethmoidal cells; *postero-superiorly* to the cranial cavity and the brain.

The walls of the **ethmoidal sinuses** are completed by the bones with which the ethmoid labyrinth articulates—the body of the sphenoid, the orbital process of the palatine bone, the orbital plate of the frontal bone, the lacrimal bone, the frontal process and the medial margin of the orbital surface of the maxilla. They are related *laterally* to the orbit; *medially* to the upper half of the cavity of the nose; *posteriorly* to the sphenoidal and palatine sinuses; *superiorly* to the sphenoidal sinus, the frontal sinus, the anterior cranial fossa, and to the ethmoidal canals which are situated between the orbital plate and the ethmoidal labyrinth; *inferiorly* the posterior sinuses are related to the superior meatus, into which they open, and the middle and anterior sinuses are related to the lower part of the middle meatus.

Sinus Sphenoidalis.—The **sphenoidal sinus** is a large cavity occupying the body of the sphenoid bone. It is situated above the cavities of the naso-pharynx and nose, and below the median part of the cranial cavity. It is divided completely into right and left halves by a median bony septum, which, however, is usually bent to one or other side: each half may be referred to as a sphenoidal sinus, and it opens into the spheno-ethmoidal recess of the nose by a round aperture 4 or 5 mm. in diameter.

The **sphenoidal sinus** may be small and limited to the anterior part of the body of the sphenoid; or it may occupy the whole of the body and extend into the roots of the lesser wings, greater wings, and pterygoid processes, and backwards into the basilar part of the occipital bone. Its average dimensions are about 20 mm. each way.

Inferiorly it is related to the cavity of the naso-pharynx and the naso-pharyngeal meatus; *anteriorly*, to the upper part of the middle section of the cavity of the nose and the posterior ethmoidal cells. *Laterally* it is related: (1) to the optic nerve in the optic foramen, and to the apical part of the orbit; (2) behind that, to the cavernous venous sinus, in the walls of which the internal carotid artery, the third, fourth, sixth, and ophthalmic nerves are imbedded; (3) to the maxillary nerve, as it runs forwards along the lower border of the cavernous sinus and as it passes through the foramen rotundum. *Superiorly* it is related: (1) to the frontal lobes of the brain and the olfactory tracts, lying on the anterior part of the body of the sphenoid; (2) more remotely, to the optic chiasma, which lies above the optic groove; (3) to the hypophysis cerebri (pituitary body), lying in the hypophyseal fossa; (4) to the pons and the basilar artery, lying on the clivus. The relation of the sinus and the nose to the hypophysis is of special interest because the hypophysis is subject to tumour growth and the operator approaches it through the nose and the sphenoidal sinus. The hypophysis is 60 mm. behind the nasion and at almost the same horizontal level. A line connecting the hypophysis with the lower margin of the apertura piriformis is 75 mm. long and forms an angle of 45° with the floor of the nose.

The **palatine sinus**, when present, occupies the orbital process of the palatine bone, and opens into either the sphenoidal sinus or a posterior ethmoidal sinus.

Mandibula.

The **mandible** or lower jaw bone lies below the anterior part of the cranium, and is the skeleton of the lower part of the face. It consists of a horseshoe-shaped **body** and two flat, broad **rami**, which stand up from the posterior part of the body, one on each side. Each ramus is surmounted by two processes, the anterior of which is named the **coronoid process**, and the posterior is named the **condyloid process**; the condyloid process consists of an articular part, called the **head**, supported on a more constricted part called the **neck**.

Corpus Mandibulæ.—The **body** of the mandible consists of a right and a left half fused together in the median plane in front, but widely separated behind. The junction between the two halves is called the **symphysis menti** [σύν (syn) = together; φύω (phyō) = grow; *mentum* = the chin]. The halves are joined together by fibrous tissue at birth, but are fused together into one bone during the second year.

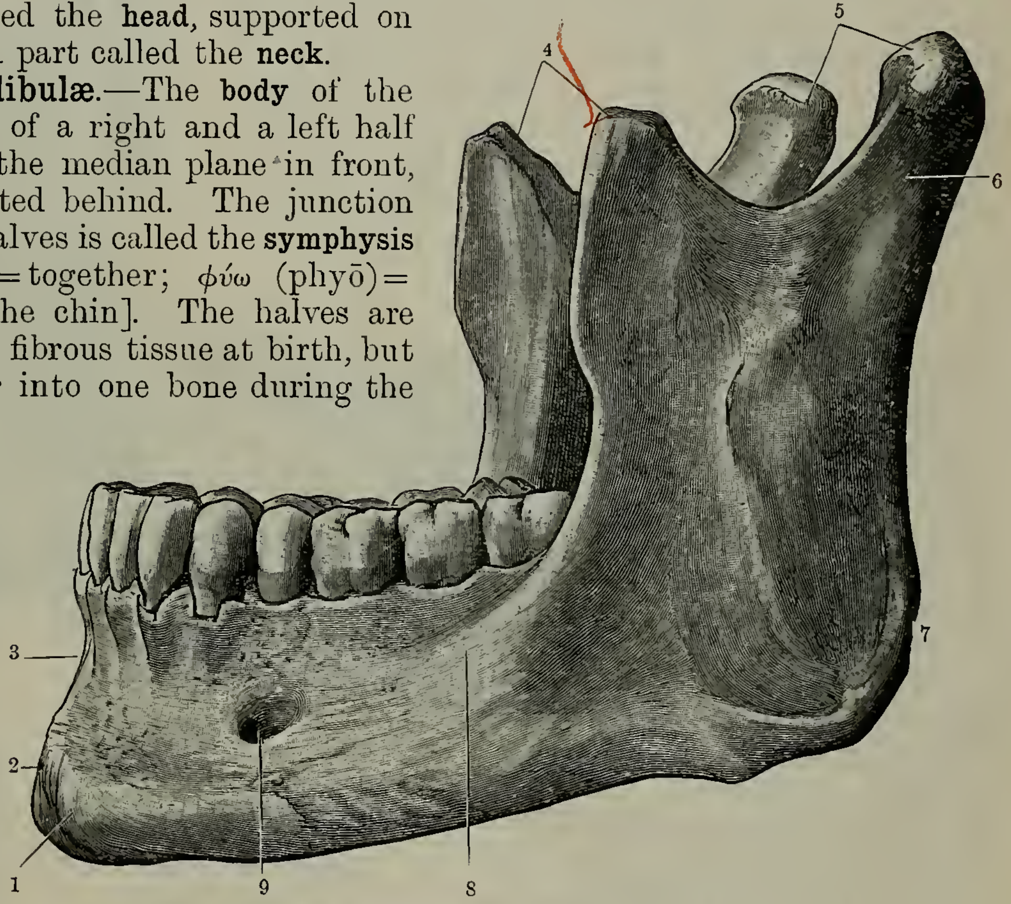


Fig. 149.—The Mandible as seen from the Left Side.

1. Mental tubercle.
2. Mental protuberance.
3. Symphysis.
4. Coronoid processes.
5. Head.
6. Neck.
7. Angle.
8. Oblique line.
9. Mental foramen.

On the front of the mandible, along the line of the symphysis, there is a faint, vertical ridge, which swells out inferiorly into a triangular elevation, of varying prominence, called the **mental protuberance**; the lower angles of the triangle are called the *mental tubercles*; in the region of the protuberance, the bone is bent forwards to produce the prominence of the **chin**. The forward projection of the lower part of the middle of the mandible to make the chin is a Human characteristic: among lower animals, not even the Anthropoid apes (Gibbon, Gorilla, Orang-utan, and Chimpanzee) have chins as an outstanding feature; and the prominence of the chin is not so marked in the primitive races of Men as in the higher, though the mandible as a whole may be a heavier bone.

Each half of the body of the mandible has a medial and a lateral surface and an upper and a lower border. The surfaces slope so that the lower border of the whole bone makes a wider arch than the upper border.

The **upper border** is called also the **alveolar margin**, because it is occupied by a row of pits or **alveoli**, which are the sockets for the teeth, and are visible if the teeth have fallen out after death. On each side the sockets for the two incisors, the canine, and the two premolars are single, but those for the three molars are double, for each mandibular molar has two roots—an anterior and a posterior. When teeth are removed during life the walls of the alveoli are gradually absorbed until no evidence of them is left; the upper border of the mandible in the region of the lost teeth is smooth, and the vertical diameter of the bone is reduced.

The **lower border** is sometimes called the *base* of the mandible. On the lower border, or behind the border, at the side of the symphysis, there is a broad, rough mark or depression called the **digastric fossa.** The rest of the lower border is smooth and rounded and has a slight fulness or downward convexity about its middle.

The **lateral surface** is slightly convex, but on its anterior part, alongside the symphysis, below the incisor teeth, there is a broad, shallow depression called the *incisive fossa.* About an inch from the symphysis, below the second premolar or the interval between the premolars, there is an oblique opening called the **mental foramen,** situated about midway between the upper and lower borders if the alveoli are present, but nearer the upper border if the alveolar walls have been absorbed. Below the mental foramen there is an ill-defined ridge called the *oblique line*; it extends from the mental tubercle to the anterior border of the ramus, but is not well marked till it approaches the ramus.

The **medial surface** is undulating, being convex and concave at different parts. Low down on the back of the symphysis there is a rough mark, which may be divided into a right and a left half, each of which is called a **mental spine**; and the mental spine may be subdivided into an upper and a lower **genial tubercle** [γένειον (geneion) = the chin].

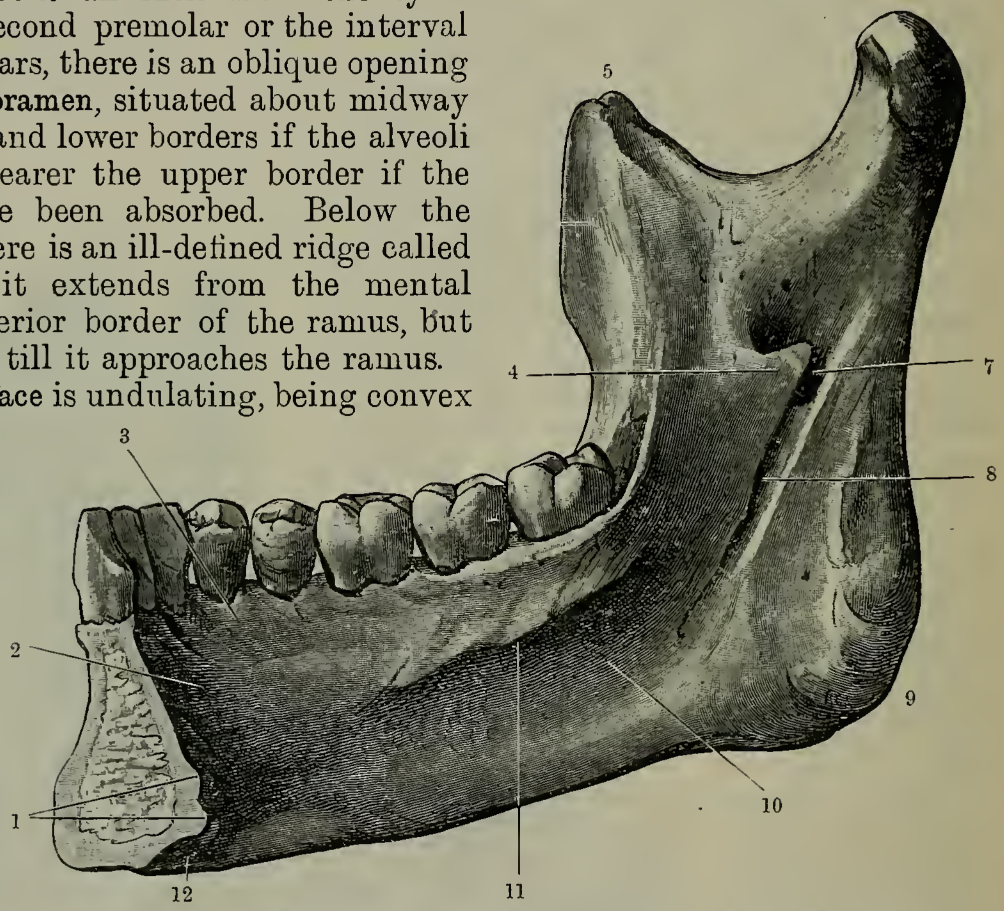


Fig. 150.—The Medial Side of the Right Half of the Mandible.

1. Mental spine divided into genial tubercles.
2. Above sublingual fossa.
3. Alveolar border.
4. Lingula.
5. Coronoid process.
6. Head.
7. Mandibular foramen.
8. Mylo-hyoid groove.
9. Angle.
10. Submaxillary fossa.
11. Mylo-hyoid line.
12. Digastric fossa.

At the side of the symphysis, a little above the digastric fossa, there is a smooth, shallow depression, about the width of a thumb-print, called the **sublingual fossa.** Farther back there is an elongated, shallow depression called the **submaxillary fossa,** which extends on to the ramus; inferiorly it reaches the lower border of the mandible; superiorly it is bounded by an oblique ridge, called the **mylo-hyoid line,** which begins at the level of the root of the last molar tooth and passes downwards and forwards to the posterior margin of the digastric fossa; the lower or anterior part of the line is faint, and separates the submaxillary and sublingual fossæ from each other.

Ramus Mandibulæ.—The **ramus** of the mandible is, properly, the broad, flattened plate which rises up above the level of the posterior part of the body: but for the sake of simplifying the description of the attachment of muscles it is convenient to include the bone down to the lower border under the term *ramus*; at the same time it is not necessary to subdivide the lower border: it is the lower border of the mandible, irrespective of subdivision into body and ramus. Each ramus has a lateral and a medial surface, an anterior and a posterior border, and an upper end or border surmounted by the coronoid and condyloid processes, which are separated by a wide gap called the **mandibular notch**.

The **lateral surface** is fairly flat, and rather rough. Where the lateral surfaces of ramus and body join, at the lower border of the bone, a faint groove may be detected; if the finger tip is placed on the corresponding point in a living person the pulsing of an artery can be felt; that is, the external maxillary artery—the chief artery of the face—as it crosses the lower border of the mandible and enters the face. The **medial surface** is more uneven. About its centre there is an oblique opening called the **mandibular foramen**; it leads into a canal which runs downwards and forwards in the substance of the bone and carries the vessels and nerves for the teeth; the spur of bone that overlaps the foramen anteriorly is called the **lingula**. A narrow groove, called the **mylo-hyoid groove**, begins at the lower margin of the foramen, runs downwards and forwards and fades away in the submaxillary fossa. The **anterior border** of the ramus is sharp, and is continuous with the oblique line of the body. The **posterior border** is smooth and rounded; the point where it meets the lower border is called the **angle of the mandible**—a point easily felt in the living and much used as a landmark.

Processus Coronoideus.—The **coronoid process** is flattened and pointed; it is triangular in outline, and is named from its resemblance, when looked at sideways, to the beak of a bird [κορώνη (corōnē) = a sea crow]. Its anterior border is continuous with the anterior border of the ramus, and both can be felt inside the mouth, above and behind the last molar tooth. Its posterior border bounds the mandibular notch anteriorly. Its surfaces are continuous with those of the ramus.

Processus Condyloideus.—The **condyloid process** consists of an articular head or condyle supported on a constricted neck.

The **head** of the mandible is elongated transversely. It includes only the part that is smooth and coated with cartilage; it has therefore an upper and a posterior aspect and a small, negligible anterior aspect. The head articulates with the mandibular fossa and articular tubercle of the temporal bone—but not directly: an articular disc of fibro-cartilage, which is placed within the joint and is attached by its circumference to the fibrous capsule of the joint, separates the head from the temporal bone and divides the joint cavity into an upper and a lower compartment. When the mandible is at rest, with the mouth shut, the upper surface of the head is in contact with the disc, below the mandibular fossa; when the mouth is opened, the mandible rotates so that the back of the head is brought into articulation, and at the same time the head travels downwards and forward till it comes to lie beneath the articular tubercle. The head can be felt in front of the ear, and the finger can follow its movements as the mouth is opened and shut.

The **neck** of the mandible is obliquely compressed from before backwards. The narrow *medial* and *lateral surfaces* widen out inferiorly as they merge into the surfaces of the ramus. The smooth *posterior surface* is continuous with the back of the head and the posterior border of the ramus. The *anterior surface* is rough and hollowed out, forming a depression which is overhung by the anterior margin of the head and is continuous inferiorly with the medial surface of the ramus; the sharp margin between the anterior and lateral surfaces bounds the mandibular notch posteriorly.

The **alveolar margin** is thicker behind than in front; it gives attachment to the gums, around the mouths of the alveoli. The socket of the canine tooth may produce a vertical eminence on the labial surface of the bone, and the incisor sockets may do so also.

The mucous membrane of the mouth covers the **lateral surface** of the body down to a line drawn from the last molar socket to the apex of the mental protuberance. The lower part of the buccinator arises from the lateral surface opposite the *molar sockets*; the incisive muscle, from the lower part of the **incisive fossa**; the mentalis, from a point opposite the bottom of the *canine socket*; the quadratus labii inferioris, from a line joining the mental tubercle and foramen; the triangularis, from the anterior part of the **oblique line**, below the mental foramen. The **mental foramen**, which may be double on one or both sides, opens obliquely in a lateral direction and upwards, and transmits the mental vessels and nerve. The external maxillary artery lies on the mandible at the junction of body and ramus. The **lower border** of the mandible gives attachment to the deep fascia of the neck; and the platysma is inserted into the anterior half.

The mucous membrane covers the **medial surface** of the body down to a line drawn from the posterior end of the mylo-hyoid line to a point just above the mental spine. A small vascular foramen is situated opposite the interval between the incisor sockets on each side; and another is placed in the symphysis above the mental spines; the genio-glossus arises from the upper part of the **mental spine**, and the genio-hyoideus from the lower part; or from the upper and lower **genial tubercles**, respectively; the anterior belly of the digastricus, from the **digastric fossa**; the mylo-hyoideus, from the **mylo-hyoid line**, the posterior end of which gives attachment also to fibres of the superior constrictor and the buccinator and to the lower end of the pterygo-mandibular raphe. The two mylo-hyoid lines form the sides of an arch which is smaller than the arches formed by the upper border and the lower border; for the surface above the lines slopes upwards and outwards, and the surface below slopes, to a still greater degree, downwards and outwards. The sublingual gland lies in the **sublingual fossa**; and the submaxillary gland lies in the **submaxillary fossa** (they should be named *submandibular* gland and fossa).

The **mandibular foramen** transmits the inferior alveolar vessels and nerve; their mylo-hyoid branches run along the **mylo-hyoid groove**, which may be partly converted into a tunnel. The pterygoideus internus is inserted into the rough patch that separates the foramen and groove from the angle of the mandible. The spheno-mandibular ligament is attached to the **lingula**; the stylo-mandibular ligament is attached to the **posterior border** *of the ramus* and also to the **angle**, which is usually everted, and is slightly obtuse in a well-formed adult jaw, more obtuse in childhood, and still more in old age after the teeth have been lost. In a young adult the slope of the jaw from angle to chin expresses almost the whole degree of obtuseness of the angle, for the posterior border of the ramus is nearly vertical; but not so in old edentulous persons, for in them the posterior border of the ramus slants downwards and forwards, chiefly owing to the backward tilt of the condyloid process. In mandibles of old people the increase of obtuseness is not so much in the angle proper as in the angle between the anterior margin of the ramus and the upper margin of the body.

The masseter is inserted into the **lateral surface** of the ramus and covers the ramus and the coronoid process, leaving the head and neck without a covering of muscle; the temporalis is inserted into the medial surface and the margins of the **coronoid process**, and also into the anterior margin of the ramus. In some specimens an oblique canal traverses a blunt, low, vertical ridge that begins near the tip of the coronoid process and extends downwards towards the posterior end of the mylo-hyoid line; the canal transmits the buccinator nerve. The coronoid process varies considerably in length, but its tip usually lies under cover of the anterior part of the zygomatic arch.

The long axis of the **head** is nearly horizontal and is directed latero-medially and backwards. The posterior surface is slightly convex; so also is the upper surface, which overhangs the front of the neck, and ends in little tubercles that overhang the sides of the neck. The articular capsule of the mandibular joint is attached to the margins of the articular surfaces of the head; a thickened part of the capsule, called the temporo-mandibular ligament, is attached to the lateral aspect of the **neck**. The pterygoideus externus is inserted into the front of the neck and the capsule. If the finger is placed in the acoustic meatus, the meatus can be felt widening as the mouth is opened, for when the mouth is shut the back of the head exerts pressure on the meatus, though it is separated by a portion of the parotid gland; the lateral aspect of the head and neck also is overlapped by the parotid gland and is crossed by the temporal branches of the facial nerve, which may be rolled between the finger and the bone. The external carotid artery ends behind the neck; the superficial temporal artery, accompanied at that level by the posterior facial vein, runs upwards behind the lateral end of the head; the internal maxillary artery passes forwards medial to the root of the neck; the auriculo-temporal nerve winds round the medial side and the back of the neck and joins the superficial temporal artery. The vessels and nerves to the masseter pass in a lateral direction, through the **mandibular notch**, in front of the neck.

Differences due to Age.—At birth the two halves are united by fibrous tissue; the body is a mere shell enclosing the rudimentary *teeth*, which are imperfectly separated from one another; the *mandibular canal* is near the lower border; so also is the *mental foramen*, which is opposite the cavity for the first milk molar tooth. The *ramus* is relatively short; the *condyloid process* is almost in line with the body, so that the angle is very obtuse; the *head* is relatively large, and the *coronoid process* rises to a higher level than the head.

During the first year the halves unite from below upwards, and union is completed during the **second** year. As the teeth erupt and the child begins to chew, the depth of the body increases by the growth of the alveoli, the lower part thickens, the rami enlarge and the angle becomes less obtuse, being about 140° in the fourth year. As growth advances the depth increases, and the body elongates, especially behind the mental foramen to provide room for the permanent molars; the mental foramen assumes its adult position and the angle is reduced to 110°.

In **old age** after teeth are lost the alveoli are absorbed, so that the chin appears more prominent, and the mental foramen is near the upper border. The angle opens out to 140° and the condyloid process is bent back so that the mandibular notch is wider.

Structure.—The body of the mandible is thicker than the rami, and is thickest near the rami at the level of the mylo-hyoid and oblique lines, for there the mandible is subject to the greatest strain when the elevating muscles bring it into contact with the resisting upper jaw. The tables of compact bone are exceptionally dense and are very thick where they join together at the lower border. The lingual walls of the alveoli are considerably thicker than the labial walls, except in the case of the **third molar** socket, where the labial wall is the thicker. The spongy substance is open-meshed below, but finer and more condensed in the walls of the alveoli. The *canal* of the mandible lies in the spongy substance, about the level of the mylo-hyoid ridge, and does not have a definite wall; the mental foramen, and the canals which carry blood-vessels and nerves to the teeth branch off the mandibular canal.

Development and Ossification.—The **mandible** begins to ossify during the sixth week of fœtal life before any other bone in the body, except the clavicle. Each half is developed from (1) the membrane overlying Meckel's cartilage, (2) the ventral portion of Meckel's cartilage, (3) certain accessory cartilages which appear between the eleventh and fourteenth weeks. The greater part of the mandible is developed from the membrane. The extreme ventral end of Meckel's cartilage disappears, but a part of it is incorporated in the mandible from a point near the symphysis backwards to the level of the mental foramen. One of the accessory cartilages forms the head and a narrow wedge-like part in the ramus; another forms a narrow strip along the front of the coronoid process; and some accessory nodules take a share in forming the symphyseal part of the bone. Those different structures are not ossified from separate centres. Each **half** of the mandible is ossified from **one** centre, which appears in the membrane overlying the ventral part of Meckel's cartilage. The ossifying process spreads through the membrane and envelops and invades the cartilages. Some small nodules, called *ossicula mentalia*, which appear at the symphysis shortly before birth and fuse with the mandible shortly after birth, may be derived from independent ossific centres in the accessory cartilages.

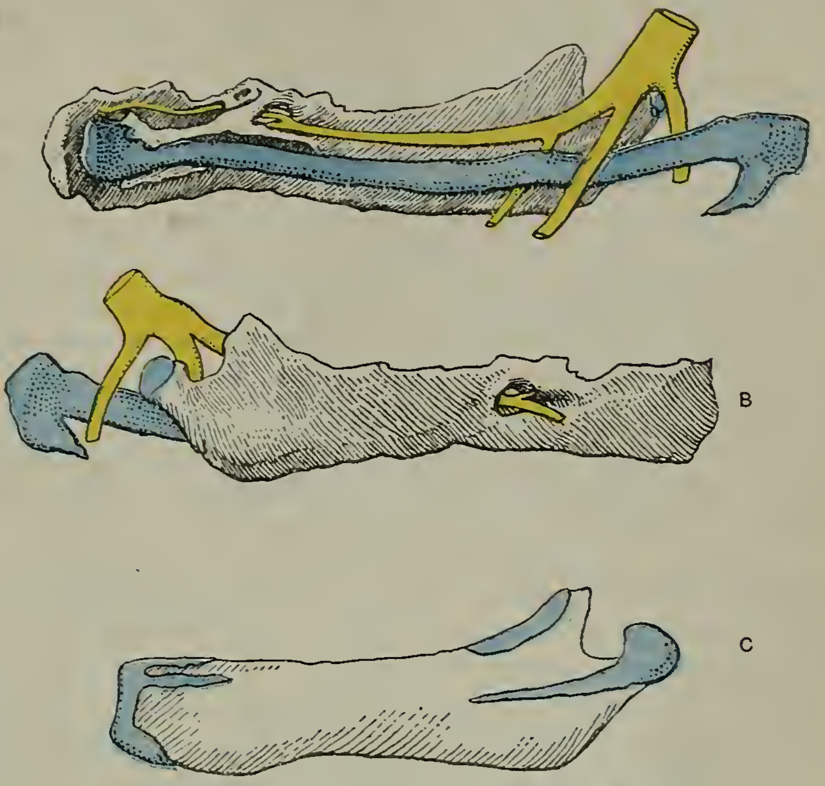


Fig. 151.—Development of the Mandible.

A, As seen from the medial side; B, from the lateral side; C, showing accessory (metaplastic) cartilages (blue).

(In A and B Meckel's cartilage is coloured blue.)

Meckel's cartilage is the cartilage of the first or **mandibular** arch of the embryo. Its dorsal end is in the region of the ear; its ventral end almost meets its fellow of the other side. The dorsal end ossifies to form two of the auditory ossicles, namely, *incus* and *malleus*; part of its ventral end is included in the mandible. The rest disappears; but the mylo-hyoid groove is the remains of the furrow in which part of it lay; and the *spheno-mandibular ligament* is derived from the fibrous sheath around it, though it has been argued that that ligament is the remnant of a muscular slip.

Dentes.

There are two sets of **teeth**: the *deciduous* or milk teeth, which are shed during childhood; and those that are potentially *permanent*.

The **deciduous teeth** are 20 in number, 5 on each side of the upper and the lower jaws, namely, 2 incisors, 1 canine, and 2 molars, in that order from before backwards. There are 32 adult or **permanent teeth**, 8 on each side above and below, namely, 2 incisors, 1 canine, 2 premolars, and 3 molars. The permanent incisor and canine teeth replace those of the same name in the milk dentition; the premolar teeth replace the milk molars. There are no teeth in the first dentition corresponding to the adult molars.

Each tooth is divided into—(1) a **crown**, above the level of the gum, (2) a **neck**, surrounded by the gum, (3) a **root** or **roots**, imbedded in the jaw. The **crowns** are chisel-shaped in *incisor* teeth; peg-shaped in *canine* teeth; have two tubercles or cusps in *premolar* teeth, one tubercle medial and the other lateral; have several tubercles in *molar* teeth. The crown of the first upper incisor is considerably wider than that of any other incisor, and the crown of the first lower incisor is usually the narrowest; the crown of the third lower molar is larger than that of the third upper molar; therefore, with the exception of the first lower incisor and the last upper molar, each tooth meets two teeth of the opposing jaw.

Each **root** or pang tapers to a point. The roots of the incisors, the canine, and the premolar teeth are single, except in the case of the first upper premolar, which may be bifid at its tip; each upper molar has three roots, two lateral and one medial, but those of the third molar may be clumped together; each lower molar has two roots, an anterior and a posterior, and both of those may be bifid at the point. If the teeth have all fallen out after death, those characters can be ascertained from the alveoli in the jaws.

The milk teeth are distinguished from adult teeth by their small size, their constricted necks, and, in the case of the molars, from the fact that the roots of the milk molars are more spread apart.

The bulk of each tooth is composed of an exceedingly hard substance called **ivory** or dentine. The crown is covered with a thin layer of still harder substance called **adamantine** or enamel. The root is covered with a crust of modified bone. A layer of fibrous tissue, called **alveolar periosteum**, lines the wall of the alveolus and surrounds the root, and is attached by Sharpey's fibres to both of them, binding them together. In the interior of each tooth there is a cavity, called the **pulp cavity**, containing connective tissue, vessels, and nerves. The vessels and nerves enter the tooth through a foramen at the tip of each root, and traverse a canal in the root to reach the pulp cavity.

The first **deciduous** tooth to **erupt** is one of the **incisors**, and it should appear about *six* **months** after birth; all the milk teeth should have appeared by the end of the *second* year. The first **permanent** tooth to **erupt** is one of the **first molars** and it should appear during the *sixth* **year**. By the *twelfth* year all the permanent teeth should have erupted, except the third molar (dens serotinus or wisdom tooth), which appears at any time between 17 and 25, and may not erupt at all.

See Figures in the chapter on the Digestive Organs, where the teeth are described fully.

Os Hyoideum.

The **hyoid bone** lies in the front of the neck, at the root of the tongue, between the mandible and the larynx. It is named from its resemblance to the letter U [the Greek letter υ aspirated thus ὑ = hy; εἶδος (eidos) = shape]. It does not articulate with any other bone. It consists of a *body*, a pair of *greater horns*, and a pair of *lesser horns*.

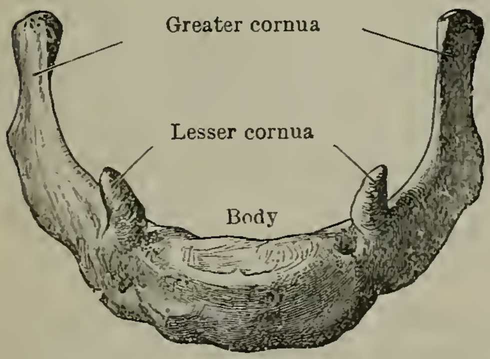


Fig. 152.—The Hyoid Bone as seen from the Front.

Corpus Ossis Hyoidei.—The **body** is the middle part or bottom of the U. It can be felt in the middle line of the neck about a finger's-breadth above the laryngeal prominence or "Adam's apple," when the chin is held up. When the chin is depressed the hyoid bone is at or above the level of the point of the chin and is closer to the larynx. If one swallows or gulps while the finger is placed on the hyoid bone, the bone is felt rapidly ascending, for the tongue, the hyoid bone, and the larynx are all suddenly jerked upwards in the movement of swallowing.

Cornua Majora.—The **greater horns** are the limbs of the U. They spring from the body about a finger's-breadth from the median plane and extend backwards in the sides of the throat; they can be gripped between finger and thumb, but the tip of the greater horn, though often referred to as a landmark, is overlapped by the anterior edge of the sterno-mastoid muscle, and cannot always be felt easily.

Cornua Minora.—The **lesser horns** are small pointed nodules of bone that project upwards from the junction of the body with the greater horns.

The **body** is compressed from before backwards and is curved from side to side with the convexity forwards. It has an upper and a lower border, and an anterior and a posterior surface. The anterior surface is divided into an upper and a lower part by a transverse ridge on which there is sometimes a small median tubercle; the upper part looks upwards rather than forwards and is divided by a median ridge into right and left halves. The genio-hyoideus is inserted into the upper part and a small adjoining area of the lower part. The anterior fibres of the hyoglossus arise at the side of the genio-hyoid; part of the mylo-hyoid is inserted below the genio-hyoid. The deep fascia of the neck is attached below the mylo-hyoid. The levator glandulæ thyreoideæ, when present, arises just below the attachment of the fascia, near the middle line.

The **lower border** gives insertion to the sterno-hyoideus. The median thyreo-hyoid ligament passes upwards behind the body to be attached to the **upper border**, which gives attachment also to the hyo-epiglottic ligament, and, occasionally, to some fibres of the genio-glossus. The **posterior surface** is smooth and concave; it is separated by some fat and a *bursa* from the median thyreo-hyoid ligament, which, in turn, is separated by a pad of fat from the stem of the epiglottis. When the larynx is pulled up during swallowing, the posterior surface of the hyoid bone overlaps the thyreoid cartilage of the larynx, and the bursa prevents friction between them.

The **greater horns** pass not only backwards, but have an upward and lateral inclination as well; they taper as they pass backwards, but each ends in a slightly swollen **tip**, to which the lateral thyreo-hyoid ligament is attached. They are compressed, so that each has a lateral and a medial surface and an upper and a lower border, but the compression is oblique, so that the surfaces are sometimes named upper and lower respectively, and the borders medial and lateral.

The **medial surface** is related to the thyreo-hyoid membrane, which passes upwards between it and the mucous membrane of the pharynx to be attached to the **upper border**. The **lateral surface** is continuous with the front of the body. It gives origin to the middle constrictor near the upper border, and to the hyo-glossus below that; the attachment of the fascial sling of the digastric tendon and the insertion of the stylo-hyoideus are close to the junction with the body. The deep fascia of the neck is attached near the lower border. The **lower border**, in its anterior two-thirds, gives insertion to the thyreo-hyoideus; the anterior belly of the omo-hyoideus is inserted into the anterior third, superficial to the thyreo-hyoid, and overlaps the insertion of the sterno-hyoid on the body.

The **lesser horn** is situated on the upper aspect of the junction of the body and the greater horn, and is often in line with the transverse ridge on the front of the body. It projects backwards and slightly in a lateral direction as well as upwards; usually it is only a few millimetres in length, but may be 10 or 12 mm. A few fibres of the middle constrictor arise from its lateral aspect, and the stylo-hyoid ligament is attached to its tip.

Development and Ossification.—The hyoid bone is developed from the cartilages of the second and third branchial or visceral arches, the ventral ends of which are fused together. On each side, the greater horn and the lateral part of the body are derived from the cartilage of the third arch. The lesser horn and the median part of the body are derived from the cartilage of the second or hyoid arch, which gives rise also to the stylo-hyoid ligament, the styloid process, and one of the auditory ossicles, namely, the *stapes*. Occasionally the stylo-hyoid ligament is ossified, and may be mistaken for a foreign body in the wall of the pharynx.

The hyoid bone is **ossified** from six centres. A pair (which soon unite into one) for the body, and one for each greater horn appear shortly before birth, and one for each lesser horn appears during the first year. The greater horn is united to the body by a plate of cartilage which ossifies at middle age. The lesser horn is united by a diarthrodial joint, which may disappear in old age.

The Skull at Birth.

At birth the skull, compared with other parts of the skeleton, is large, especially the vault. The facial region, however, compared with the rest of the skull, is small; in the adult the facial region, including the mandible, accounts for about one-half of the whole skull, but in the new-born child it is only one-eighth, for the teeth and the air sinuses are only rudimentary, and therefore the mandible, the maxillæ, and the nasal cavities are relatively small. A boy's head at birth is larger than a girl's, but so also is his body.

In the **vault**, the edges of the bones are not yet serrated, and are separated by linear intervals filled with strips of fibrous tissue continuous with the pericranium on the outer surface of the bones, and with the dura mater on the inner surface. Owing to the presence of those intervals, the bones of the vault have a certain degree of mobility, so that the head can be moulded into the required shape during the birth of the child. The bones are very thin, but, in addition to their mobility, they are less brittle than in an adult, and the pericranium is very tough, so that they are little liable to fracture.

In certain situations there are areas, rather than linear intervals, between the bones of the vault. Those areas are called **fonticuli** or fontanelles. They are seven in number—frontal, sagittal, occipital, right and left sphenoidal, right and left mastoid.

Fonticulus Frontalis.—The **frontal** or **antero-median fontanelle** is much the largest, and is easily felt in the fore part of the top of the head in the new-born child. It is lozenge-shaped, and measures about an inch and a half antero-posteriorly and an inch across. It is situated between the two halves of the frontal bone and the two parietal bones. The ossifying process going on in those bones spreads into the fibrous membrane of the fontanelle; the bones meet and the fontanelle is closed during the second year.

The **sagittal fontanelle** is a small unossified space in the region of the sagittal suture at the *obelion*; it extends like a cleft into the upper part of each parietal bone. The parietal foramina in the adult are derived from it and indicate its position. The fontanelle is often quite closed at birth; in such cases the parietal foramina are absent.

The **occipital** or **postero-median fontanelle** is situated at the apex of the occipital bone between the two parietal bones. It is closed two months after birth.

The **sphenoidal** or **antero-lateral fontanelle** is situated at the anterior inferior angle of the parietal bone. It is closed three months after birth.

The **mastoid** or **postero-lateral fontanelle** is situated at the postero-inferior angle of the parietal bone. It is closed at the end of the first year.

From irregularities in ossification **sutural bones** may be developed in various sutures, and at the fontanelles. Those formed at the sphenoidal fontanelle, being in the region of the pterion, are called **epipteric bones**.

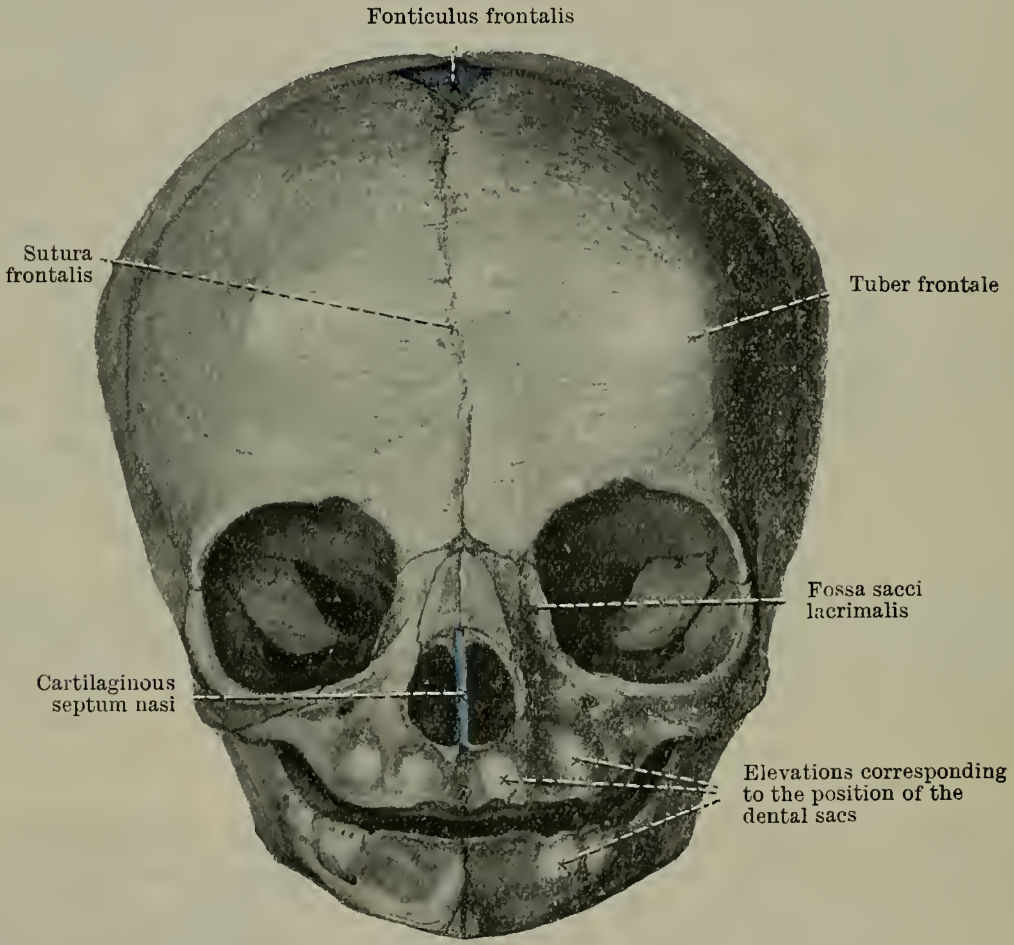

Fonticulus frontalis
Sutura frontalis
Tuber frontale
Fossa sacci lacrimalis
Cartilaginous septum nasi
Elevations corresponding to the position of the dental sacs

FIG. 153.—FRONTAL ASPECT OF THE SKULL AT BIRTH.

At birth the *occipital* bone is in four separate pieces, and on each side of the squama there is a cleft partially separating the upper, interparietal part of the bone from the rest; occasionally the two clefts meet. The *sphenoid* bone is in three separate parts—a median and two lateral—in addition to the sphenoidal conchæ. The *temporal* bone is in four parts—petro-mastoid, squamous, tympanic, and the styloid process. The mastoid process has not begun to develop. There is no *osseous* part of the external acoustic meatus, for the tympanic part of the temporal bone is not a plate as yet, but is a mere ring, incomplete superiorly. The tympanic membrane is therefore near the surface of the head; the obliquity of the membrane is greater than in the adult; it looks downwards and forwards more than in a lateral direction. The mandibular fossa is relatively large, and looks in a lateral direction as well as downwards.

The *mandible* is in two halves. The ramus is relatively short but wide, the angle is very obtuse, and the coronoid process is at a higher level than the head. The body has little substance beyond the walls of a wide groove incompletely divided into compartments for the dental sacs; the mental foramen is near the lower border. (See also p. 180.)

The *maxilla* is vertical and of small height, for the maxillary sinus is a mere groove in the lateral wall of the middle meatus; the distance between palate and orbit is therefore short. The alveolar process is small, reaching only a little below the level of the zygomatic arch; and it is hollowed out for the dental sacs.

The *nasal bones* are nearly flat. The *nasal cavity* is low, but the apertura piriformis is relatively large and is a broad ovoid in outline; its lower margin is not far below the inferior orbital margin; for the nasal cavity is situated almost entirely between the orbits.

The *orbital opening* is large and nearly circular, and has sharp margins; the orbital fissures are wide; the fossa for the lacrimal gland is deep, and the fossa for the sac looks forwards rather than in a lateral direction.

The *frontal* bone is divided into halves by the frontal suture. The frontal tuberosities or eminences are very prominent; their prominence, combined with the absence of superciliary arches, gives the bulging appearance to the child's forehead. The *parietal eminences* or tuberosities are even more prominent and convex, and are situated at the widest part of the head, which is not always the case in the adult. The frontal and parietal eminences are more convex in the child than in the adult because the child's head is a smaller sphere.

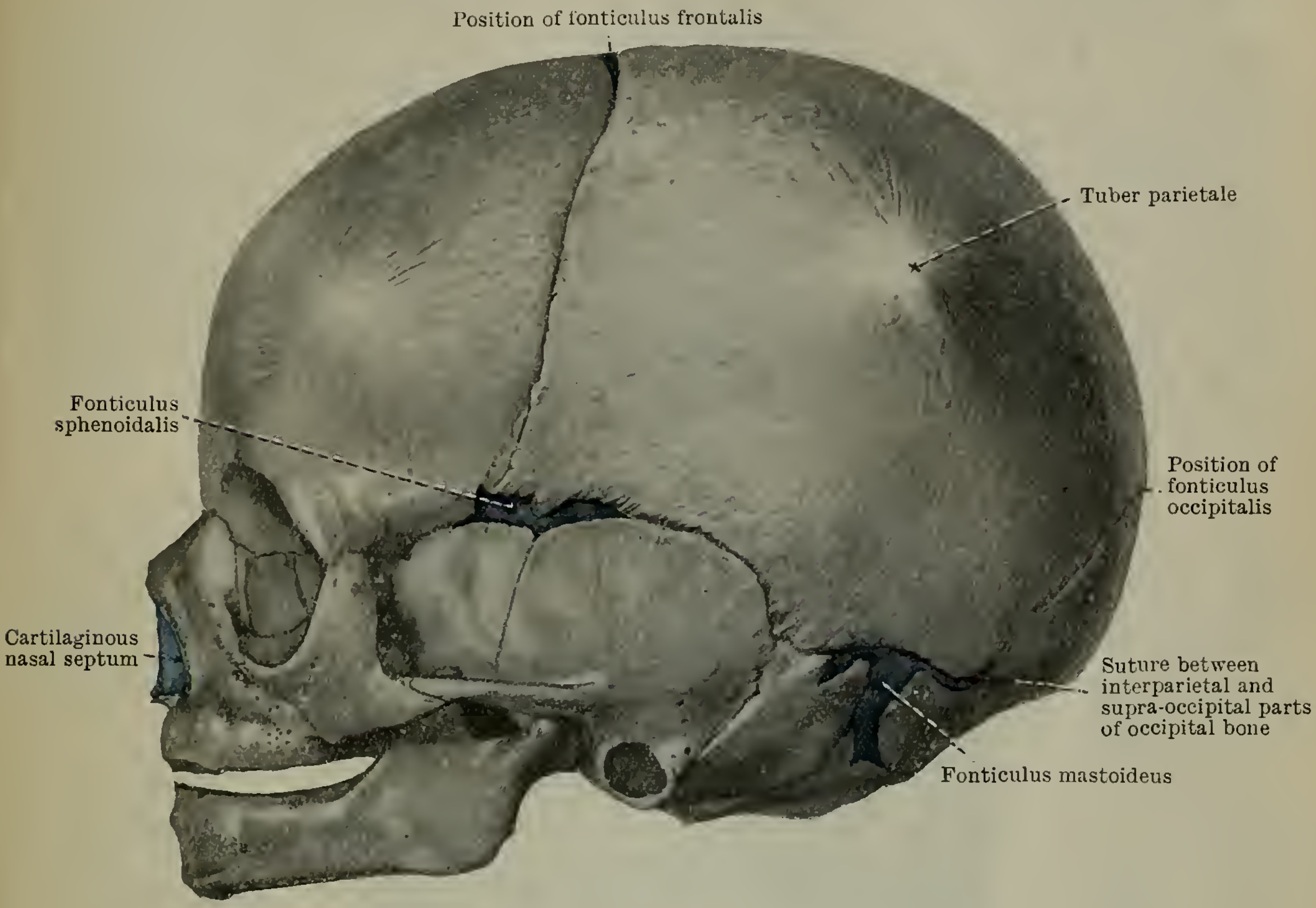

Position of fonticulus frontalis
Tuber parietale
Fonticulus sphenoidalis
Position of fonticulus occipitalis
Cartilaginous nasal septum
Suture between interparietal and supra-occipital parts of occipital bone
Fonticulus mastoideus

Fig. 154.—Lateral Aspect of the Skull at Birth.

Growth and Age Changes of Skull.

The skull grows rapidly from birth till the seventh year. At that age the orbits are almost as large as in the adult; the laminæ cribrosæ of the ethmoid, the body of the sphenoid, the petrous parts of the temporal bones and the foramen magnum have reached their full size; the jaws have enlarged in preparation for, as well as coincidently with, the eruption of the teeth, the chief enlargement in them being in the alveolar processes. For some years after the seventh growth is slower, but at puberty a rapid increase in the rate of growth takes place in all directions, especially in the frontal and facial regions, owing to the great increase of size of the air sinuses.

Growth in the thickness of bones takes place under the periosteum; growth in the area of the flat bones, and consequently growth in the capacity of the cranial cavity, takes place at the articulating margins of the bones; therefore, in order that increase may take place in the three dimensions, the sutures are arranged in three planes.

Up to maturity the age of the person can be ascertained approximately from the skull and the teeth.

A deciduous incisor erupts at the *sixth month* after birth, and all the incisors, except the lower lateral, appear during the *first year*; during that year the portions of the temporal bone and of the sphenoid unite. During the *second year*, the rest of the deciduous teeth erupt; the two halves of the mandible unite; the frontal fontanelle closes up; and the mastoid process appears. The lateral parts of the occipital bone unite with the occipital squama during the *third year*, and with the basi-occiput during the *fourth or fifth year*. The two halves of the frontal bone have almost completely united at the *sixth year*, and during that year the first of the permanent teeth—a first molar—erupts. The permanent incisors erupt during the *seventh and eighth years*, the premolars during the *ninth and tenth*, the canines during the *eleventh*, and the second molars during the *twelfth year*.

When the third molar is present the *seventeenth year* has been passed. If that tooth is present, and also the plate of cartilage between the body of the sphenoid and the occipital bone, the age is between 17 and 25. If the sphenoid and occipital are fused the age is over 25, for about that time the synchondroses of the skull disappear, *i.e.*, the synchondroses uniting the body of the sphenoid to the ethmoid and to the occipital, and the synchondrosis, on each side, between the lateral part of the occipital bone and the petrous part of the temporal bone.

After maturity, the wear of the teeth and the degree of obliteration of the sutures may give a rough indication of the age. Obliteration of sutures in the cranial vault—first in the coronal, next in the sagittal, and third in the lambdoidal—begins on the inner surface about ten years sooner than on the outer surface, and may begin between the *thirtieth and fortieth years*; but the order, the time, and the rate are all very variable, and complete obliteration does not take place till an advanced age.

In old age the skull vault may be thicker owing to deposit of bone on the inner surface; but in nearly all cases the skull bones are thinner, and the skull is lighter owing to absorption of diploë; associated with the absorption there are extension and enlargement of the sinuses. Consequent on loss of teeth there is diminution of the size of the jaws owing to absorption of the walls of the alveoli; the chin protrudes and the angle of the mandible becomes more obtuse. Less obvious changes are diminution of height and increase of breadth of the skull, transverse flattening of the base and the back of the head, and increase of the slope of the front and the back of the head; those changes may be due to the interaction of gravity and the support given to the skull by the vertebral column.

Sex Differences in the Skull.

There is little difference between the skulls of boys and girls till the age of puberty; but the skull of a woman is, as a whole, smaller than that of a man, and the air sinuses are small relatively to the size of the skull. The capacity of the cranial cavity is one-tenth less than in a man of the same race, and that is more or less in conformity with the relative size of the whole body of women and men of respective average build; the frontal and occipital regions of the cranial cavity are said to be relatively less capacious than the parietal region. Very often it is not possible to say with certainty whether a given adult skull is that of a man or of a woman, but the sex may be determined if the following differences are well marked.

The skull of a *woman* is lighter than that of a man and retains more of the character of a young skull; the muscular ridges are less pronounced; the mastoid processes are relatively small. The glabella and superciliary arches are less prominent; the forehead is therefore more vertical, and the frontal eminences appear to bulge more; the upper margin of the orbital opening is sharper—a fact appreciated better by touch than by sight; the parietal eminences are more convex. The facial region is rounder, and the jaws and teeth are smaller. The lower edge of the tympanic plate is said to be thicker and more tubercular. The vertex is said to be more flattened and the relative height of the skull to be less.

Development and Morphology of the Skull.[1]

At an early stage of development, the cerebral vesicles are enclosed in a membranous envelope, called the **primordial membranous cranium**, which is derived from the mesoderm. In certain lower vertebrates, *e.g.*, sharks and other *elasmobranch* fishes, a complete, thick-walled cartilaginous capsule, called the **primordial cartilaginous cranium**, is developed in the membranous envelope; but in mammals cartilage is developed only in the basal part; the roof, the greater part of the sides, and even part of the base of the skull remain membranous till bone is formed in them.

The **notochord** or chorda dorsalis [νῶτον (nōton) = the back] is imbedded in the basal part of the membranous envelope, but does not extend through the whole length of the base; its cephalic extremity reaches only to a point beneath the anterior end of the middle cerebral vesicle; and in the mammalian cartilaginous base it is related to that part which extends from the foramen magnum to the root of the dorsum sellæ. The cartilaginous base can therefore be divided into a **chordal** part and a **prechordal** part.

What is regarded as the typical occurrence of the chondrifying process in the mammalian skull is the appearance of a pair of elongated **parachordal cartilages** alongside the notochord, and a pair of elongated, curved **prechordal cartilages** or trabeculæ cranii, one at each side of the cranio-pharyngeal canal, *i.e.* the passage through which the pharyngeal part of the hypophysis enters the cranial cavity; those pairs of cartilages enlarge to form the cartilaginous base. But the process, so far as it has been observed, is not quite the same in the human embryo.

In the **human embryo** chondrification of the base of the cranium begins early in the second month and has almost attained its maximum about the end of the third month. Cartilage appears in the following situations.

(1) A pair of **parachordal cartilages** appear and fuse together around the notochord, to form a cartilaginous bar in which the *basi-occiput* ossifies. Extensions grow from its sides to form the

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[1] Within the limits of a general text-book it is not possible to do more than glimpse at this abstruse and complicated subject. The reader who is interested is referred to the works of Gegenbauer, Froriep, Keibel and Mall, Hertwig, and Bardeen; and to the more recent writings of Gaupp, *Hertwig's Handbuch*, 1906; Viot, *Anat. Hefte*, 1909; H. Fuchs, *Anat. Anz.*, 1911; and Edward Fawcett, *Jour. Anat.*

cartilaginous precursors of the *lateral parts of the occipital bone*; and they grow backwards to form the thin plate of cartilage in which the part of the *occipital squama* below the superior nuchal lines ossifies; the two halves of the plate are tardy in uniting, so that the part immediately behind the foramen magnum remains membranous till shortly before birth, and is the commonest site for a cerebral meningocele.

(2) Chondrification takes place in the mesoderm around the developing internal ear, giving rise to what is called the **auditory capsule**, in which the *petrous* and *mastoid* parts of the *temporal* bone ossify.

(3) In front of the parachordal cartilages a small transverse strip of cartilage appears, which gives rise to the *dorsum sellæ*.

(4) At a more ventral level, in front of and ventral to the end of the notochord, a nodule of cartilage appears, which gives rise to the cartilaginous *body of the sphenoid* bone. It enlarges and grows forwards as two extensions which pass one on each side of the cranio-pharyngeal canal; they join together in front of the canal to form the anterior part of the cartilaginous body of the sphenoid, and so provide the canal with cartilaginous boundaries, which grow inwards and usually occlude the canal during the third month, though occasionally it may remain open.

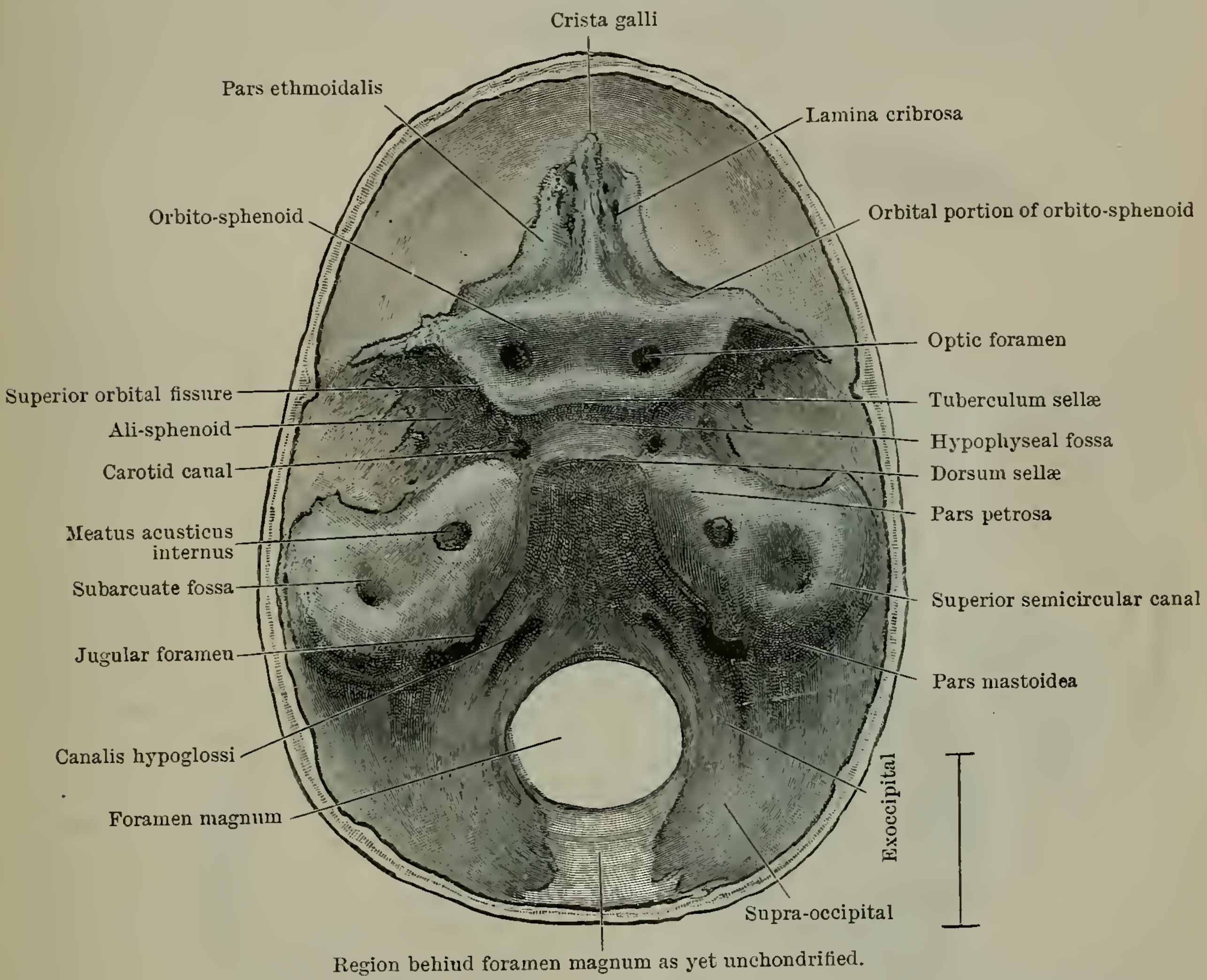


FIG. 155.—VIEW OF THE CHONDRO-CRANIUM OF A HUMAN FŒTUS 5 CM. IN LENGTH FROM VERTEX TO COCCYX (about the middle of the third month); the cartilage is coloured blue. The line to the right of the drawing shows the actual antero-posterior length.

(The parachordal cartilages do not fuse together in such a way that the notochord traverses the basi-occipital bar lengthwise. The notochord lies in a groove on the posterior part of the cerebral surface of the bar, then pierces it to reach its pharyngeal surface, whence it runs upwards, between the basi-occipital and sphenoidal cartilages, to the root of the dorsum sellæ.)

(5) Chondrification occurs in the region that corresponds to the root of the *pterygoid process* and the root of the *great wing* of the sphenoid, including the *lingula* and the part around the *foramen rotundum*.

(6) Chondrification occurs in the whole of the region of the small wing, so that in the cartilaginous state it is bigger than the great wing.

(7) Chondrification occurs in the region of the nose to form a cartilaginous **nasal capsule** during the third month. A cartilaginous plate, called the **paranasal cartilage**, appears in the lateral wall of the cavity and gives rise to the *labyrinth* of the ethmoid, including *its conchæ*, to the *inferior concha*, and the *sphenoidal concha*, while part of it is included in the maxilla, and part persists through life as the *cartilages of the side* of the nose. Chondrification in the primitive septum takes place partly by extension from the cartilaginous sphenoid, and partly by the development of independent **para-septal cartilages** in each side of the ventral part of the septum. The perpendicular lamina of the ethmoid ossifies in the cartilaginous septum, but a great part of

the cartilaginous septum persists throughout life. The cartilaginous roof is formed partly by fusion of the cartilage in the side wall with that in the septum, and partly by independent chondrification of the mesoderm around the filaments of the olfactory nerve. Chondrification in the floor is very incomplete.

All the various chondrified areas of the mesoderm fuse together and form a cartilaginous platform in the base of the skull from which the cartilages of the branchial or visceral arches are suspended. Most of the cartilage is ossified; part is replaced by bone ossified in the surrounding membrane; parts persist as the cartilages in the *sides* and *septum* of the nose and in the *foramina lacera*; and parts survive till maturity in the *synchondroses* of the skull.

Some of the bones of the skull are ossified in the cartilage of the base, namely: the occipital bone, except the part of its squama above the nuchal lines; the petrous and mastoid parts of the temporal bone; the body of the sphenoid, the small wings, the roots of the great wings and of the pterygoid processes; the ethmoid; the inferior concha.

Some of them are ossified in the membrane overlying the cartilages of the nose, namely, the vomer, the lacrimal, the nasal, and the upper part of the maxilla.

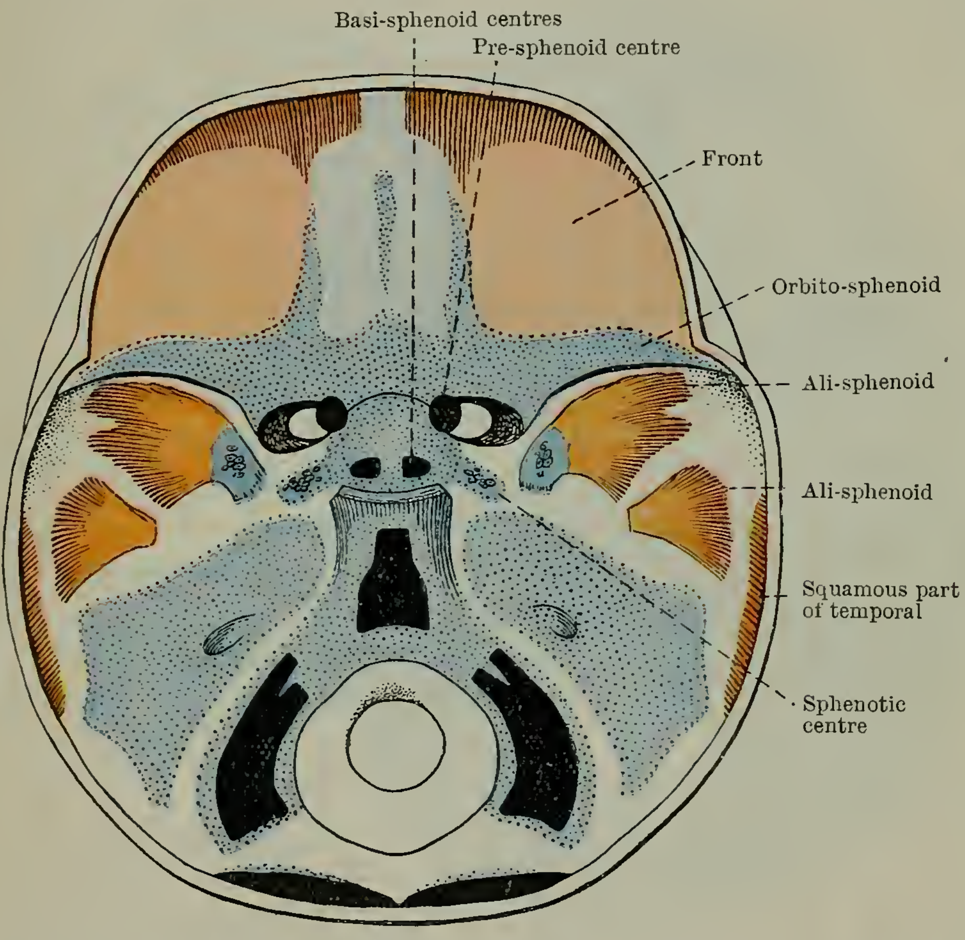


Fig. 156.—Ossification on Base and Side Walls of Skull of a four and a half Months' Fœtus (Schultze's method). Cartilage, blue; cartilage-bone, black; membrane-bone, red.

Some are ossified from the membrane underlying the mucous lining of the bucco-pharyngeal cavity, namely, the lower part of the maxilla, the palatine, and the greater part of the pterygoid process.

The frontal, the parietal, the squamous temporal, the upper part of the occipital squama, and the great wing of the sphenoid, all but its root, are ossified in the membranous brain envelope. The zygomatic bone ossifies in membrane which is continuous with the brain-case round the lateral margin of the orbit. The tympanic plate ossifies in membrane overlying the cartilaginous auditory capsule.

Skull bones therefore have been divided into two classes according to their method of ossification—cartilage or **primordial** bones and membranous or **secondary** bones. The distinction may be of not much importance, for the persisting osseous substance of every bone, whether its ossification began in cartilage or in membrane, is produced by ossification in the periosteum, *i.e.* in membrane; and some of the individual bones, *e.g.*, the temporal and the sphenoid, are ossified partly in cartilage and partly in membrane. It has been suggested, however, that the mammalian skull is derived from the two envelopes which have become modified and fused during the process of evolution. The inner envelope is the primordial chondro-cranium. The outer is of membranous origin, and is the more extensively evolved in the mammal; it appears first in certain fishes as ossified dermal plates overlying the primordial skull.

Although the skull never shows evidence of segmentation, probably owing to the need of stability even in the early evolutionary forms, it is assumed that the chordal part of the base has arisen by the fusion of segments equivalent to vertebræ, because—(1) of the presence of myotomes in the head region, (2) of the connexion with the series of branchial arches, and (3) of the segmental arrangement of nerves. The guide to the disposition of the nerves is their points of exit through the dura mater, for that is derived from the inner part of the primitive brain envelope; owing to the evolutionary changes that have taken place in the outer parts of the mammalian brain envelope, the apertures through which the nerves leave the skull, though very constant in position, do not in every case correspond to the points where they pierce the dura, *e.g.*, the oculo-motor and the abducent nerves in the human head.

The mammalian occipital bone is regarded (Froriep) as the equivalent of four fused vertebræ, and there is reason to believe that in some vertebrates the occipital region of the primordial cranium is increased by inclusion of vertebræ from the cephalic end of the vertebral column. Gegenbauer concluded, from a study of the metameric arrangement of cerebral nerves, that the chordal part of the primordial cranium—and that is the part to which the cerebral nerves are primitively related, excepting the olfactory and the optic nerves, which are metamorphosed portions of the brain—consisted of the equivalents of nine fused vertebræ, and he called the chordal part the **vertebral** part of the cranium. The prechordal part he called **evertebral** or non-vertebral, and regarded it as a new formation developed to contain and protect the enlarging brain and the organs of smell and sight.

The outstanding features that distinguish the human skull are the large size of the brain-case, the small size of the face, and the fact that the skull is poised on the end of the backbone. Its position on the vertebral column reacts on its outward configuration; the occipito-vertebral joints are placed so that the fore and hind parts of the head nearly balance each other; therefore the prominent ridges and crests for the attachment of the muscles and ligaments required in lower mammals to hold the head in position are absent. The small size of the face is due chiefly to reduction of the bulk and length of the jaws and of the size of the teeth. Diminution of the mandible reacts on the form of the skull, for the muscles of mastication do not need to be so large, and there is corresponding reduction in the fossæ that lodge them, and in the surfaces and crests that give origin to them.

OSSA CRANII.

Os Frontale.

The **frontal bone** is situated in the front of the skull. It is divisible into—a **frontal part**, which lies in the forehead; two **orbital parts**, which lie in the roofs of the two orbits; and a **nasal part**, which lies in the roof of the nose.

Pars Frontalis.—The **frontal part** is the shell-like portion situated above the orbital openings. Its *external surface* is rounded from side to side and from above downwards. The convexity is most pronounced, on each side, about 35 mm. above the orbit, constituting what are known as the **frontal tuberosities** or eminences; they mark the original sites of the centres from which the bone ossifies. On each side, the lower border of the frontal part is the curved **supra-orbital margin**. The margin ends laterally in the prominent **zygomatic process**. The medial end descends to a slightly lower level and is called the **medial angular process**; it is separated from its fellow by a rough articular area called the **nasal notch**. The curve of the supra-orbital margin varies in different persons and races. Between its medial and intermediate thirds it is crossed by a groove, often (25 per cent., Krause) converted into a foramen—the **supra-orbital notch** or **foramen**, for the supra-orbital nerve. Sometimes (16 per cent., Loja) a series of grooves, radiating upwards and laterally, indicate the course of the nerve (Dixon). Above the supra-orbital margin the character of the bone displays marked differences in the two sexes: in the male, above the

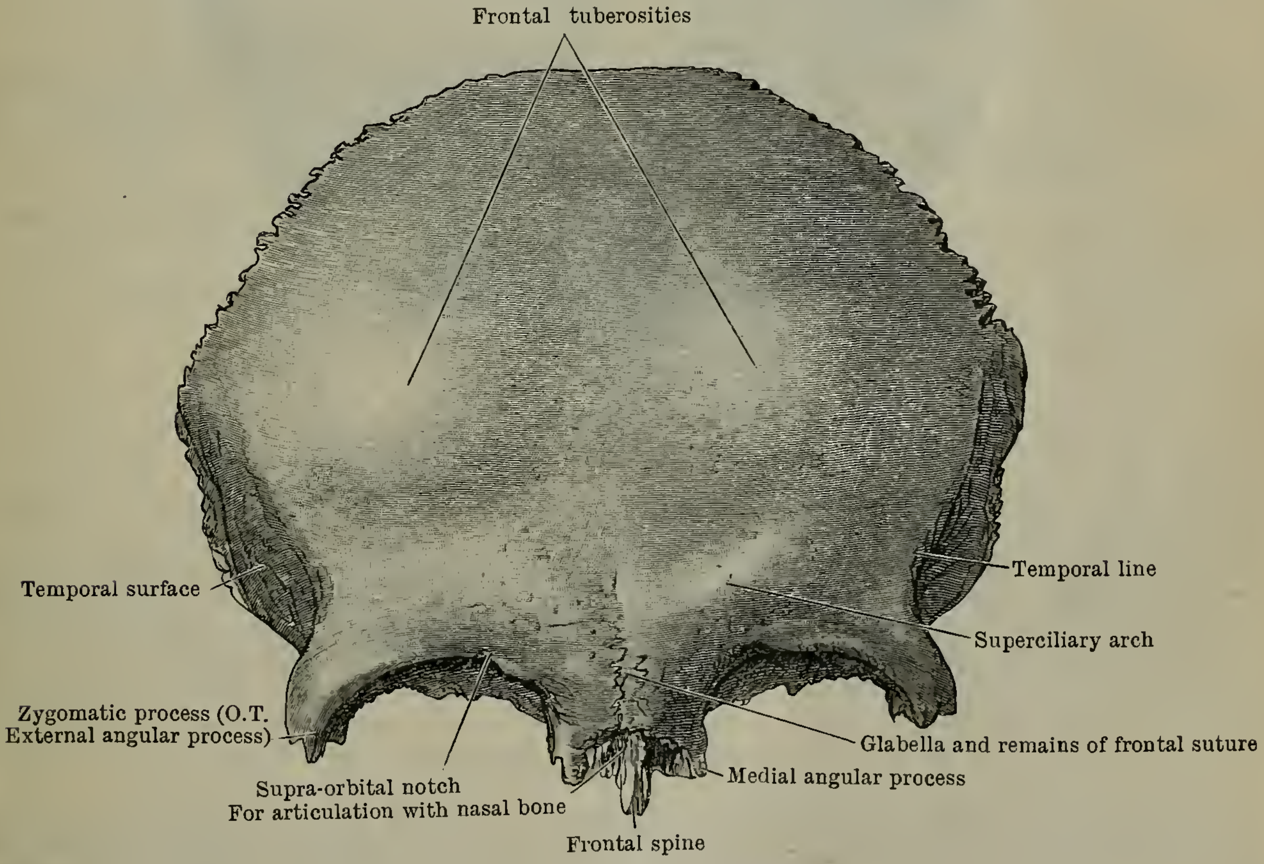


Fig. 157.—The Frontal Bone (Anterior View).

interval between the two medial angular processes, there is usually a well-marked prominence, called the **glabella**; from this, the fulness extends laterally above the supra-orbital margin, varying in degree and extent, and forming the elevations known as the **superciliary arches**. Their prominence reacts on the character of the supra-orbital margins, which are thicker and more rounded in the male than in the female. The remains of the frontal suture can usually be seen in the glabella.

Extending from the **zygomatic process** is a well-marked ridge, called the **linea temporalis**, which curves upwards and slightly medially, and then, turning backwards, it arches across the lateral aspect of the bone. The line separates the anterior surface of the frontal portion of the bone from its *temporal surface*.

The *cerebral surface* of the frontal part is concave; it is marked by **digital impressions** for the gyri of the brain, and by narrow grooves for meningeal vessels, while on each side of the median plane there are **granular foveolæ**, varying in number and size, for the lodgment of arachnoid granulations. On the lower part of the surface there is a median ridge, called the **frontal crest**, which fades away as it is traced upwards. A groove called the **sagittal sulcus** begins on the crest and extends upwards to the articular margin of the bone, widening as it proceeds. A small hole, called the **foramen cæcum**, which is situated usually between the ethmoid and the lower end of the frontal crest, may be seen in its entirety on the separate frontal bone.

Pars Orbitalis.—Each **orbital part** or **plate** is a thin, brittle, curved plate which is convex upwards and has the outline of a sextant. Its upper or *cerebral surface* is convex and uneven, showing ridges and depressions corresponding to the sulci and gyri of the frontal lobe, which lies on it; it shows also narrow grooves for meningeal vessels.

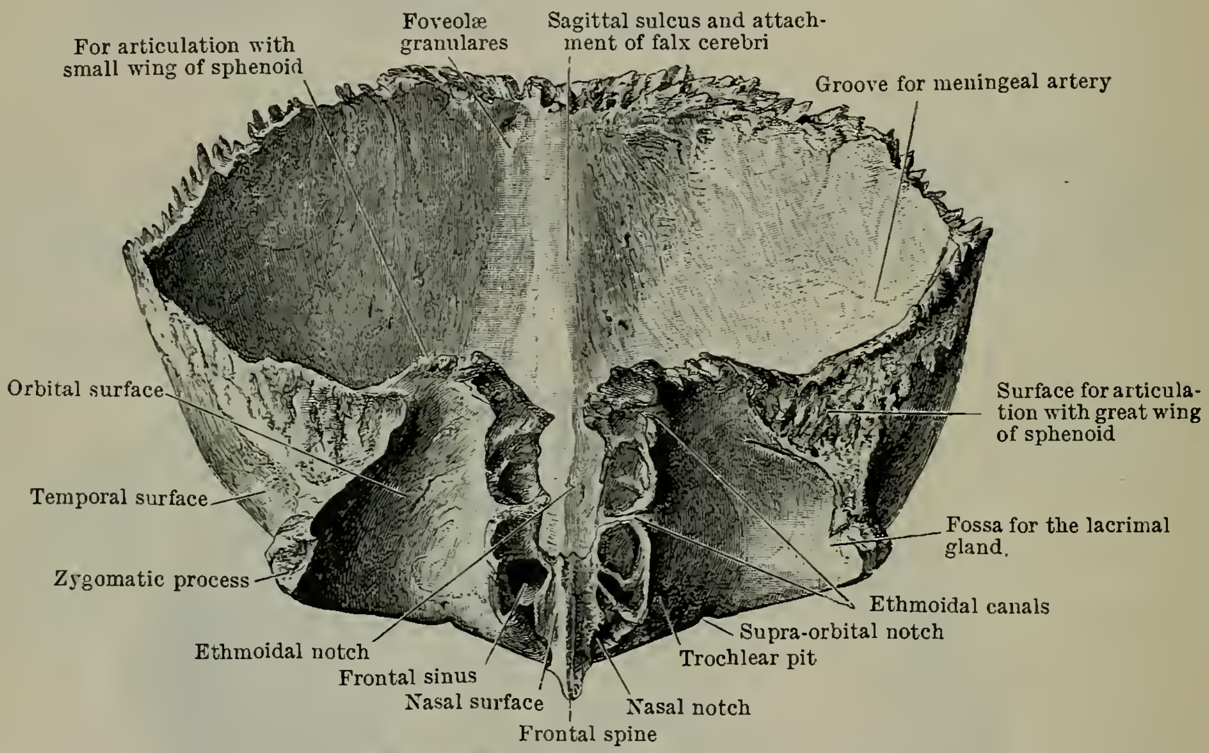

Foveolæ granulares
Sagittal sulcus and attachment of falx cerebri
For articulation with small wing of sphenoid
Groove for meningeal artery
Orbital surface
Surface for articulation with great wing of sphenoid
Temporal surface
Fossa for the lacrimal gland.
Zygomatic process
Ethmoidal canals
Supra-orbital notch
Ethmoidal notch
Trochlear pit
Frontal sinus
Nasal surface
Nasal notch
Frontal spine

Fig. 158.—The Frontal Bone as seen from below.

The larger, lateral part of the *inferior surface* is smooth and concave, and forms the greater part of the roof of the orbit, extending forward to the supra-orbital margin. Near that margin, about midway between the medial angular process and the supra-orbital notch, there is either a very small depression (**fovea trochlearis**), or a spicule of bone (**spina trochlearis**), or both, for the attachment of the trochlea or pulley of the superior oblique muscle of the eyeball. Laterally the surface is overhung by the supra-orbital margin and the zygomatic process, so that a wide depression or **fossa for the lacrimal gland** is formed. The medial part of the inferior surface is a wide strip which overlies the labyrinth of the ethmoid, roofing in ethmoidal air-cells, so that it presents a number of irregular depressions corresponding to those cells. Anteriorly the opening from the frontal sinus is seen. Further back there are two narrow, nearly transverse, grooves which, with corresponding grooves on the ethmoid labyrinth, form the **anterior** and **posterior ethmoidal canals**. The medial margin of the orbital plate is parallel with its fellow of the other side. Their posterior halves, or more, are separated by an interval, called the **ethmoidal notch** because it is occupied by the laminæ cribrosæ of the ethmoid when the bones are articulated. The anterior halves of the margins are united to the nasal part of the bone.

Pars Nasalis.—The **nasal part** is the small portion of bone that lies in front of the ethmoidal notch. From its centre the **frontal spine** projects downwards and forwards into the nasal septum between the nasal crest of the nasal bones and the perpendicular lamina of the ethmoid, articulating with both. On each side of the root of the spine the nasal part presents a smooth, grooved surface that slopes from above downwards and forwards, and forms part of the roof of the nasal cavity.

Articulations.—The zygomatic process articulates with the frontal process of the zygomatic bone. Behind that, a rough, triangular area articulates with the great wing of the sphenoid. Above that, the whole serrated posterior margin of the frontal part articulates with the two parietal bones. The posterior margin of the orbital plate articulates with the small wing of the sphenoid. The medial part of the inferior surface articulates with the labyrinth of the ethmoid. The medial angular process articulates with the lacrimal bone. The nasal notch articulates with the upper ends of the nasal bone and frontal process of the maxilla on each side. The frontal spine articulates with the nasal bones and the perpendicular lamina of the ethmoid.

Ossification.—Ossification begins in membrane from one centre for each half. Each centre appears about the sixth or seventh week in the region above the zygomatic process. From them the two halves of the frontal part of the bone are ossified, and by extension medially and backwards from their lower part the orbital parts also are ossified. Serres, Rambaud and Renault, and v. Ihering describe the occurrence of three pairs of secondary centres somewhat later: one pair for the frontal spine, on each side of the foramen cæcum; a centre on each side in the position of the trochlear pit; and a centre for each zygomatic process. Fusion between those secondary and the primary centres is usually complete about the sixth or seventh month of fœtal life. At birth the two symmetrical halves of the bone are separated by the *frontal suture*, obliteration of which, commencing as a rule on a level with the frontal tubera, gradually takes place, so that about the fifth or sixth year it is more or less completely closed, traces only of the suture being left above and below. In about 8 per cent. of Europeans the suture persists in the adult. At birth the supra-orbital notches lie near the middle of the supra-orbital margins.

Traces of the frontal sinuses may be met with about the second year, but it is only about the age of 7 that they can be definitely recognised. They increase in size slowly till the age of puberty and rapidly after puberty.

Structure and Variations.—Like other bones of the skull vault the frontal bone is made of two tables of compact substance enclosing a layer of spongy substance called the **diploë**. The diploë disappears from the part above the nose and the orbital openings to form the frontal air sinuses. The zygomatic process is dense in structure and is shaped so as to meet the pressure transmitted through the zygomatic bone from the closed jaws.

The commonest variation is a persistence of the frontal suture: skulls displaying this peculiarity are termed **metopic**. The researches of various observers point to the more frequent occurrence of the metopic suture in the higher than in the lower races of man; and Calmette asserts its greater frequency in the brachycephalic than in the dolichocephalic type. Sutural bones may occur in the region of the frontal fontanelle; their fusion with one or other half of the frontal explains how the metopic suture is not always in line with the sagittal suture (Stieda, *Anat. Anz.* 1897); occasionally they coalesce to form a *bregmatic bone* (G. Zoja, *Bull. Scientifico*, xvii.). Turner (*Challenger Reports*, part xxix.) records an instance of direct articulation of the frontal bone with the orbital surface of the maxilla in a Bush skull; other examples of the same condition, which obtains normally in the skulls of the chimpanzee and gorilla, have been observed (*Jour. Anat. and Physiol.* vol. xxiv.). There is sometimes a small arterial groove just medial to the supra-orbital notch or foramen, and occasionally that foramen is double, the lateral aperture appearing in the orbital margin wide of its middle point. Frequently the bone corresponding to the floor of the lacrimal fossa displays a cribriform appearance. Schwalbe (1901) records the presence of small independent ossicles (supra-nasal bones) in the anterior part of the metopic suture. He has directed attention also (*Zeit. f. Morph. und Anthr.* vol. iii.) to the existence of the metopic fontanelle, first described by Gerdy, and the occurrence of *metopic ossicles* (ossa interfrontalia) and *canals*.

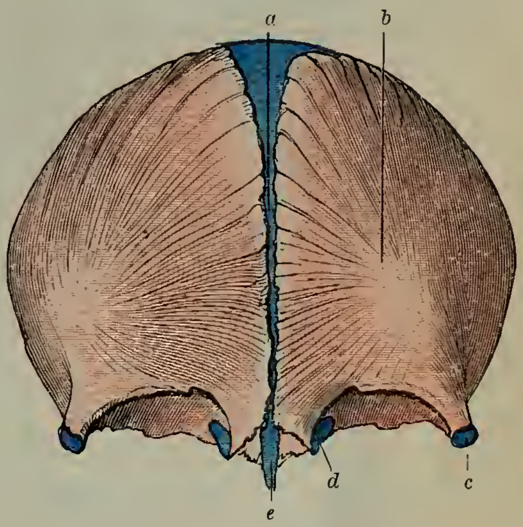


Fig. 159.—Ossification of the Frontal Bone.

a, Frontal suture still open. *b*, Position of primary centre. *c*, Centre for zygomatic process. *d*, Centre for region of trochlea. *e*, Centres for frontal spine.

Ossa Parietalia.

The **parietal bones** are placed one on each side of the vault of the cranium. Each articulates with its fellow of the opposite side, with the frontal *anteriorly*, with the occipital *posteriorly*, and with the temporal and the sphenoid *inferiorly*. Each bone possesses a parietal and cerebral surface, four borders, and four angles.

The **parietal surface**, convex from above downwards and from before backwards, displays towards its centre a more or less pronounced elevation called the **parietal tuberosity** or **eminence**. The eminence marks the position of the ossific centre, and not infrequently corresponds to the point of maximum width of the head. At a variable distance from the inferior border of the bone, and more or less parallel to it, two curved lines can usually be distinguished. They are the two branches into which the temporal line, seen already on the frontal bone, divides, and they are named the **superior** and **inferior temporal lines.** The area below the lines forms part of the floor of the **temporal fossa**, and is called the **planum temporale**; it is often faintly marked by grooves for branches of the middle temporal artery. Near the upper border of the bone, and about an inch from its postero-superior angle, is the small **parietal foramen.**

The **cerebral surface** is concave. It is moulded over the surface of portions of the frontal, parietal, occipital, and temporal lobes of the cerebrum, and displays digital impressions for the gyri of the brain. It presents also well-marked grooves for the branches of the middle meningeal vessels; the grooves radiate from the antero-inferior angle and the lower margin of the bone, the best marked running upwards at some little distance behind and parallel to the anterior border. Close to the superior margin there is a series of pits for arachnoideal granulations, and there also the bone is channelled so as to form a groove (**sulcus sagittalis**), which is completed by articulation with its fellow of the opposite side. Close to the postero-inferior angle there is a short curved groove called the **transverse sulcus.**

The *anterior*, *superior*, and *posterior borders* are deeply serrated. The **anterior border** articulates with the frontal bone, forming with it the *coronal suture.* In the upper part of the suture the frontal bone overlaps the parietal, while the parietal overlies the frontal below. The **posterior border** is united with the occipital bone to form the *lambdoid suture.* The **superior border** articulates with its fellow of the opposite side to form the *sagittal suture*; in the interval between the two parietal foramina this suture is usually simple in its outline. The **frontal** or **antero-superior angle** is almost rectangular; the **occipital** or **postero-superior angle** is usually more or less rounded. The **inferior border (margo squamosus)** is curved, and shorter than the others. Sharp and bevelled at the expense of its outer table, it displays a fluted arrangement, and articulates with the squamous part of the temporal bone. The **sphenoidal** or **antero-inferior angle,** pointed and prominent, articulates with the great wing of the sphenoid. It is wedged into the angle between the great wing and the frontal bone, and is bevelled at the expense of its inner table anteriorly, whilst inferiorly it is thinned at the expense of its outer table. The **mastoid** or **postero-inferior angle** is a truncated angle lying between the inferior and posterior borders. It is deeply serrated, and articulates with the mastoid part of the temporal bone.

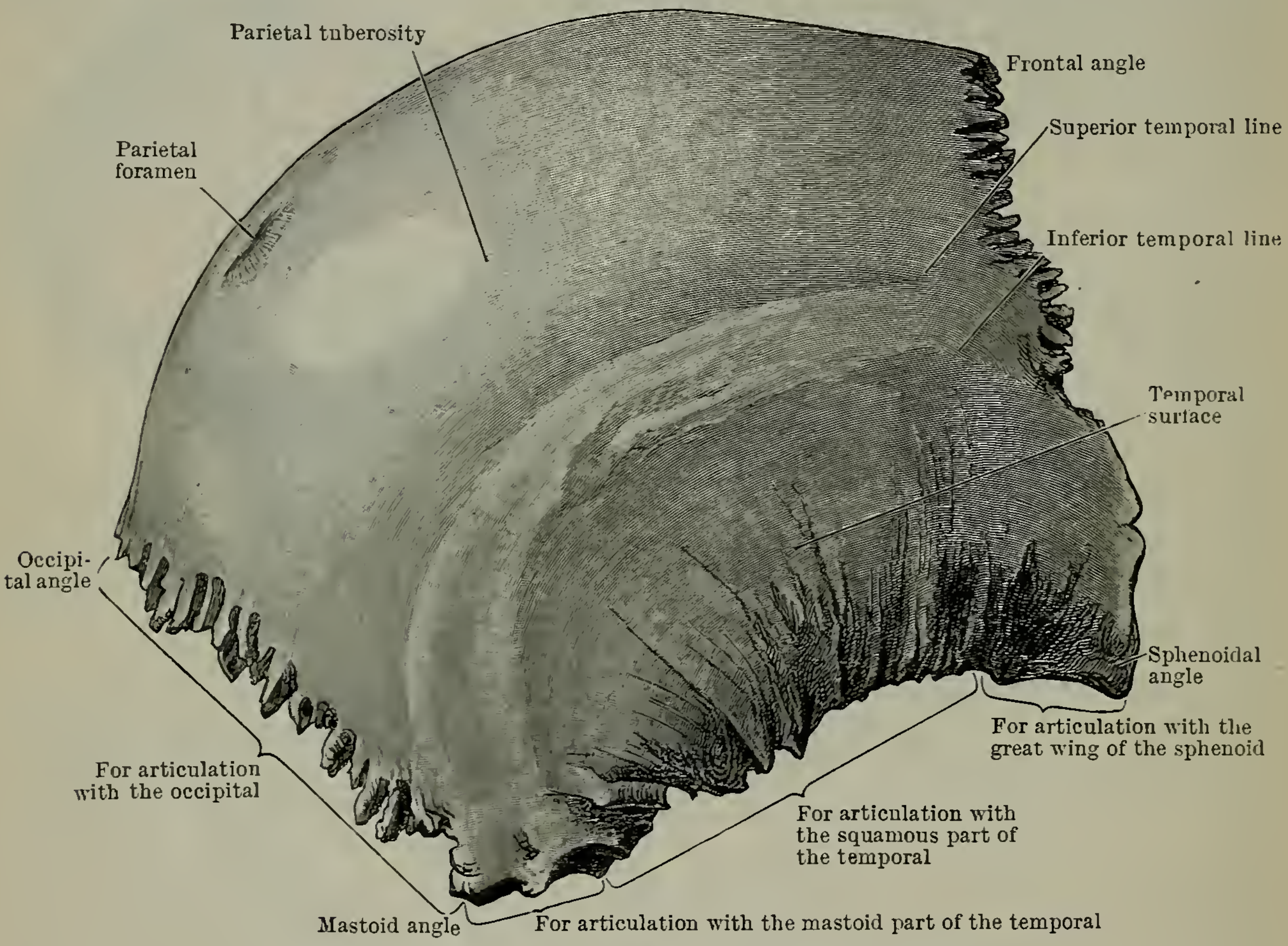

Parietal tuberosity
Frontal angle
Superior temporal line
Parietal foramen
Inferior temporal line
Temporal surface
Occipital angle
Sphenoidal angle
For articulation with the great wing of the sphenoid
For articulation with the occipital
For articulation with the squamous part of the temporal
Mastoid angle
For articulation with the mastoid part of the temporal

FIG. 160.—THE RIGHT PARIETAL BONE (Parietal Surface).

Ossification.—Ossification takes place in membrane by two centres which appear, one above the other, in the eighth week of fœtal life; they gradually unite during the fourth month and correspond in position to the future parietal tuberosity; from that region ossification spreads in a radial manner towards the edges and angles of the bone, where, however, the membranous condition persists for some time, constituting the fontanelles. Ossification is also somewhat delayed in the region of the parietal foramina, so that a membranous interval, called the sagittal fontanelle, is not infrequently apparent even at birth.

Structure and Variations.—The parietal bone is thin towards its lower part, and is thickest along the upper border.

A number of cases have been recorded in which the parietal bone is divided into an upper and lower part by an antero-posterior suture. Coraini records a case in which the parietal was incompletely divided into an anterior and posterior part by a vertical suture. A tripartite condition of the bone has also been observed (Frasetto). The parietal foramina vary greatly in size, and to some extent in position. They are sometimes absent on one or other side, or both. They correspond in position to the sagittal fontanelle. Sometimes the ossification of the sagittal fontanelle is incomplete and a small transverse fissure remains. Occasionally in the region of the frontal fontanelle an ossicle of variable size may be met with. According to its fusion with adjacent bones it may disturb the direction of the sagittal suture.

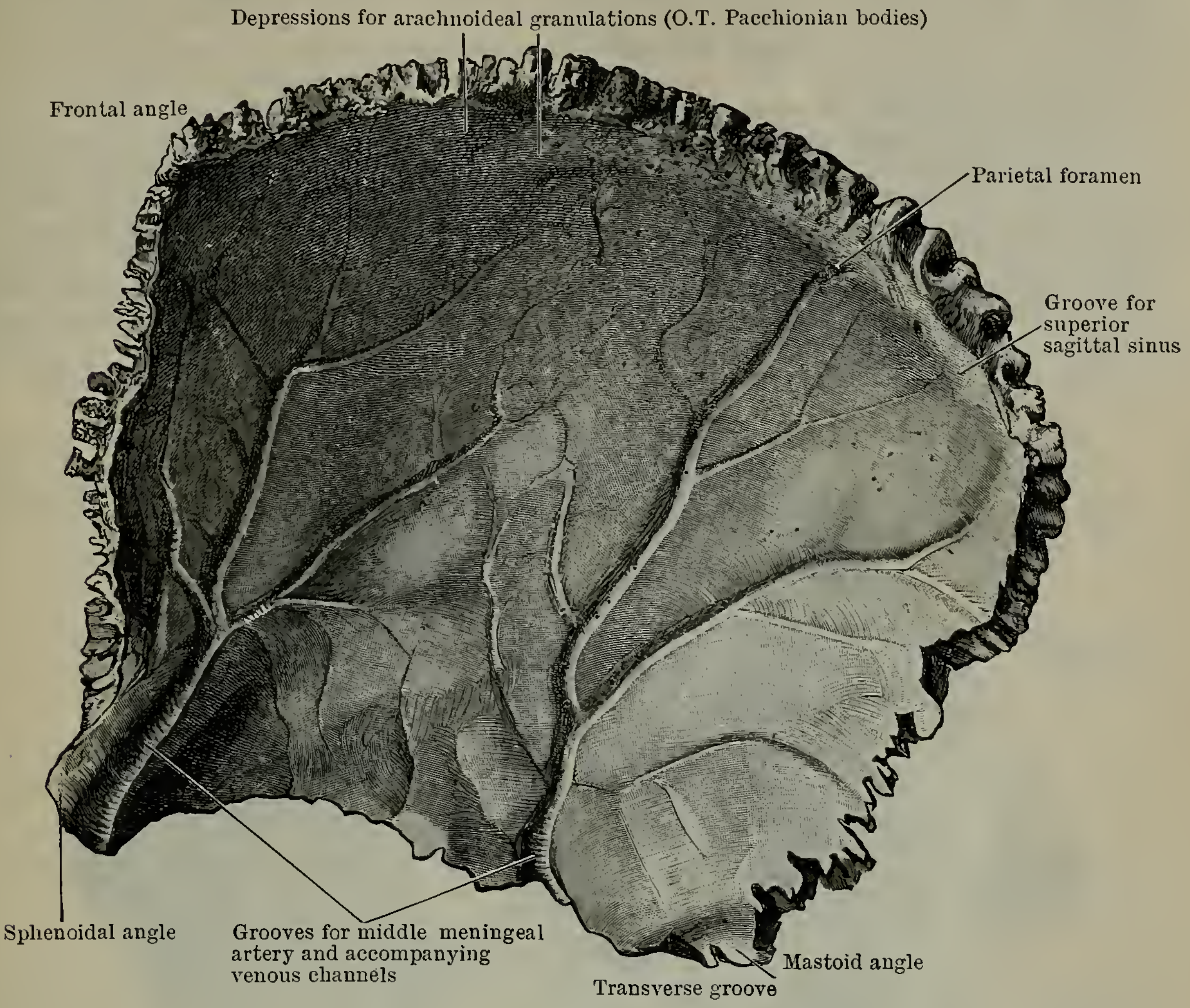

Depressions for arachnoideal granulations (O.T. Pacchionian bodies)
Frontal angle
Parietal foramen
Groove for superior sagittal sinus
Sphenoidal angle
Grooves for middle meningeal artery and accompanying venous channels
Mastoid angle
Transverse groove

FIG. 161.—THE RIGHT PARIETAL BONE (Cerebral Surface).

Os Occipitale.

The **occipital bone**, placed at the posterior and lower part of the cranium, consists of four parts, arranged around a large ovoid hole, called the foramen magnum. The expanded, curved plate behind the foramen is the **squama occipitalis.** The thick rod-like portion anterior to the foramen is the **basilar part.** On each side the foramen is bounded by the **lateral** or **exoccipital parts.**

Squama Occipitalis.—The **squamous part** in shape somewhat resembles a Gothic arch, and is curved from side to side and from above downwards. It forms inferiorly a small portion of the middle of the posterior boundary of the foramen magnum, and unites, on each side of that, with the lateral parts of the bone.

About the centre of the *external surface* of the squama there is a prominence, varying in distinctness, called the **external occipital protuberance.** On each side, a curved line, called the **superior nuchal line,** extends from the protuberance towards the lateral angle of the bone; immediately above it there is often another curved ridge called the **highest nuchal line.** The right and left superior nuchal lines divide the external surface of the squama into an upper part called the occipital plane and a lower part called the nuchal plane. The **occipital plane** bulges backwards beyond the protuberance, but in exceptional cases the protuberance is the most posterior part of the skull. The **nuchal plane** is rough and uneven. It is divided into a right and a left half by a median ridge, called the **external occipital crest,** which extends from the protuberance to the foramen magnum. From the middle of the crest a curved line, called the **inferior nuchal line,** extends towards the lateral margin of the bone on each side.

The *internal surface* of the squamous part is concave, and is subdivided into four fossæ by a crucial arrangement of grooved ridges called the **eminentia cruciata.** In the upper pair of fossæ are lodged the occipital lobes of the cerebrum, whilst the hemispheres of the cerebellum occupy the lower pair. Near the centre of the eminence is the **internal occipital protuberance,** an irregular elevation, the sides of which are variously channelled according to the disposition of the grooves; the internal protuberance is usually at a slightly higher level than the external. Leading from the protuberance to the posterior margin of the foramen magnum is a sharp and well-defined ridge called the **internal occipital crest.** Passing upwards from the protuberance there is usually a well-marked ridge, to one or other side of which, more frequently the right, there is a well-defined groove called the **sulcus sagittalis.** A pair of **transverse sulci** extend horizontally from the protuberance, and separate the upper pair of fossæ from the lower. Commonly the right transverse groove is confluent with the groove on the right side of the median ridge, but exceptions are not infrequent.

The **superior angle,** more or less sharp and pointed, is wedged in between the two parietal bones. Each **lateral angle** articulates with the posterior extremity of the mastoid portion of the corresponding temporal bone. The **superior borders,** much serrated, articulate with the parietal bones, forming the **lambdoid suture**; and the **lateral borders,** extending from the lateral angles to the jugular processes inferiorly, are connected with the medial margins of the mastoid portions of the temporal bones.

Pars Lateralis.—Each **lateral part** of the occipital bone is placed at the side of the foramen magnum; on their inferior surfaces they bear the **occipital condyles,** by means of which the skull articulates with the atlas. The condyles are elongated and oval; they are situated at the side of the anterior half of the foramen magnum; their anterior ends are closer together than their posterior ends; their articular surfaces are convex from before backwards and look in a lateral direction as well as downwards. Each articular surface is supported on a boss of bone through which the **canal for the hypoglossal nerve** passes. The canal opens externally into a depression just lateral to the anterior part of the condyle; its internal opening is a little above the margin of the foramen magnum. Behind the condyle there is a wide depression called the **condyloid fossa,** into which there opens a canal called the **condyloid canal**; the canal, however, is not always present. The edge of the foramen magnum immediately behind the condyle is often grooved by the vertebral artery. The bone which lies lateral to the posterior half of the condyle is called the **jugular process.** The *anterior* border of the process is free, rounded, and forms the posterior boundary of the jugular foramen; the border is concave from side to side, and the concavity is called the **jugular notch.** *Laterally,* the jugular process articulates by a synchondrosis with the jugular surface of the petrous part of the temporal bone. Its *posterior* border is confluent with the occipital squama, and its *lower* surface is rough.

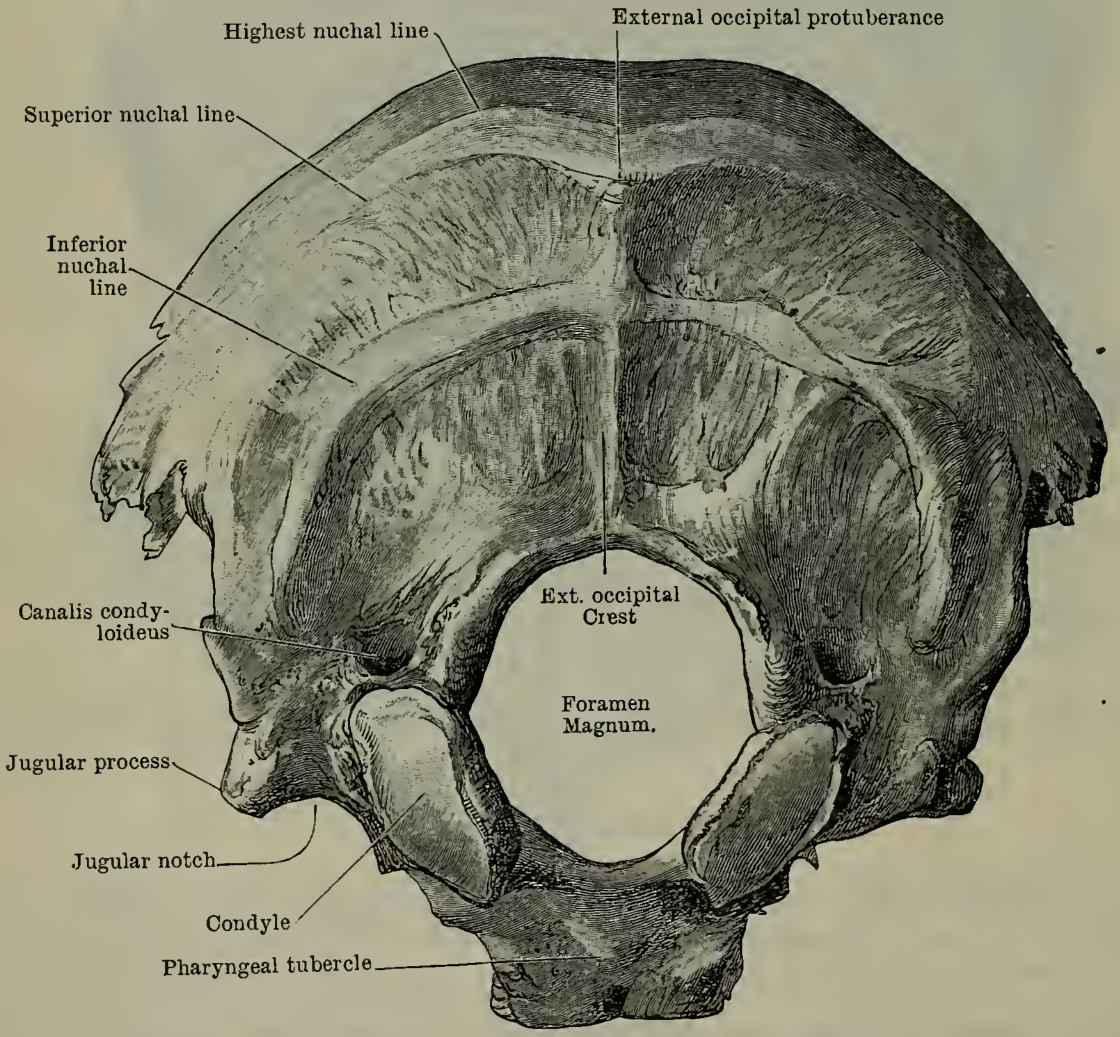


Fig. 162.—The Occipital Bone as seen from Below.

The *superior aspect* of the lateral part displays, at the side of the foramen magnum, a smooth, oval elevation, called the **jugular tubercle,** which overlies the hypoglossal canal; in many cases there is a shallow oblique groove, on or behind the tubercle, which lodges the vagus, accessory and glosso-pharyngeal nerves. The upper surface of the jugular process presents a wide, deep, groove for the lower part of the transverse sinus; the condyloid canal, when present, opens into, or near, the groove.

Pars Basilaris.—The **basilar part** of the occipital bone extends forwards and upwards from the foramen magnum. Its anterior extremity is usually sawn across, as, after the twenty-fifth year, it is fused with the body of the sphenoid bone. The sawn surface is quadrilateral in outline; but posteriorly, where the basilar part bounds the foramen magnum, it is broad and thin. On its *inferior surface* some little distance anterior to the foramen magnum, there is a small elevation called the **pharyngeal tubercle.** The *superior surface* forms a broad and shallow groove which slopes upwards and forwards from the foramen magnum. *On each side* its lateral edge is faintly grooved for the inferior petrosal venous sinus, below which the lateral aspect of the bone is rough for the cartilage which unites it to the sides and apex of the petrous part of the temporal bone.

Foramen Occipitale Magnum.—The **foramen magnum** is variable in size and outline, but is usually ovoid, with the long axis antero-posterior. The plane of its outlet varies in different skulls, but usually it is directed downwards and slightly forwards. Anteriorly the condyles encroach upon it, and narrow its transverse diameter to some extent.

Ossification.—The major part of the bone ossifies in cartilage, the upper part of the squama (interparietal) alone ossifying in membrane. The **basilar part** begins to ossify about the sixth week of fœtal life by the appearance of two centres, one in front of the other; the anterior, according to Albrecht, constitutes the *basiotic* (p. 196), the posterior the *basi-occipital.* Those two centres—which there is some reason to believe may themselves be formed by the fusion of pairs—rapidly unite, so that the occurrence of one centre alone is frequently described. From it the anterior part of the margin of the foramen magnum is ossified, together with the anterior ends of the occipital condyles. It helps also to close up the front of the hypoglossal canal. Union with the condylic parts is complete about the fourth or fifth year. Ankylosis between the basi-occipital and the sphenoid takes place about the twenty-fifth year.

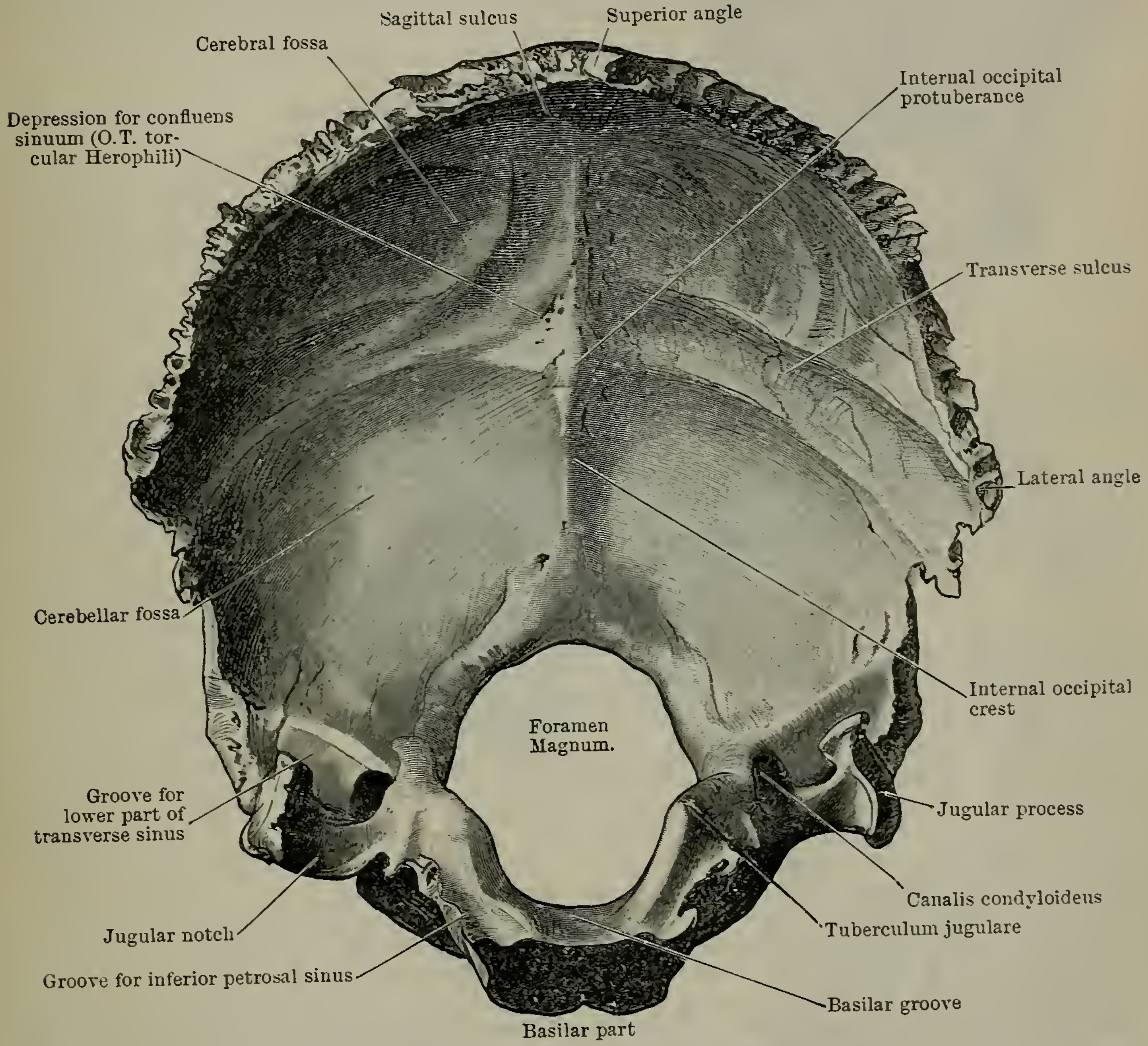


FIG. 163.—OCCIPITAL BONE (Cerebral Surface).

The **lateral part**, including the posterior three-fourths of the condyle, begins to ossify in the eighth week of fœtal life from a single centre. The lateral part is usually completely fused with the squamous part by the third year or earlier.

As already noted, the squama consists of two parts, an upper and a lower. The part above the nuchal lines ossifies in membrane; the part below ossifies in cartilage. In a three-months fœtus this difference is very characteristic. The cartilaginous part (*supra-occipital*) begins to ossify in the sixth or seventh week from two centres (four according to Mall), which rapidly join to form an elongated strip placed transversely in the region of the occipital protuberance. The centres for the superior part (*interparietal*) appear later. According to Maggi (*Arch. Ital. Biol.* tom. 26, fasc. 2), they are four in number, of which two, placed on each side of the median plane, appear in the eighth week. The other pair, placed laterally, are seen in the ninth week; fusion between them takes place early. Union between the supra-occipital and the interparietal elements occurs about the third or fourth month; but evidence of their separation is frequently met with, even in the adult, by the persistence of a transverse suture running medially from each lateral angle of the squama. The supra-occipital forms a small part of the median part of the posterior border of the foramen magnum, though there a small independent centre, known as the *ossicle of Kerkring*, is occasionally met with. Other independent centres are sometimes seen between the supra-occipital and the lateral parts of the bone.

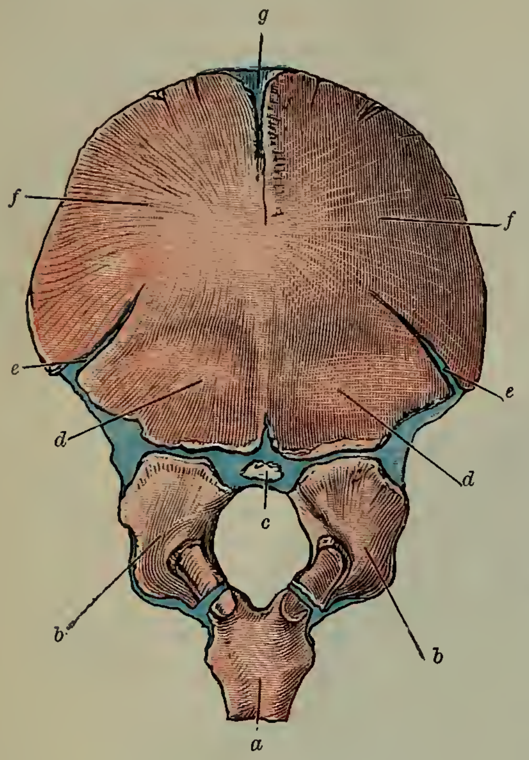


Fig. 164.—Ossification of the Occipital Bone.

a, Basilar centre; *b*, Lateral part; *c*, Ossicle of Kerkring; *d*, Supra-occipital (from cartilage); *e*, Fissure between supra-occipital and interparietal; *f*, Interparietal (from membrane); *g*, Fissure between interparietals.

At birth the occipital bone is in four pieces: the interparietal and supra-occipital combined; the basilar part; and the lateral parts.

Structure and Variations.—The squama shows thickenings of compact bone at the ridges and crests, and it is thickest at the protuberances; the floors of the lower pair of fossæ are thinner than the upper pair and their lower parts have no diploë. The basilar part is made of spongy substance surrounded by compact substance which is thickest on the lower surface. In the condyles the spongy substance is arranged radially to the convex articular surfaces. The hypoglossal canal is surrounded by very dense bone.

The *torus occipitalis transversus* is the term applied to an occasional elevation which includes the external occipital protuberance and extends laterally along the superior nuchal line. Occasionally an emissary vein pierces the bone opposite the occipital protuberance. In about 15 per cent. of cases the hypoglossal canal is double; much rarer, three or even four foramina may be met with. The most striking of the many variations to which the occipital bone is subject is the separation of the upper part of the squama to form an independent bone—the *interparietal bone*, called also, from the supposed frequency of its occurrence in Peruvian skulls, the *os Incæ*. By a reference to the account of the ossification of the bone, the occurrence of this anomaly is explained developmentally, an independent bone being formed from one or more of the interparietal centres. In place of forming a single bone the interparietal is occasionally met with in two symmetrical halves, and instances have been recorded of its occurrence in three or even four pieces. In the latter cases the two upper parts form the *pre-interparietals.* Not uncommonly the lower end of the internal occipital crest divides to enclose a depression, called the *vermiform fossa*, which lodges the vermis of the cerebellum. Instances are recorded of the presence of a separate epiphysis between the basi-occipital and the sphenoid, called the *os basioticum* (Albrecht) or the *os pre-basi-occipitale.* An oval pit, called the *fovea bursæ* or *pharyngeal fossa*, is sometimes seen in front of the tuberculum pharyngeum; it marks the site of the bursa pharyngea. Occasionally the basilar part is pierced by a small venous canal. The so-called **third occipital condyle** is a process which arises from the anterior border of the foramen magnum, and articulates with the dens of the epistropheus. Guerri has recorded a case in which, in a fœtal skull, there were two projecting tubercles in the position of the third occipital condyle, independent of the basi-occipital portions of the condyles, apparently supporting the view of Macalister that there are two different structures included under this name, one ossified in the sheath of the notochord, the other in the vertebral bow of the lowest occipital vertebra. On the lower surface of the jugular process, a rough or smooth elevated surface, or else a projecting process, the extremity of which may articulate with the transverse process of the atlas, is sometimes met with. This is the paroccipital or *paramastoid process.* The size and shape of the foramen magnum varies much in different individuals and races, as also the disposition of its plane. Elliot Smith has called attention to the asymmetry of the cerebral fossæ, which is correlated with asymmetry of the occipital poles of the cerebral hemispheres. Numerous instances of fusion of the atlas with the occipital bone have been recorded. Many are, no doubt, pathological in their origin; others are associated with errors in development. Interesting anomalies are those in which there is evidence of the intercalation of a new vertebral element between the atlas and occipital, constituting what is termed a **pro-atlas.**

Ossa Temporalia.

The **temporal bone** lies about the middle of the lower half of the side of the skull, and enters largely into the formation of the cranial base. It is placed between the occipital behind, the parietal above, the sphenoid in front, and the occipital and sphenoid medially and below. It has four main parts—squamous, petrous, mastoid, and tympanic.

Squama Temporalis.—The **squamous part** is a thin scale-like plate of bone placed vertically in the side of the skull. It has a semicircular upper border, a cerebral or medial surface, a temporal or lateral surface and a small inferior surface; the zygomatic process projects forwards from the lower part of its lateral surface; most of its inferior surface is occupied by a hollow called the mandibular fossa, and an eminence called the articular tubercle, in front of the fossa.

The anterior part of the **upper border** is nearly vertical and articulates with the great wing of the sphenoid. The remainder of the border is bevelled at the expense of the inner table, overlaps and articulates with the parietal bone, and ends posteriorly by joining the upper border of the mastoid part at an angle, called the **parietal notch** because the posterior inferior angle of the parietal bone fits into it.

The **cerebral surface** is limited below by the petro-squamous suture, the remains of which can often be seen in the adult skull. The surface is marked by *digital impressions* for gyri of the brain, and is crossed by a groove or grooves for branches of the middle meningeal vessels.

The **temporal surface**, smooth and slightly convex, is larger than the cerebral surface; it forms a considerable part of the floor of the temporal fossa. Near its posterior part it is crossed by one or more ascending grooves for the branches of the middle temporal artery.

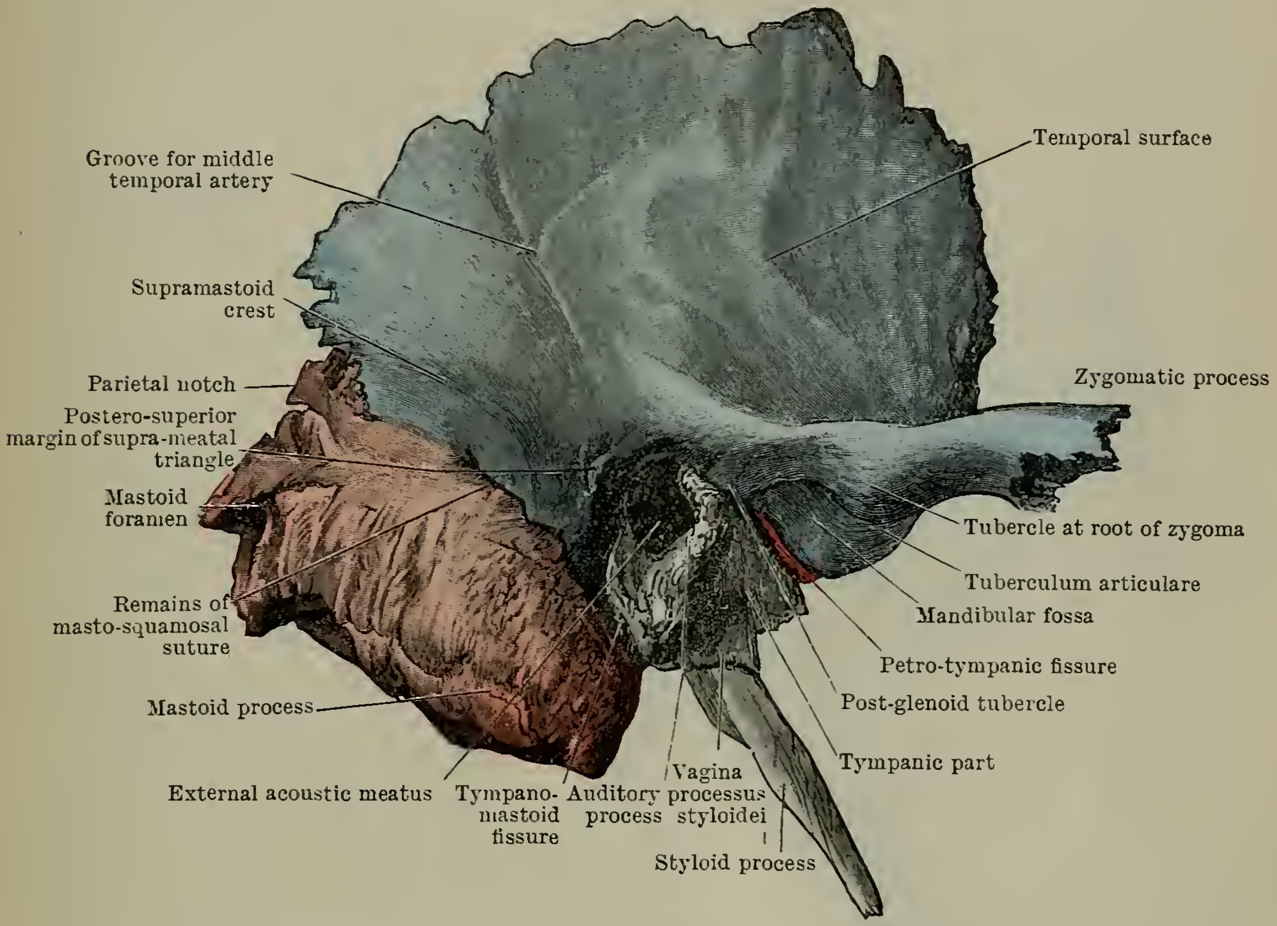


Fig. 165.—The Right Temporal Bone seen from the Parietal Side.

The squamo-zygomatic part is coloured blue; the petro-mastoid, red. The tympanic part and styloid process are left uncoloured.

The **zygomatic process** or **zygoma** springs from the lower and anterior part of the temporal surface by two roots, and curves forwards to end in an oblique, serrated edge which articulates with the temporal process of the zygomatic bone. The *upper border* of the process is sharp and is continuous with the posterior root. The *posterior root* is a salient ridge that extends backwards above the external acoustic meatus and becomes continuous with a blunt low ridge, called the **supra-mastoid crest**, which curves upwards, forming the lower part of the posterior boundary of the temporal fossa, and becomes continuous with the temporal line of the parietal bone. The *lower border* of the zygomatic process is continuous with the *anterior root*, which is a broad, thick bar of bone that turns abruptly in a medial direction to join the side of the skull. The lateral end of the root is prominent and is called the **tubercle** of the root of the zygoma; the medial end is continuous with a smooth transverse elevation on the lower surface of the squama, called the **articular tubercle**, the lower surface of the root forming part of the tubercle.

In front of the medial part of the tubercle, and medial to it, there is a small triangular area, called the **infra-temporal surface** because it forms part of the roof of the infra-temporal fossa; it articulates medially with the great wing of the sphenoid.

Behind the articular tubercle there is a smooth concavity called the **mandibular fossa**. The fossa and the tubercle articulate with the head of the mandible. At the lateral part of the posterior boundary of the fossa, just in front of the opening of the external acoustic meatus, there is a small smooth projection called the **post-glenoid tubercle**; it is sometimes called the *middle root* of the zygoma.

Immediately behind the mandibular fossa there is a narrow cleft called the **petro-tympanic fissure**; its posterior boundary is the upper edge of the tympanic plate. In some skulls the lower edge of the tegmen tympani appears in the medial part of the fissure (p. 152).

Behind the external acoustic meatus, and below the supramastoid crest, the squamous element extends downwards as a pointed process, which assists in forming the posterior wall of the external acoustic meatus, where it unites inferiorly with the tympanic part and forms the lateral wall of a cavity in the interior of the temporal bone called the tympanic antrum. In the adult this process is occasionally sharply defined posteriorly by an oblique irregular fissure, the remains of the masto-squamosal suture, which is often not closed till puberty. Immediately above and behind the external acoustic meatus there is a small depression called the **supra-meatal triangle**; in rare cases there is a little spur of bone, called the *spina supra meatum* on the antero-inferior margin of the triangle.

Pars Tympanica.—The **tympanic part** of the temporal bone is a curved plate the concave **upper surface** of which forms the anterior, lower, and part of the posterior wall of the external acoustic meatus. *Medially* it is fused with the petrous temporal. Its **anterior surface** is free and concave and has three borders. The *upper border* forms the posterior boundary of the petro-tympanic fissure. The *lower border* is sharp and uneven, and partly ensheathes the root of the styloid process, forming what is called the **vagina** or **sheath** of the styloid process. The *lateral border*, curved, thick, and rough, gives attachment to the cartilage of the auricle and is sometimes called the **auditory process**. The part of the plate that curves upwards in the posterior wall of the meatus is united with the mastoid temporal and with the descending process of the squamous temporal; but between it and the mastoid there is a narrow cleft, often very indistinct, called the **tympano-mastoid fissure**.

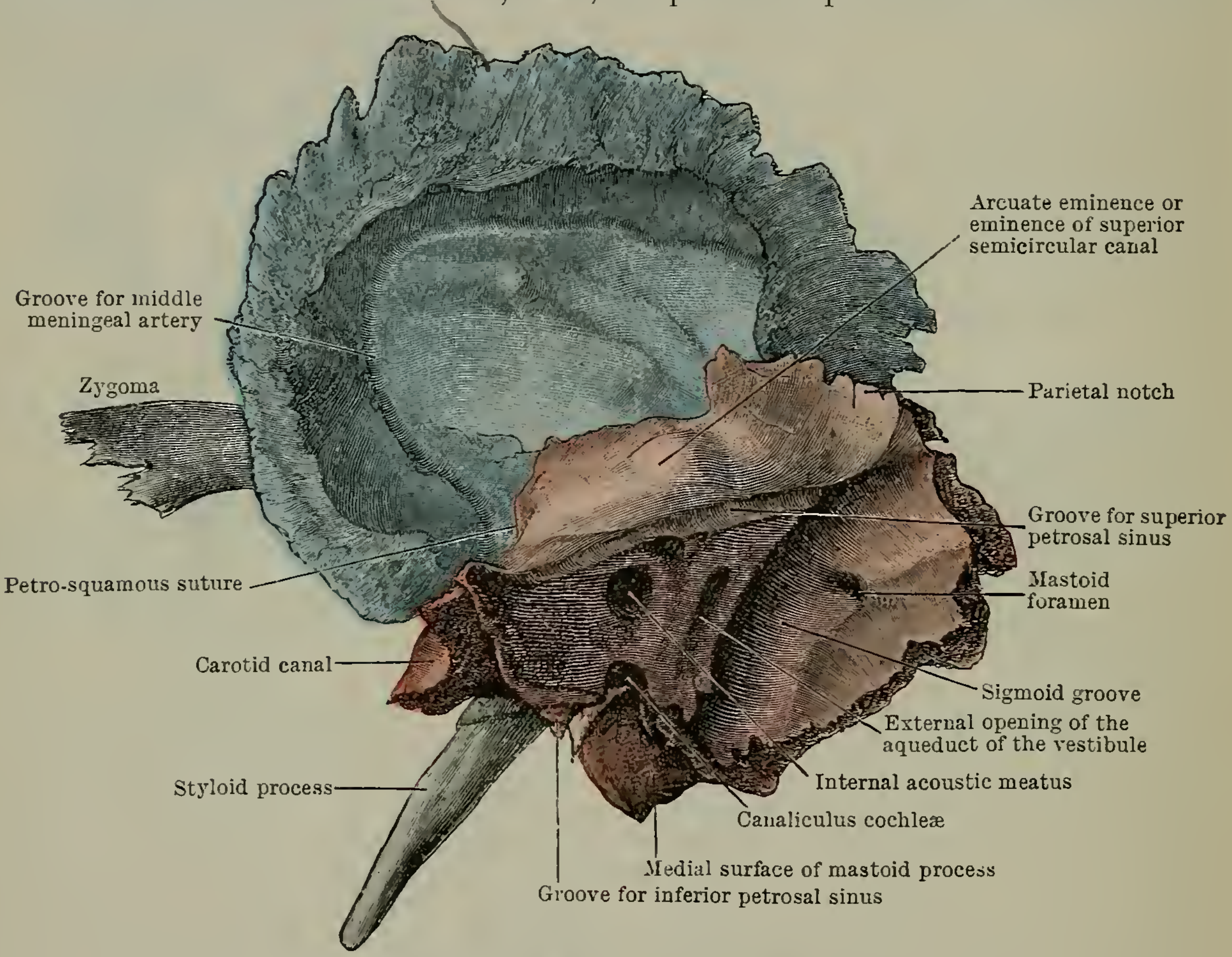

Arcuate eminence or eminence of superior semicircular canal
Groove for middle meningeal artery
Zygoma
Parietal notch
Groove for superior petrosal sinus
Mastoid foramen
Petro-squamous suture
Carotid canal
Sigmoid groove
External opening of the aqueduct of the vestibule
Styloid process
Internal acoustic meatus
Canaliculus cochleæ
Medial surface of mastoid process
Groove for inferior petrosal sinus

FIG. 166.—THE RIGHT TEMPORAL BONE (Cerebral aspect).

The squamous part is coloured blue; the petro-mastoid part, red. The styloid process and the zygoma are left uncoloured.

Meatus Acusticus Externus.—The **external acoustic meatus** is a canal about 15 mm. long; it is directed obliquely medially and a little forwards, and describes a slight curve, the convexity of which is directed upwards. It is oval in outline, the long axis of the oval being nearly vertical near the lateral end, but oblique from above downwards and backwards near the medial end. The upper margin of the *porus* or lateral orifice of the meatus overhangs the lower margin, but the medial orifice, which is closed by the tympanic membrane, is so oblique that the lower wall of the meatus is almost, or quite, as long as the upper wall.

Pars Mastoidea.—The **mastoid part** lies behind the squamous and tympanic parts. *Anteriorly* it is fused with those parts, and more deeply with the petrous part. Its *upper border* articulates with the parietal bone, forming the parieto-mastoid suture; its *posterior border* articulates with the occipital squama to form the occipito-mastoid suture. *Inferiorly* it sends down a blunt projection, called the *mastoid process*, the root of which is bounded medially by a well-marked **mastoid notch**. Between the notch and the lower part of the occipito-mastoid suture there is an uneven strip of bone, on which there may be a shallow groove made by the occipital artery; the groove is nearly parallel to the notch. The *lateral surface* is convex and slightly roughened; the **mastoid foramen** opens on it near its posterior border; the foramen is variable in size and position and may open into the occipito-mastoid suture. The *medial surface* of the mastoid portion forms, in part, the side wall of the posterior cranial fossa. Coursing over this aspect of the bone there is a broad curved groove, called the **sigmoid sulcus**, the convexity of which is directed forwards and lies in the angle formed by the base of the petrous part and its fusion with the mastoid portion.

Pars petrosa (pyramis).—The **petrous part** of the temporal bone is shaped like a three-sided pyramid. By its base it is partly united obliquely to the other parts of the bone, and is partly free, forming the medial wall of the tympanic cavity. Its apex is directed medially, forwards, and a little upwards. Its three surfaces are arranged as follows: The **anterior** looks upwards, slightly forwards, and a little laterally, and forms part of the posterior wall of the middle cranial fossa. The **posterior** is directed backwards and medially, and forms part of the anterior wall of the posterior cranial fossa. The **inferior** is seen on the lower surface of the skull, and is directed downwards. The margins or angles are named anterior, superior, and posterior.

The **anterior margin** is short and articulates with the posterior border of the great wing of the sphenoid; it forms an acute angle with the anterior border of the squamous part; within the angle is wedged the posterior corner of the great wing. At the apex of the angle there is seen the opening of the **musculo-tubal canal**, which leads backwards and laterally to the tympanic cavity; the canal is divided by a thin bony septum into an upper part called the *semi-canal for the tensor tympani* muscle, and a larger, lower part which is the *osseous part* of the **auditory tube**.

The **posterior margin** is in part articular and in part non-articular. Posteriorly and laterally it corresponds to the upper margin of an area on the inferior surface which articulates with the jugular process of the occipital. Medial to that it is irregularly notched, and forms the free anterior edge of the jugular foramen. The remaining antero-medial part, which extends from the jugular foramen to the apex of the bone, articulates with the margin of the basilar part of the occipital bone; the inferior petrosal sinus runs along the articulation, grooving both bones.

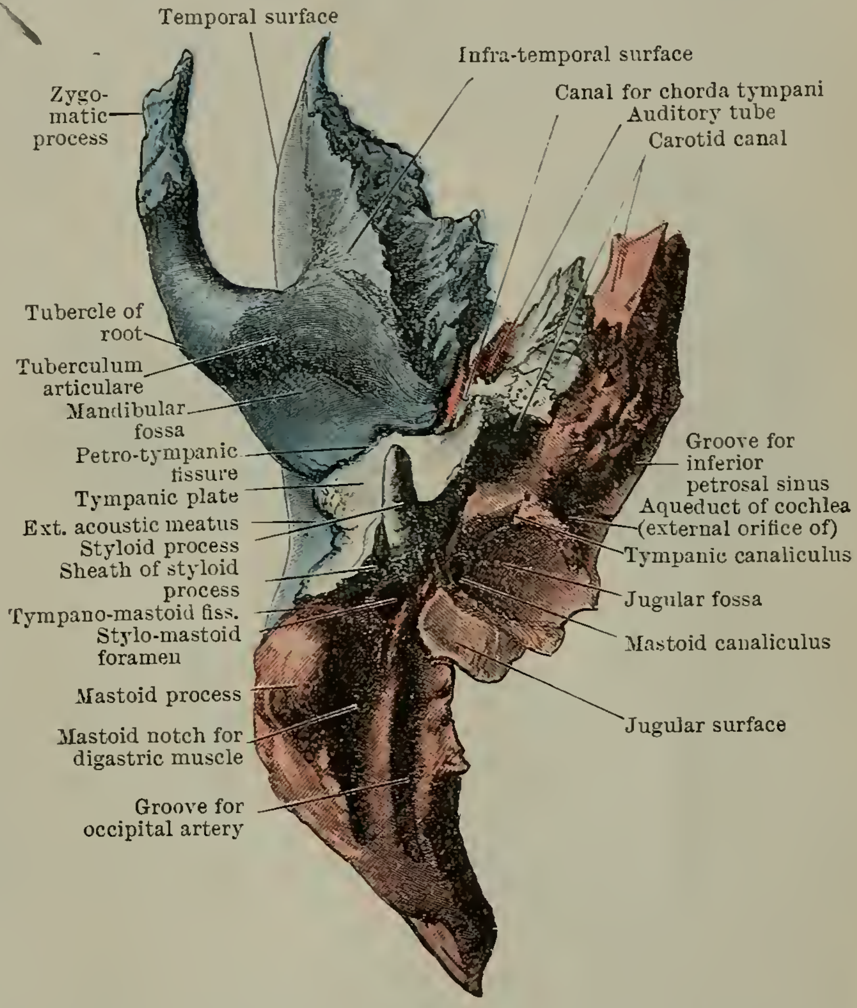


Fig. 167.—The Right Temporal Bone seen from below.

The squamo-zygomatic part is coloured blue; the petro-mastoid, red. The tympanic portion and styloid process are left uncoloured.

The **superior margin** is a sinuous edge which is grooved lengthwise for the superior petrosal sinus, while near the apex it is crossed by the trigeminal nerve, which produces a shallow notch on the margin.

The inferior surface of the petrous part is bounded in front by the anterior border medially and the tympanic plate laterally, and behind by the posterior border. On it the following parts are to be noted: A slender process, about an inch long, called the **styloid process**, projects downwards, forwards, and medially from behind the lower edge of the tympanic plate. The **stylo-mastoid foramen** is the opening behind the root of the styloid process and in front of the mastoid notch. Medial to the root of the styloid process there is a smooth, deep concavity, called the **jugular fossa** because it lies in the antero-lateral wall of the jugular foramen. Behind and lateral to the jugular fossa there is a small area, called the *jugular surface*, which is united by cartilage to the jugular process of the occipital bone. On the lateral part of the wall of the fossa there is a very small aperture; that is the medial end of the **mastoid canaliculus**, which opens laterally in the tympano-mastoid fissure. In front of the jugular fossa there is an oval or circular aperture which is the lower end of the **carotid canal**; the canal passes upwards for a short distance, and then, becoming horizontal, it passes medially and forwards, and ends at the apex as an oblique opening with jagged margins. On the lateral wall of the ascending part of the canal there are two or more small openings of **carotico-tympanic canaliculi**, which communicate with the tympanum. On the ridge between the carotid canal and the jugular fossa, there is the lower opening of the **tympanic canaliculus**, which leads up to the tympanum. Medial to the interval between the carotid canal and jugular fossa there is a small angular depression at the bottom of which there is the external aperture of the **aqueduct of the cochlea**. Medial to and in front of the lower opening of the carotid canal there is a rough **quadrate area**; a strip along its antero-lateral border articulates with the posterior margin of the great wing of the sphenoid and helps to form the groove for the lodgment of the cartilage of the auditory tube; its postero-medial border is united to the occipital bone by dense fibrous tissue or cartilage, the gutter between the two bones being called the *petro-basilar fissure*.

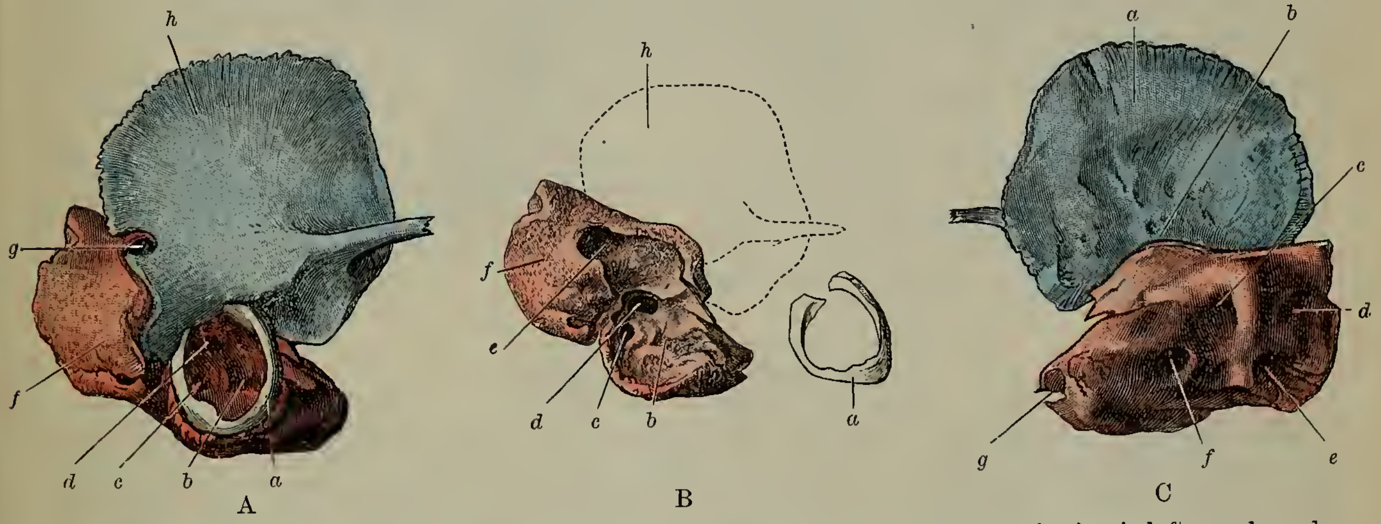
The **anterior surface** of the petrous part bears the impress of gyri of the temporal lobe of the cerebrum; in addition, there is a distinct but shallow depression, called the **trigeminal impression**, near the apex, on the roof of the carotid canal; it lodges the semilunar ganglion. Lateral to the middle of the anterior surface, and close to its superior border, there is an elevation called the **eminentia arcuata**, more or less pronounced, which marks the position of the superior semicircular canal within the substance of the bone. A little in front of this, and in line with the angle formed by the anterior border and the squamous part, is the slit-like opening of the **hiatus canalis facialis**. Leading forwards and medially from the hiatus towards the anterior border there is a groove for the greater superficial petrosal nerve, which passes out of the hiatus. A little lateral to the hiatus there is another small opening (**apertura superior canalis tympanici**), often difficult to see; from it a groove runs forwards which channels the upper surface of the roof of the semi-canal for the tensor tympani muscle. Through the aperture and along the groove passes the lesser superficial petrosal nerve. The bone forming the lateral part of the anterior surface, lateral to and in front of the arcuate eminence, is called the **tegmen tympani**, for it roofs over the tympanic cavity and antrum; it forms the roof of the semi-canal for the tensor tympani also. The line of fusion between the petrous and squamous parts of the bone is often indicated by a faint, irregular **petro-squamous fissure** along the lateral margin of the anterior surface of the petrous temporal.

The most conspicuous feature on the **posterior surface** of the petrous part of the bone is an oblique, oval aperture which leads into the internal acoustic meatus. The **internal acoustic meatus** is a canal about 10 mm. long which passes laterally and slightly downwards into the bone, and ends blindly, except that the bony substance at the **fundus** or far end has a number of small holes in it. That bone is therefore called the **lamina cribrosa**, and it separates the meatus from the internal ear. It is crossed by a ridge, called the **transverse crest**, which divides it into two unequal parts. In the *upper*, smaller *part*, posteriorly, there is a small spot, called the **area vestibularis superior**, with a few holes in it for the transmission of branches of the vestibular nerve; in front of that there is the **area facialis**, with one large aperture through which the facial nerve enters the **facial canal**. In the *lower part*, posteriorly, there is a small spot called the **area vestibularis inferior**; branches of the vestibular nerve pass through small holes in it and through the **foramen singulare**, which is a small aperture situated immediately below and behind the area; in front of the area the branches of the cochlear nerve pass (*a*) through a small opening that leads into the **central canal of the cochlea**, and (*b*) through a number of smaller holes which are arranged in a spiral curve around the opening of the central canal and are named collectively the **tractus spiralis foraminosus**. Lateral to the internal acoustic meatus and above it, close to the superior border, there is an irregular depression called the **subarcuate fossa**, with one or two small foramina opening into it. It is often faintly marked; it is seen best in young bones (see Fig. 168, C), where it forms a distinct recess, which is bounded above by the bulging caused by the superior semicircular canal, within the concavity of which it is placed. About half an inch lateral to the meatus there is the **apertura externa aquæductus vestibuli**, often concealed in a narrow curved fissure overhung by a sharp scale of bone. The ridge above it corresponds to the upper half of the posterior semicircular canal.

Ossification.—The temporal bone of man represents the fused periotic, squamosal, and tympanic elements; the squamosal and tympanic are membrane bones, whilst the periotic is ossified in the cartilaginous auditory capsule. The cartilages of the first and second visceral arches are also intimately associated with its development. The human temporal bone is characterised by the large proportionate size of the squamosal, the comparatively small size of the tympanic, the absence of an auditory bulla, and the large size of the mastoid process.

Ossification commences in the ear capsule in the fifth month, and proceeds so rapidly that by the end of the sixth month the individual centres are more or less fused. Of these, one, the **Pro-otic** (Huxley), which appears in the vicinity of the eminentia arcuata, is the most definite in position and form; from it a lamina of bone of spiral form is developed, which covers in the medial limb of the superior semicircular canal, and forms the roof of the internal acoustic meatus, together with the commencement of the facial canal. Reaching forwards, it extends to the apex of the petrous part; whilst laterally it forms part of the medial wall of the tympanum, surrounds the fenestra vestibuli, and encloses within its substance portions of the cochlea, vestibule, and superior semicircular canal. Another centre, the **Opisthotic**, appears in the vicinity of the promontory on the medial wall of the tympanum, surrounds the fenestra cochleæ, forms the floor of the vestibule, and extends medially to complete the floor of the internal acoustic meatus. Surrounding the cochlea inferiorly and laterally, it completes the floor of the tympanum, and ultimately blends with the anterior and inferior part of the tympanic ring. The carotid canal at first grooves it, and is then subsequently surrounded by it. According to Lambertz the lamina spiralis of the cochlea ossifies in membrane. The roof of the tympanum is formed from a separate centre, the **Pterotic**, which extends backwards towards the superior semicircular canal, and encloses the tympanic part of the facial canal; laterally it unites by suture with the squamosal, and sends down a thin process, which appears between the lips of the petro-tympanic fissure, and forms the lateral wall of the auditory tube. Nuclei, either single or multiple, **Epiotic**, appear in the base of the petrous part, envelop the posterior and lateral semicircular canals, and extend into the region of the mastoid process. The **styloid process**, an independent development from the upper end of the cartilage of the second visceral arch, is ossified from two centres. The upper or basal appears before birth, and rapidly unites with the petro-mastoid, the tympanic plate encircling it in front. This represents the **tympanohyal** of comparative anatomy. At or after birth another centre appears in the lower part of the cartilage to form the **stylohyal**. Ankylosis usually occurs in adult life between the tympanohyal and stylohyal portions.

The centre for the **squamo-zygomatic** appears in membrane about the end of the second month near the root of the zygoma; it extends forwards and laterally into the zygoma, medially into the roof of the infra-temporal fossa, and upwards into the squamosal. From the squamosal, ossification extends downwards and backwards to form the post-auditory process between the mastoid and tympanic parts. It forms the lateral wall of the tympanic antrum, and is the area above the anterior part of the root of the mastoid process in the adult. About the third month a centre appears in the lateral membranous wall of the tympanum: from it the **tympanic ring** is ossified. Incomplete above, it displays two free extremities. Of these, the anterior is somewhat enlarged, and unites in front with the mandibular portion of the squamo-zygomatic, being separated from it by the petro-tympanic fissure and the downgrowth from the tegmen tympani; the posterior joins the post-auditory process of the squamo-zygomatic. Below, it blends medially with the portion of the petro-mastoid which forms the floor of the tympanum and ensheathes the tympanohyal behind. From the medial surface of the ring below there is an extension medially and forwards which forms the floor of the osseous part of the auditory tube, as well as the lateral wall and half of the floor of the carotid canal. From the lateral side of the lower part of this ring two tubercles arise, which grow laterally, and so form the floor of the bony external acoustic meatus. The interval between them remains unossified till about the age of five or six, after which closure takes place. The deficiency may, however, persist even in adult life.



The squamo-zygomatic part is coloured blue; the petro-mastoid red. The tympanic ring is left uncoloured.

FIG. 168.—A. THE PARIETAL SURFACE OF THE RIGHT TEMPORAL BONE AT BIRTH. B. THE SAME WITH THE SQUAMO-ZYGOMATIC PORTION REMOVED.

(The lettering is the same in both A and B.) *a*, Tympanic ring. *b*, Medial wall of tympanum. *c*, Fenestra cochleæ. *d*, Fenestra vestibuli. *e*, Tympanic antrum. *f*, Mastoid process. *g*. Masto-squamosal suture, with foramen for transmission of vessels. *h*, Squamo-zygomatic, removed in figure B to show how its descending process forms the lateral wall of the tympanic antrum.

C. CEREBRAL SURFACE OF THE RIGHT TEMPORAL BONE AT BIRTH.

a, Squamo-zygomatic. *b*, Petro-squamosal suture and foramen (just above the end of the lead line). *c*, Subarcuate fossa. *d*, Aquæductus vestibuli. *e*, Aquæductus cochleæ. *f*, Internal acoustic meatus. *g*, Upper end of carotid canal.

At **birth** the temporal bone can usually be separated into its component parts. The lateral surface of the petrous part not only forms the medial wall of the tympanum, but is hollowed out behind and above to form the medial wall of the tympanic antrum, the lateral wall of which is completed by the post-auditory process of the squamo-zygomatic. As yet the mastoid process is undeveloped. It assumes its nipple-like form about the second year. Towards puberty its spongy substance becomes permeated with air spaces, which are extensions from the tympanic antrum. Occasionally this pneumatic condition is met with in early childhood. The external acoustic meatus is unossified in front and below, the outgrowth from the tympanic ring occurring subsequent to birth. The mandibular fossa is shallow and everted; the jugular fossa is ill-marked; whilst the subarcuate fossa is represented by a deep pit, the so-called *floccular fossa* of comparative anatomy. The hiatus of the facial canal is an open groove, displaying at either end the openings of the medial and lateral portions of the facial canal.

Structure and Variations.—The temporal bone is remarkable for the hardness and density of its petrous part, which contains the osseous labyrinth, wherein are lodged the delicate organs associated with the senses of hearing and equilibration. Owing to the disposition of the internal and external acoustic meatus the weakest part of the bone corresponds to a line connecting those two channels, the only parts intervening being the cochlea and tympanum. It is usually in this position that fracture of the bone occurs.

The line of the petro-squamosal suture is occasionally grooved for the lodgment of a sinus (petro-squamosal); sometimes the posterior end of the groove is continuous with a canal which traverses the upper border of the bone and opens into the transverse sulcus. Anteriorly the groove may pass into a canal which traverses the root of the zygoma and appears externally above the lateral end of the petro-tympanic fissure. They are the remains of channels through which the blood passed in the fœtal condition. Kazzander has recorded a case in which the squamous part of the temporal was pneumatic, the sinus reaching as high as the parietal and the squamoso-sphenoidal suture. Symington has described a case in which the squamous part was distinct and separate from the rest of the temporal bone in an adult; whilst Hyrtl has observed the division of the squamous part of the temporal into two by a transverse suture. The zygomatic process has been observed separated from the rest of the bone by a suture close to its root (Adacni). P. P. Laidlaw (*Journ. Anat. and Physiol.* vol. xxxvii.) describes a temporal bone in which there was absence of the internal acoustic meatus and of the stylo-mastoid foramen. The jugular fossa also was absent, and there was partial absence of the groove for the transverse sinus, associated with the presence of a large mastoid foramen. An instance of a rudimentary condition of the carotid canal is referred to in the same volume by G. H. K. Macalister. G. Caribbe (*Anat. Anz.* vol. xx.) notes the occurrence in idiots and imbeciles of a more pronounced form of post-glenoid tubercle, and associates it with regressive changes in the development of the temporal bone.

Occasionally the temporal articulates with the frontal, as happens normally in the anthropoid apes; although the region of the pterion is characterised by an X-like form in the lower races of man, there is no evidence that the occurrence of a fronto-squamosal suture is more frequent in the lower than the higher races, its occurrence being due to the manner of fusion of the so-called epipteric ossicles with the surrounding bones.

Os Sphenoidale.

The **sphenoid bone** lies in front of the basilar part of the occipital bone and the two temporal bones. It enters into the formation of the cranial, orbital, and nasal cavities, as well as the temporal, infra-temporal, and pterygo-palatine fossæ. It consists of a body and three pairs of processes, called the great wings, the small wings, and the pterygoid processes.

Corpus.—The **body** is more or less cubical in form, and is hollow, for it contains within it the two large **sphenoidal air sinuses.** The sinuses are separated by a median partition, which, however, is usually deflected to one or other side of the median plane. Each sinus may extend for a short distance into the root of the great wing and the base of the pterygoid process. They communicate by apertures with the upper and posterior part of the nasal cavities. In the adult the **posterior aspect** of the body displays a sawn surface due to its separation from the basi-occipital, with which, in the adult, it is firmly ankylosed. The **superior surface** displays an appearance comparable to that of an oriental saddle (**sella turcica**). Over its middle there is a deep depression, called the **fossa hypophyseos,** in which the hypophysis is lodged. The fossa is overhung posteriorly by a sloping ridge called the **dorsum sellæ,** the posterior surface of which is inclined upwards, and is in continuation with the basilar groove of the occipital bone. The upper angles of the dorsum sellæ are prominent tubercles called the **posterior clinoid processes.** In front of the fossa hypophyseos there is a transverse elevation called the **tuberculum sellæ,** behind the lateral ends of which there are sometimes little spurs of bone called the **middle clinoid processes.** In front of the tuberculum sellæ there is a groove called **sulcus chiasmatis** or **optic groove,** which passes laterally to become continuous with the optic foramina. In front of the optic groove the superior surface continues forwards on the same plane as the upper surfaces of the small wings, and terminates anteriorly in a ragged edge which articulates with the laminæ cribrosæ of the ethmoid, and has often projecting from it, in the median plane, a pointed process called the **sphenoidal spine.**

The lower parts of the **lateral aspects** of the body are fused with the great wings, and in part also with the roots of the pterygoid processes. Curving along the side of the body, above its attachment to the great wing, is an ∫-shaped groove, called the **carotid groove,** in which the internal carotid artery lies. Posteriorly, the hinder margin of that groove, formed by the salient lateral edge of the posterior surface of the body, articulates with the apex of the petrous portion of the temporal bone, and is hence called the **petrosal process**; just above it, on the lateral border of the dorsum sellæ, there is often a groove for the abducent nerve.

The **anterior surface** of the body displays a vertical, median ridge, called the **sphenoidal crest,** which is continuous above with the sphenoidal spine, and below with the pointed projection called the **sphenoidal rostrum.** The crest articulates in front with the perpendicular plate of the ethmoid. On each side of the median plane there is a triangular area which forms part of the roof of the nose; in that area there is an opening leading into the sphenoidal sinus. The lateral part of the anterior surface, on each side, articulates with the labyrinth of the ethmoid and the orbital process of the palatine bone. The **sphenoidal rostrum** is continued backwards for some distance along the **inferior surface** of the body, where it forms a prominent keel which fits into the recess between the alæ of the vomer. Posteriorly, the inferior surface of the body of the sphenoid is rougher, and is covered with the mucous membrane of the roof of the pharynx.

Alæ Parvæ.—The **small wings** are two flattened triangular plates of bone which project laterally from the anterior and upper part of the body of the bone; each wing is united to the body by two roots, an anterior and a posterior, which enclose the **optic foramen.** The posterior root springs from the body just wide of the tuberculum sellæ, separating the carotid groove behind from the optic foramen in front; laterally this root is confluent with the recurved posterior angle of the small wing which projects backwards and is known as the **anterior clinoid process.** The anterior root, broad and compressed, joins the anterior part of the upper surface of the body. Laterally, the small wing terminates in a pointed process which reaches the region of the pterion and articulates there with the frontal, and may come in contact with the great wing. The superior aspect is smooth, and forms part of the floor of the anterior cranial fossa. The inferior surface constitutes part of the posterior portion of the roof of the orbit, and is also the upper boundary of the **superior orbital fissure,** which separates the small wing from the great wing. The anterior edge is ragged and irregular, and articulates with the orbital plate of the frontal bone. The posterior margin, sharp and sickle-shaped, separates the anterior from the middle cranial fossa, and ends medially in the anterior clinoid process.

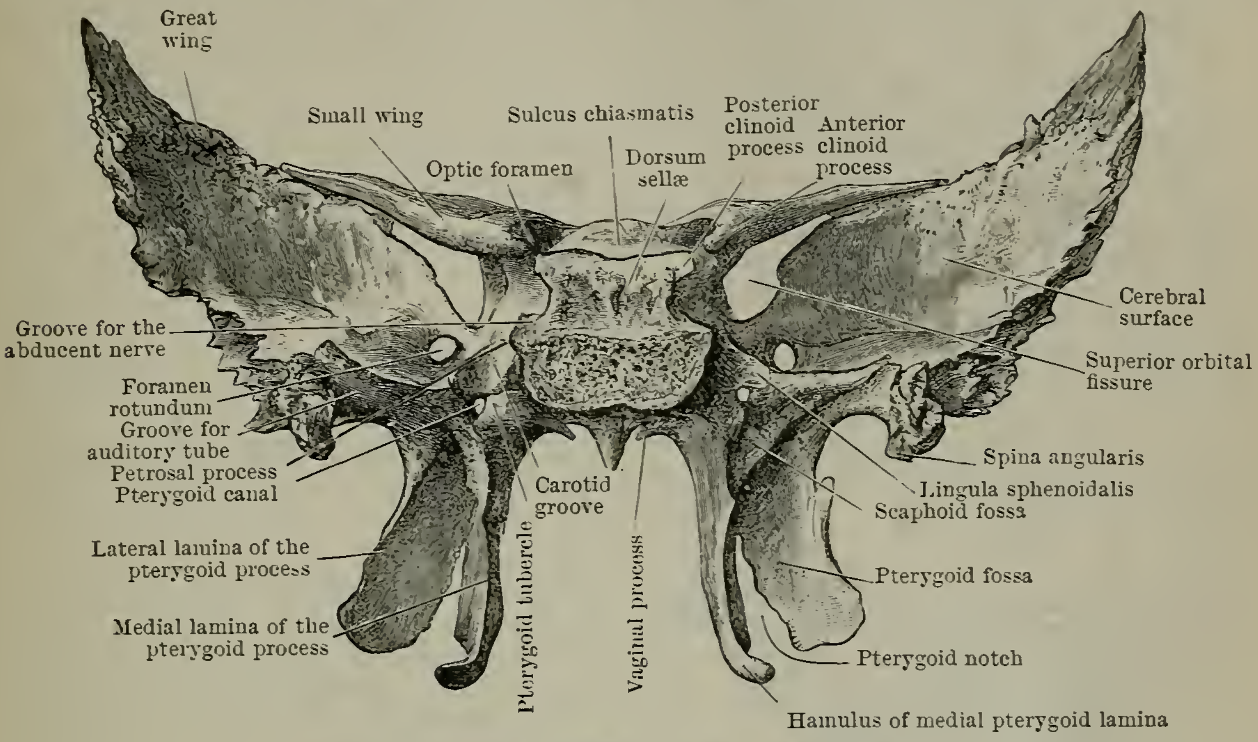


FIG. 169.—THE SPHENOID SEEN FROM BEHIND.

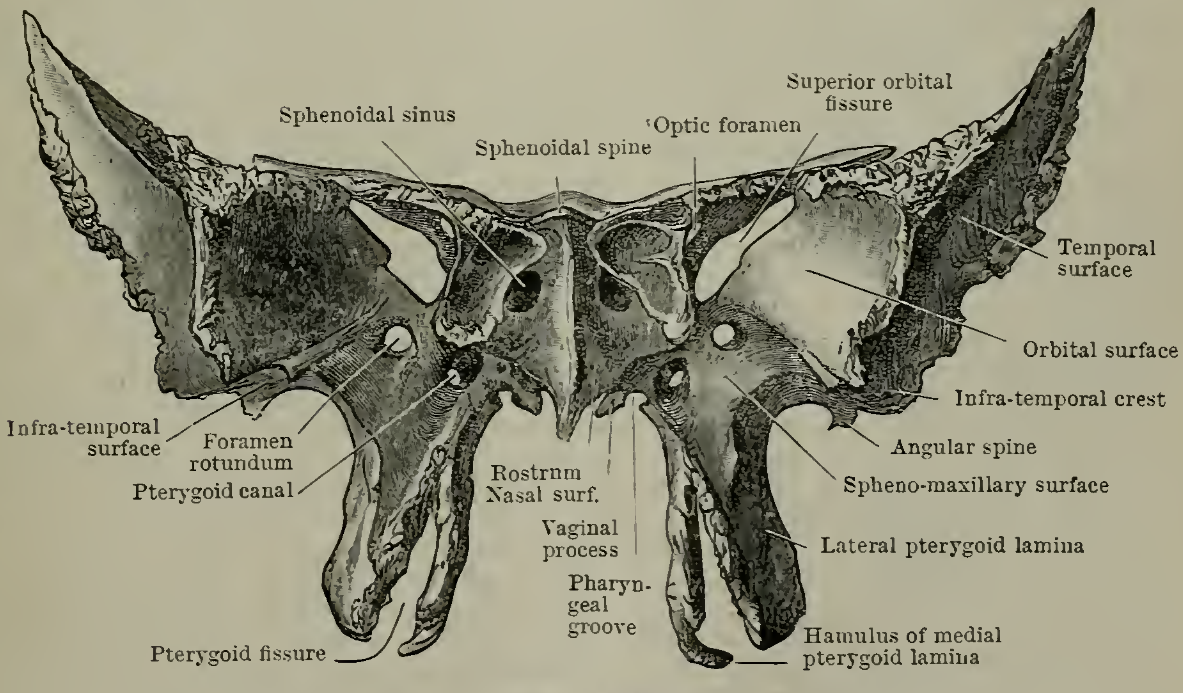


FIG. 170.—THE SPHENOID SEEN FROM THE FRONT.

Alæ Magnæ.—The **great wings,** as seen from above, are of a somewhat crescentic shape, and form a considerable portion of the floor of the middle cranial fossa. Each great wing spreads out from the side of the body of the sphenoid in the floor of the middle cranial fossa, and turns upward into the side wall of the skull. It has three surfaces—an internal or *cerebral*, an *orbital*, and an external, which is divided into a *temporal surface* and an *infra-temporal.*

The **cerebral surface** is concave and is marked by digital impressions for gyri of the temporal lobe, and by grooves for meningeal vessels. Three, and sometimes four, foramina are seen in it. The **foramen rotundum** is a short horizontal canal that passes forwards below the medial part of the superior orbital fissure. The **foramen ovale** is situated about 10 or 12 mm. behind and lateral to the foramen rotundum. The **foramen spinosum** is the smaller aperture immediately behind and lateral to the foramen ovale. The fourth foramen, which is not always present, is a small hole, called the **foramen of Vesalius,** situated medial to the foramen ovale. In rare cases there is a fifth aperture, very small, called the **canaliculus innominatus,** situated behind the foramen ovale. The *borders* of the cerebral surface are upper or anterior, medial, and posterior. The *medial border* is fused with the side of the body of the sphenoid. The *posterior border* is divided into two distinct parts that meet together posteriorly in a sharp projecting **angle.** The medial part of the posterior border is a short distance behind the foramen ovale and spinosum and is oblique in direction; laterally it articulates with the petrous temporal, medially it forms the anterior boundary of the foramen lacerum, and there projects backwards from it a spur of bone of variable size called the **lingula,** which forms the anterior or lateral margin of the commencement of the carotid groove, and, when long enough, the lateral margin of the foramen lacerum. The lateral part of the posterior border is a long, concave, serrated edge that articulates with the squamous temporal. The *upper border* also is divided into parts. The medial part, thin and sharp, forms the lower boundary of the superior orbital fissure; the next part articulates with the frontal bone; and the third part is the extreme upper part of the wing and articulates with the antero-inferior angle of the parietal bone.

The **orbital surface** is smooth, nearly flat, more or less quadrilateral, and forms a great part of the lateral wall of the orbit. The *posterior border* is the medial part of the upper border of the cerebral surface and forms the lower margin of the superior orbital fissure; towards its lower or medial part there is sometimes a small projection, called the **spina recti lateralis,** for the attachment of the inferior common ligament of origin of the ocular muscles. The *lower border* is smooth and forms the upper or lateral boundary of a cleft called the inferior orbital fissure; immediately below that border there is an oblique, horizontal groove that forms part of the posterior wall of the pterygo-palatine fossa. The *anterior border* articulates with the zygomatic bone; and the *upper border* articulates with the frontal bone.

The **temporal surface** forms part of the floor of the temporal fossa; it slopes from above downwards and medially, and is concave from before backwards. *Posteriorly* it is separated from the cerebral surface by the part of the posterior border which articulates with the squamous temporal. *Anteriorly* it is separated from the orbital surface by the sharp border or crest that articulates with the zygomatic bone and sometimes also with the zygomatic process of the maxilla. *Superiorly* the uppermost part of the surface is separated from the cerebral surface by the short border that articulates with the parietal bone; in front of that it articulates with the frontal bone. The articulation of the great wing with the frontal bone is by a rough triangular area bounded by the upper margins of the three surfaces of the wing. *Inferiorly* the temporal surface is limited by a rough horizontal ridge called the **infra-temporal line** or **crest.**

The **infra-temporal surface** is situated almost at right angles to the temporal surface, and forms the greater part of the roof of the infra-temporal fossa. The **foramen ovale** and **foramen spinosum** are seen in it near its posterior border, and occasionally the **foramen of Vesalius,** medial to the foramen ovale. The *posterior border* articulates with the petrous temporal and is grooved lengthwise for the cartilage of the auditory tube, which lies along the junction of the two bones. *Medially* the surface is fused with the pterygoid process. *Anteriorly* it is bounded by a sharp margin behind the inferior orbital fissure. *Laterally* it is bounded by the infra-temporal crest, and behind that it is separated from the cerebral surface by the part of the posterior border that articulates with the lower part of the squamous temporal. That boundary and the posterior border which articulates with the petrous temporal meet at the **angle** of the great wing, which fits into the angular interval between the squamous and petrous temporal. From the angle a projection called the **angular spine** of the sphenoid juts downwards; it is situated behind and lateral to the foramen spinosum.

Processus Pterygoidei.—The **pterygoid processes** spring from the inferior surface of each lateral aspect of the body as well as from the under side of the roots of the great wings, and pass vertically downwards. Each consists of a *lateral* and a *medial lamina,* which enclose the **pterygoid fossa** between them; the upper parts of their anterior borders are fused together.

The **lateral pterygoid plate,** thin and expanded, is directed obliquely backwards and laterally, its lower part being often somewhat everted. Its posterior edge is sharp, and often has projecting from it one or two spines, to one of which (**processus pterygospinosus**) the pterygo-spinous ligament, which stretches towards the angular spine, is attached.

The **medial pterygoid plate** is narrower and rather thicker. It is placed between the pterygoid fossa and the posterior part of the nasal cavity. Its posterior edge ends below as a slender curved process, called the **hamulus pterygoideus,** which, reaching a lower level than the lateral plate, curves backwards and laterally, furnishing a groove on its lower surface in which the tendon of the tensor veli palatini muscle glides; superiorly, the sharp posterior margin of the medial plate bifurcates, so as to enclose a small, shallow, oval concavity called the **scaphoid fossa**; below the scaphoid fossa there juts backwards from the posterior margin of the plate a small projection which supports the cartilage of the auditory tube. Above and medial to the scaphoid fossa, at the extreme upper end of the posterior border of the plate, there is a small, blunt projection called the **pterygoid tubercle**. A thin lamina, called the **vaginal process**, passes medially from the upper end of the plate. Near the plate it is fused with the lower surface of the body of the sphenoid. More medially it is free and is separated from the rostum by a groove in which the edge of the ala of the vomer fits in the articulated skull, and it articulates with the ala. On the lower surface of the vaginal process, near the medial pterygoid plate, there is a groove called the sulcus pterygo-palatinus or **pharyngeal groove** ; in an articulated skull it leads forwards into the pharyngeal canal.

Above the pterygoid tubercle, and below the lingula, there is a small aperture leading into the **pterygoid canal**, which passes forwards through the root of the pterygoid process. In front, at its root, the pterygoid process displays a broad smooth surface (**facies sphenomaxillaris**), which is confluent above with the root of the great wing around the foramen rotundum, and forms the posterior wall of the **pterygo-palatine fossa**. To the medial side of the foramen rotundum, and below it, the anterior opening of the **pterygoid canal** is seen. Below, the pterygoid laminæ are separated by an angular cleft called the **pterygoid fissure**, in which is lodged the pyramidal process of the palate bone, the margins of which articulate with the serrated edges of the fissure.

Ossification.—The sphenoid of Man is formed by the fusion of two parts, the **pre-sphenoid** and the **post-sphenoid**, each associated with certain processes. In most mammals the **orbito-sphenoids** or small wings fuse with the pre-sphenoid, whilst the **ali-sphenoids** or great wings, together with the **medial pterygoid lamina**, ankylose with the post-sphenoid.

In the eighth week a centre appears in the root of the great wing between the foramen ovale and foramen rotundum ; from that centre the ossification spreads laterally and backwards, and also downwards into the lateral pterygoid lamina. Two centres appear about the same time in the basi-sphenoid in relation to the floor of the fossa hypophyseos and on each side of the cranio-pharyngeal canal, around which they ossify, ultimately leading to the obliteration of that channel. Somewhat later a **sphenotic** centre appears on each side, from which the lateral aspect of the body and the **lingula** are ossified. Fusion between those four centres is usually complete by the sixth month.

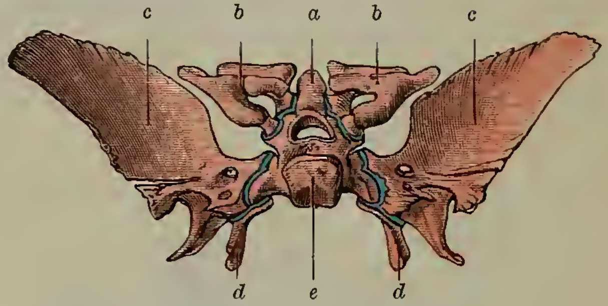


FIG. 171.—OSSIFICATION OF THE SPHENOID.

a, Pre-sphenoid; *b*, Orbito-sphenoids; *c*, Ali-sphenoids; *d*, Medial pterygoid laminæ ; *e*, Basi-sphenoid.

In the **pre-sphenoid** a pair of lateral nuclei appear about the tenth week, just lateral to the optic foramina ; from each of those the **orbito-sphenoids** (small wings) and their roots are ossified. About the same time another pair of centres, placed medial to the optic foramina, appear for the body of the pre-sphenoid. At first the superior surface of the body of the pre-sphenoid is exposed in the interval between the orbito-sphenoids, but by the ultimate coalescence of the medial borders of the orbito-sphenoids to form the **jugum sphenoidale**—*i.e.* the smooth surface in front of the optic groove—the body of the pre-sphenoid is almost completely covered over superiorly. By their coalescence in front, and their ultimate union with the basi-sphenoid behind, a cartilaginous interval is enclosed, of triangular shape, which, however, becomes gradually reduced in size by the ingrowth of its margins so as to form two medially placed foramina, as may be frequently observed in young bones—one opening on the surface of the tuberculum sellæ, the other being placed further forward (Lawrence, *Jour. Anat. and Phys.* vol. xxviii.).

The **medial pterygoid laminæ** are developed in membrane and are the first parts of the sphenoid to ossify. (Fawcett, *Anat. Anz.*, 1905.) Each is derived from a single nucleus which appears about the ninth or tenth week, and fuses with the inferior surface of the great wing, there forming a groove which is converted into the pterygoid canal when the ali-sphenoid and medial pterygoid laminæ fuse later with the body of the post-sphenoid. The hamulus, however, chondrifies before it ossifies during the third month.

At **birth** the sphenoid consists of **three parts** : one comprising the orbito-sphenoids together with the body of the pre-sphenoid and the basi-sphenoid, the others consisting of the ali-sphenoids, one on each side. Fusion of the latter with the former occurs near the end of the first year. The dorsum sellæ at birth consists of a cartilaginous plate which separates the body of the post-sphenoid from the basi-occipital. The plate slowly ossifies, but the cartilage does not entirely disappear till the age of twenty-five, by which time bony ankylosis of the basi-cranial axis is complete. For a considerable time the lower surface of the body of the pre-sphenoid displays a bullate appearance, with the sides of which the sphenoidal conchæ articulate. After the seventh or eighth year the spongy tissue within this part of the bone becomes absorbed to form the sphenoidal sinuses.

The **sphenoidal conchæ**, or bones of Bertin, best studied in children, are formed by the fusion of four distinct ossicles (Cleland), the centres for which appear during the later months of utero-gestation. Each bone is a hollow, three-sided pyramid, the apex of which is in contact with the anterior part of the vaginal process of the medial pterygoid lamina, whilst the base fits on to the posterior surface of the labyrinth of the ethmoid. The *inferior surface* of each forms part of the roof of the corresponding nasal cavity, and completes the formation of the spheno-palatine foramen, whilst the lateral aspect is united with the palatine bone and forms the medial wall of the pterygo-palatine fossa, and occasionally constitutes a part of the orbital wall behind the ethmoid. The *superior surface* of each sphenoidal concha is applied to the anterior and inferior surface of the body of the pre-sphenoid on the corresponding side of the rostrum. It is by the absorption of that surface that the contained sphenoidal sinus is ultimately extended. In the bases of the pyramids are formed the apertures through which the sinuses open in to the nasal cavity in the adult. Up to the age of five those ossicles remain independent, but subsequently, owing to their firm ankylosis with the surrounding bones, they are represented in the adult disarticulated skull merely by the irregular fragments adherent to the separated borders of the ethmoid, palatine, and sphenoid bones.

Variations.—The foramen spinosum and the foramen ovale are sometimes incomplete posteriorly. Le Double records a case in which the foramen rotundum and the superior orbital fissure formed one cleft. The fissure, in rare cases, communicates with the optic foramen. The optic foramen has been found double, the nerve passing through one canal and the artery through the other. Ossification of fibrous bands leads to the formation of anomalous foramina, *e.g.* the *carotico-clinoid foramen*, between the anterior and middle clinoid processes; the *pterygo-spinous foramen*, enclosed by ossification of the band between the angular spine and the lateral pterygoid lamina; the *porus crotaphitico-buccinatorius*, enclosed by ossification of a ligament below and lateral to the foramen ovale. The sphenoidal sinus varies in extent, and is occasionally multilocular; sometimes it is absent.

Os Ethmoidale.

The **ethmoid bone** lies in front of the sphenoid, and occupies the interval between the orbital plates of the frontal bone; it enters into the formation of the anterior cranial fossa, the medial walls of both of the orbits and the roof and medial and lateral walls of the nasal cavities. The bone, which is extremely light, consists of two cellular parts called the **ethmoidal labyrinths**, united superiorly to a median **perpendicular plate** by two thin horizontal laminæ which, from their perforated condition, are called the **laminæ cribrosæ** or **cribriform plates**.

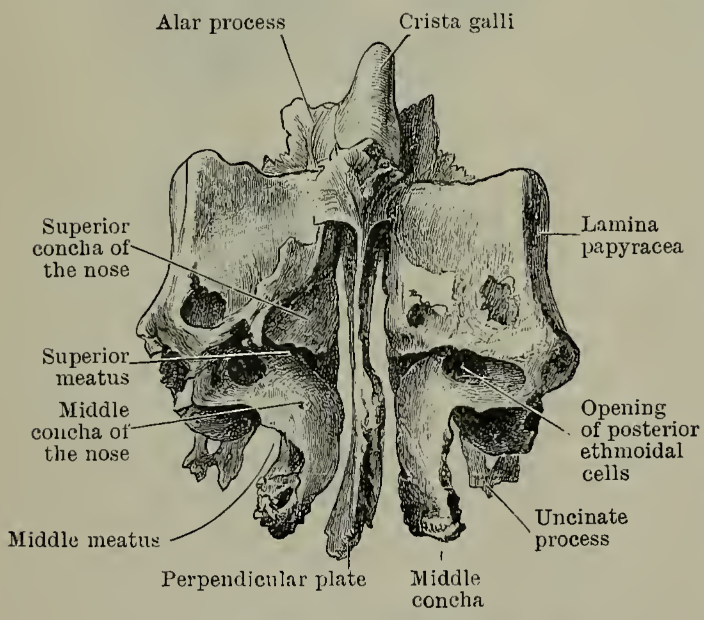


Fig. 172.—The Ethmoid seen from behind.

The study of the ethmoid bone will be much facilitated if the cribriform plate is cut through on one side of the perpendicular plate.

Lamina Perpendicularis.—The **perpendicular plate**, of irregular pentagonal shape, forms the superior part of the nasal septum. Its superior border projects above the level of the cribriform plates to form a crest, called the **crista galli**. The crest is thick and contains either spongy bone or an air cell. It is highest anteriorly, where its lower part divides into two **alar processes** which project forwards and articulate with the frontal bone, and enclose the **foramen cæcum**. The **posterior border** of the perpendicular plate is thin, and articulates with the crest of the sphenoid. The **posterior inferior border** in the adult is ankylosed with the vomer; and the **anterior inferior border**, which is usually thicker than the others, unites with the cartilaginous nasal septum. The **anterior superior border** articulates with the frontal spine and with the median crest formed by the union of the two nasal bones. The perpendicular plate, which is usually deflected to one or other side, has generally smooth *surfaces*, except above, where they are channelled by short and shallow grooves leading to the foramina in the cribriform plate.

Labyrinthus Ethmoidalis.—The **ethmoidal labyrinth** is composed of exceedingly thin bone, enclosing a large number of air cells; the cells are arranged in three groups—an anterior, a middle, and a posterior, the walls of which have been broken in front, above, behind, and below, in the process of disarticulation. *Laterally* they are closed in by a thin oblong lamina, called the **lamina papyracea**, which forms a part of the medial wall of the orbit. The lamina articulates *above* with the orbital part of the frontal bone; *in front* with the lacrimal bone; *below* with the orbital surface of the maxilla; *posteriorly* with the sphenoid; and, at its posterior inferior angle for a variable distance, with the orbital process of the palatine bone. The *medial aspect* of the ethmoidal labyrinth displays the convoluted **ethmoidal conchæ**, usually two in number, though occasionally there may be three—rarely more. In cases where there are two conchæ or **ethmoturbinals**[1] they are separated posteriorly by a deep groove, called the **superior meatus**, which is roofed in by the **superior concha**, whilst its floor is formed by the superior surface of the **middle concha**. The posterior ethmoidal cells open into this meatus. In front of the superior meatus, which grooves only the posterior half of this aspect of the bone, the surface forms the medial wall of the anterior and middle ethmoidal cells. Running obliquely from above downwards and backwards over the medial surface of the superior concha there is a number of fine grooves continuous above with the foramina in the cribriform plate; they are fewer and more scattered in front, do not pass on to the middle concha, and are for the lodgment of olfactory nerves.

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[1] So called to distinguish them from the maxillo-turbinals and naso-turbinals of comparative anatomy.

The **middle concha** is nearly twice the length of the superior. It projects medially and then downwards from the labyrinth. Its anterior extremity articulates with the ethmoidal crest of the maxilla; its posterior extremity articulates with the ethmoidal crest of the palatine bone. The space that lies lateral to the concha is the upper part of the **middle meatus** of the nose. It receives the openings of the middle ethmoidal cells, which project into the meatus, forming a rounded elevation called the **ethmoidal bulla**. In front of and below the bulla there is a groove, called the **hiatus semilunaris**, which is continuous above with a canal, called the **infundibulum**, which runs upwards and forwards, and opens into the frontal sinus. A long process, called the **uncinate process**, curves downwards, backwards, and a little laterally from the roof of the anterior part of this meatus, in front of the hiatus. It bridges across the opening on the medial wall of the maxillary sinus, and articulates below with the ethmoidal process of the inferior concha.

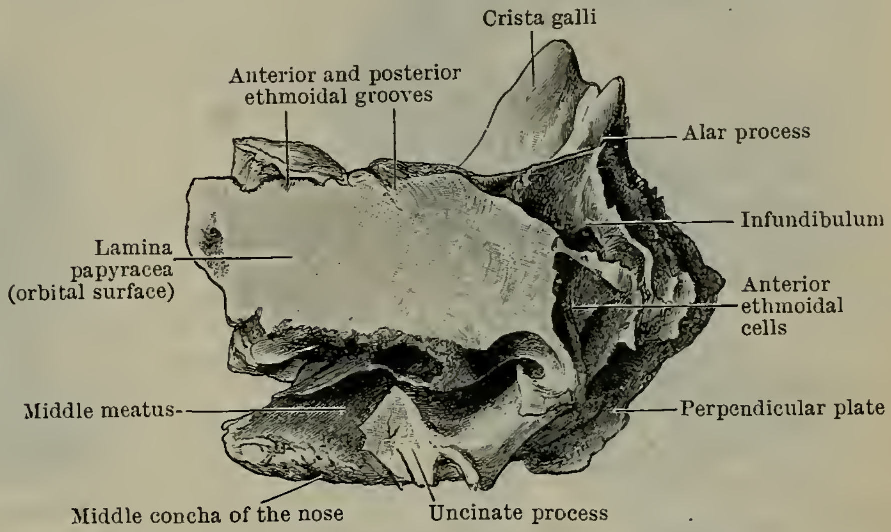

Fig. 173.—The Ethmoid seen from the Right Side.

The *posterior aspect* of the labyrinth articulates with the front of the body of the sphenoid and the orbital process of the palatine bone, which close in the posterior ethmoidal cells. The *anterior aspect* is oblique and is covered by the lacrimal bone and the upper part of the frontal process of the maxilla, which close the anterior ethmoidal cells. The *upper surface* is covered by the orbital plate of the frontal bone, which completes the cells superiorly; and it is crossed by two grooves which are converted into the **anterior** and **posterior ethmoidal canals** when the orbital plate is in position.

Lamina Cribrosa.—Each **cribriform plate** is the horizontal lamina which connects the ethmoidal labyrinth with the perpendicular plate. It occupies the interval between the orbital plate of the frontal bone and the crista galli; it lies in the roof of the nose and in the floor of the anterior cranial fossa. There are numerous foramina in it for the transmission of olfactory nerves; and between its anterior part and the crista galli there is a narrow **nasal slit** which leads down to the nasal cavity. Posteriorly the lamina articulates with the sphenoid.

Ossification takes place in the cartilage of the nasal capsule. Each labyrinth has one centre, which appears about the fourth or fifth month in the neighbourhood of the lamina papyracea. According to Fawcett ossification first commences in a process which passes outside the naso-lacrimal duct to reach the frontal process of the maxilla. From that centre the laminæ around the ethmoidal air cells are formed, which are complete at birth, the air sinuses in this instance not being formed by the absorption of spongy bone. From that centre the conchæ also are developed, and they too are ossified at the ninth month.

At birth the ossified labyrinths are united to the cartilaginous septum by a fibrous layer. Two centres make their appearance in the septal cartilage on each side of the root of the crista galli about the end of the first year; from them the crista galli and the perpendicular plate are ossified, as well as the medial part of the cribriform plate, the lateral portions of which are ossified by a medial extension from the labyrinths.

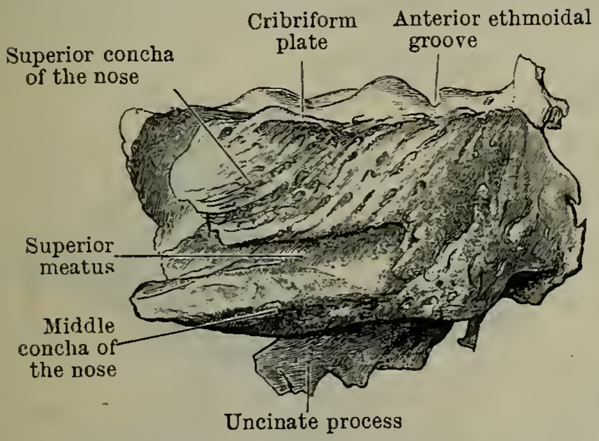
Cribriform plate
Anterior ethmoidal groove
Superior concha of the nose
Superior meatus
Middle concha of the nose
Uncinate process

Fig. 174.—Section showing the Nasal Aspect of the Left Labyrinth of the Ethmoid.

Ossification is usually complete about the fifth or sixth year. About the twenty-fifth year bony union has taken place between the cribriform plate and the sphenoid, but ankylosis between the perpendicular plate and the vomer is not usual till the fortieth or forty-fifth year.

Variations.—The size of the lamina papyracea is liable to considerable variations. In the lower races it tends to be narrower from above downwards than in the higher, in this respect resembling the condition met with in the anthropoids. The lamina papyracea may fail to articulate with the lacrimal, owing to the union of the frontal with the orbital surface of the maxilla in front of it (Orbito-maxillary-frontal suture. A. Thomson, *Jour. Anat. and Physiol.* vol. xxiv. p. 349). Division of the lamina papyracea by a vertical suture into an anterior and posterior part has been frequently recorded. The number of the conchæ may be increased from two to four, or may be reduced to one.

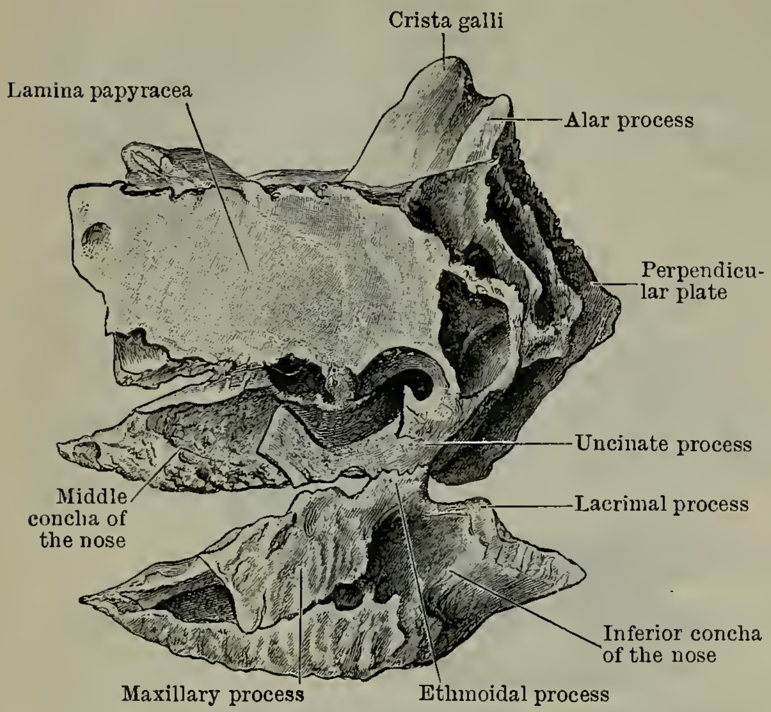

Fig. 175.—Showing the Articulation of the Inferior Concha with the Ethmoid.

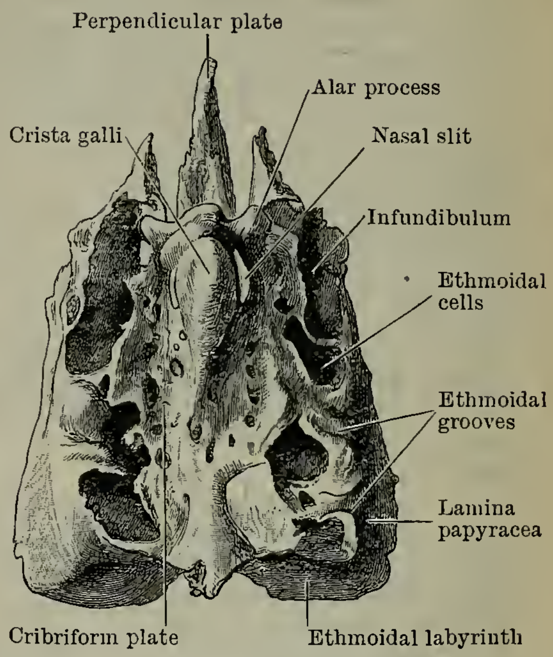

Fig. 176.—The Ethmoid seen from above.

Conchæ Nasales Inferiores.

Each **inferior concha** (O.T. **inferior turbinated bones**) is a shell-like lamina of bone lying along the lower part of the lateral wall of the nasal cavity. Of elongated form, the bone displays two curved borders bounding a medial and a lateral surface.

The **superior** or **attached border** is thin and sharp in front and behind, where it articulates with the conchal crests of the maxilla and the palatine bone, respectively. Between those two articulations the central part of the superior border rises in the form of a sharp crest; the anterior part of the crest forms the upstanding **lacrimal process**, which articulates above with the descending process of the lacrimal bone, as well as with the edges of the naso-lacrimal groove of the maxilla, thus completing the wall of the naso-lacrimal canal. The posterior end of the crest is elevated in the form of an irregular projection, called the **ethmoidal process**, which unites with the uncinate process of the ethmoid bone (see Fig. 175). Spreading downwards from the middle of the superior border, on its lateral side, is a thin irregular plate of bone, called the **maxillary process**, which partially conceals the lateral, concave surface of the bone, and, by its union with the medial wall of the maxillary sinus, assists in the completion of the partition which separates that cavity from the inferior nasal meatus. The **inferior** or **free border**, gently curved from before backwards and turned slightly laterally, is rounded and full, and formed of bone which is deeply pitted and of a somewhat cellular character. The anterior and posterior extremities of the bone, formed by the convergence of the superior and inferior borders, are thin and sharp; as a rule the posterior end is the more pointed of the two.

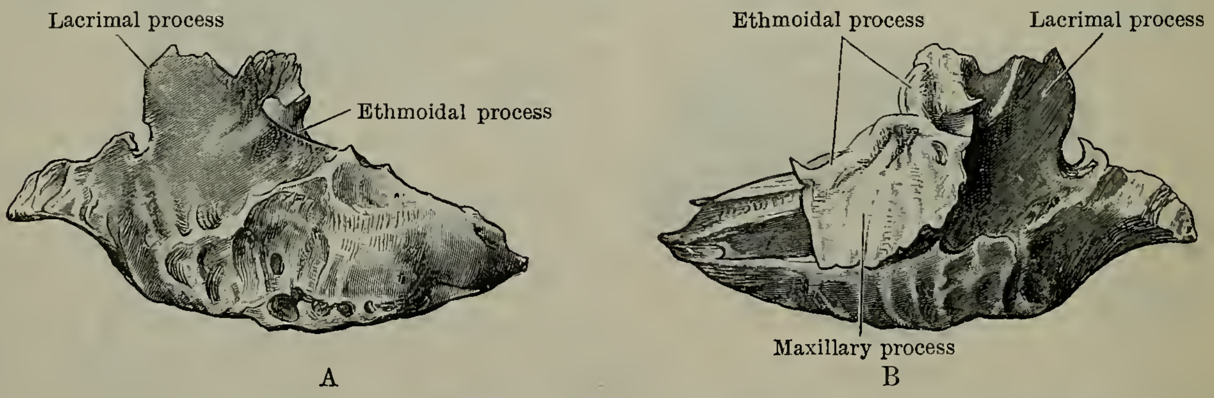

Fig. 177.—The Right Inferior Concha. A, Medial Surface; B, Lateral Surface.

The **medial surface** is uneven and convex and bulges into the nasal cavity; it is rough and pitted, and displays some scattered and longitudinally directed vascular grooves. The **lateral surface** is concave and forms the medial boundary of the inferior meatus of the nose. It is smooth in front, where it corresponds to the opening of the naso-lacrimal canal; posteriorly and towards its inferior border it is irregular and pitted. In the disarticulated bone this surface is in part concealed by the downward projecting maxillary process. Hyrtl records a case in which the inferior conchæ were absent.

Ossification.—The inferior concha (the maxillo-turbinal of comparative anatomy) is derived from the cartilage forming the lateral wall of the nasal capsule. It ossifies, however, from a separate centre, which appears about the fifth month of fœtal life.

Ossa Lacrimalia.

The **lacrimal bone**, a thin scale of bone about the size of a finger-nail, forms part of the medial orbital wall behind the frontal process of the maxilla. Irregularly quadrangular, it has two surfaces—a medial and a lateral—and four borders.

Its **lateral** or **orbital surface** has a vertical ridge, called the **posterior lacrimal crest**, running downwards upon it. In front of this is the **lacrimal groove** for the lodgment of the lacrimal sac. The medial wall of this groove descends below the level of the main part of the bone, and forms the **descending process**, which helps to complete the naso-lacrimal canal, and articulates inferiorly with the inferior concha. The inferior end of the lacrimal crest terminates in a hook-like projection, called the **hamulus lacrimalis**, which curves round the posterior and lateral edge of the naso-lacrimal notch of the maxilla, and thus defines the upper aperture of the naso-lacrimal canal. The part of the bone behind the lacrimal crest is smooth and continuous with the surface of the lamina papyracea of the ethmoid. The **medial surface** is irregular and cellular above; it closes in some of the anterior ethmoidal cells and helps to complete the infundibulum. Where it is smoother it forms a part of the lateral wall of the middle meatus of the nose immediately behind the frontal process of the maxilla, and above the inferior concha. The **superior border** articulates with the medial angular process of the frontal bone; the **anterior edge** articulates with the posterior border of the frontal process of the maxilla, with which it completes the lacrimal groove for the lodgment of the lacrimal sac. The **inferior margin** articulates with the orbital surface of the maxilla, and in front, by its **descending process**, with the inferior concha. *Posteriorly* the bone articulates with the anterior border of the lamina papyracea of the ethmoid.

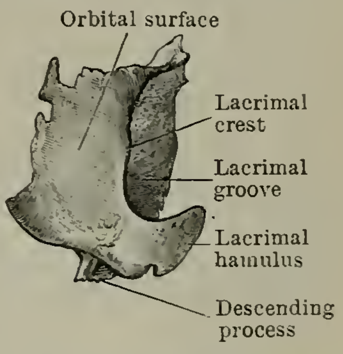

FIG. 178.—RIGHT LACRIMAL BONE (Orbital Surface).

Ossification.—The lacrimal is ossified from a single centre, which appears about the end of the second month of intra-uterine life in the membrane around the cartilaginous nasal capsule.

Variations.—The lacrimal bone is occasionally absent. In some cases it is divided into two parts; in others it is replaced by a number of smaller ossicles. In rare instances the hamulus may extend forwards to reach the orbital margin, and so bear a share in the formation of the face, as in lemurs (Gegenbauer). In other instances the hamulus is much reduced in size. Occasionally the lacrimal is separated from the lamina papyracea of the ethmoid by a downgrowth from the frontal, which articulates with the orbital surface of the maxilla, as is the normal disposition in the gorilla and chimpanzee (Turner, *Challenger Reports*, "Zoology," vol. x. Part IV. Plate I.; and A. Thomson, *Jour. Anat. and Physiol.*, London, vol. xxiv. p. 349).

Vomer.

The **vomer** is placed in the posterior part of the nasal septum. It has four borders and two surfaces. The **superior border**, which can readily be distinguished by the presence on each side of an everted lip or **ala**, slopes from behind upwards and forwards, and articulates with the inferior surface of the body of the sphenoid, the rostrum of which is received into the groove between the alæ. The **alæ** are wedged in between the sphenoidal processes of the palate bones in front, and the vaginal processes of the medial pterygoid laminæ behind. The **posterior border**, which slopes from behind downwards and forwards, is a free, sharp, slightly curved edge, and forms the posterior margin of the nasal septum. The **inferior border**, more or less horizontal in direction, articulates with the nasal crest formed by the maxillæ and palatine bones. The **anterior edge** is the longest; it slopes obliquely from above downwards and forwards. In its upper half it is ankylosed to the perpendicular plate of the ethmoid; in its lower half it is grooved for

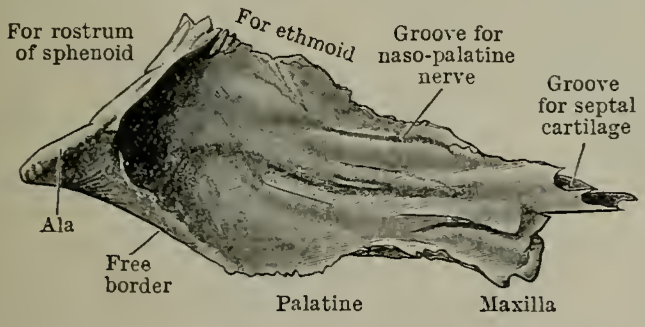

FIG. 179.—THE VOMER AS SEEN FROM THE RIGHT SIDE.

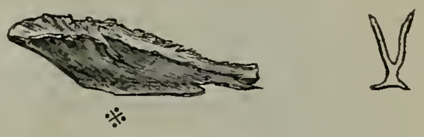

FIG. 180.

Vomer at Birth, displaying its formation by two Osseous Laminæ united inferiorly. The figure to the right exhibits the appearance of the bone, in vertical section, at the point marked ✻ in the left figure.

the reception of the septal cartilage of the nose. The **anterior extremity** of the bone forms a truncated angle which articulates with the posterior border of the incisor crest of the maxillæ, and sends downwards a pointed process which passes between the incisor foramina. The *surfaces* of the bone are smooth; but a few vascular grooves may be noticed; and one groove, usually more distinct than the others, runs obliquely downwards and forwards, and lodges the naso-palatine nerve.

Ossification.—The vomer commences to ossify in membrane at the end of the second month. A nucleus appears on each side of the middle line, below the nasal septum, medial to the plane of the anterior paraseptal cartilages and posterior to them. During the third month the nuclei, which have increased in height and length, fuse at their lower edges, and by forward growth invade the posterior end of each anterior paraseptal cartilage, thus forming a deep groove in which the septal cartilage is lodged (Fawcett). As growth goes on, the groove becomes reduced by the further fusion of the lateral plates and the absorption of the cartilage, until the age of puberty, by which time the lateral laminæ have united to form a median plate, the primitively divided condition of which is now represented only by the eversion of the alæ and the grooving along the anterior border. According to Fawcett, the ossification of the Jacobsonian cartilage produces a hitherto undescribed element in the formation of the osseous nasal septum.

Structure and Variations.—The bone is composed of two compact layers fused below, but separated above by the groove for the lodgment of the rostrum of the sphenoid behind, and the septal cartilage in front. The lamellæ are also separated from each other by a canal which runs horizontally from behind forwards in the substance of the bone, and transmits the nutrient vessel of the bone.

Owing to imperfect ossification there may be a deficiency in the bone, filled up during life with cartilage. The separation of the two lamellæ along the anterior border varies considerably, and instances are recorded where they were separated by a considerable cavity within the substance of the bone. Instances of an extension forwards of the sphenoidal air sinus into and separating the laminæ of the bone have also been described. The *spheno-vomerine canal* is a minute opening behind the rostrum of the sphenoid, and between it and the alæ of the vomer, by which the nutrient artery enters the bone.

Ossa Nasalia.

The **nasal bones**, a right and a left, lie in the interval between the frontal processes of the maxillæ, and form the bridge of the nose. Each bone is of elongated quadrangular form, having two surfaces—an inner and an outer—and four borders. The **outer surface**, somewhat constricted about its middle, is convex from side to side, and slightly concavo-convex from above downwards. Near its centre there is usually the opening of a nutrient canal. The **inner surface** is concave, and is not so extensive as the outer, as the superior and anterior articular borders encroach upon it above. Running downwards along the surface there is a narrow groove (**sulcus ethmoidalis**) for the anterior ethmoidal nerve. The **anterior** or **medial border**, thin below, is thick above, and in conjunction with its fellow of the opposite side, with which it articulates, forms a median *nasal crest* posteriorly, which is united to the spine of the frontal, the perpendicular plate of the ethmoid, and the septal cartilage of the nose, in that order from above downwards. The **posterior** or **lateral border**, usually the longest, is serrated and bevelled to fit on to the anterior edge of the frontal process of the maxilla. The **superior border** forms a wide toothed surface, which articulates with the medial part of the nasal notch of the frontal bone anteriorly; whilst, posteriorly, it rests in contact with the root of the frontal spine. The **inferior border** is thin and sharp; it is connected with the lateral cartilage of the nose, and is usually deeply notched near its medial extremity.

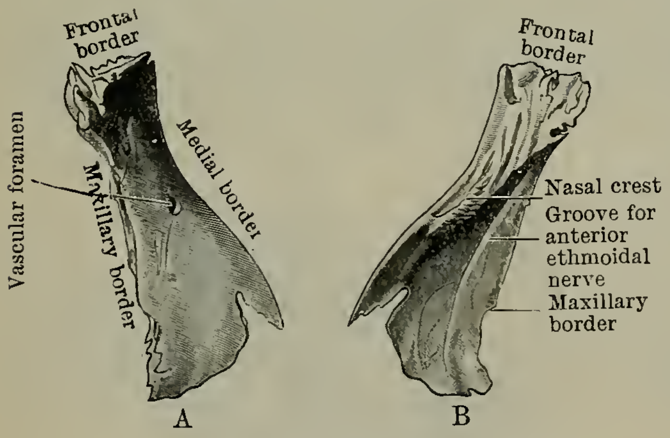

Fig. 181.—The Right Nasal Bone.
A, Lateral side; B, Medial side.

Ossification.—The nasal bones are each developed from a single centre, which appears about the end of the second month, in the membrane covering the cartilaginous nasal capsule.

Structure and Variations.—The nasal bone is made of dense compact tissue, and is strengthened by the formation of the nasal crest.

The size and configuration of the nasal bones vary greatly in different races, being, as a rule, large and prominent in the white races, and flat and reduced in size, as well as depressed, in the Mongolian and Negro stock. Complete absence of the nasal bones has been recorded, and their division into two or more parts has also been noted. Obliteration of the internasal suture is unusual; it is stated to occur more frequently in negroes, and is the recognised condition in adult apes. Duckworth has recorded a case (*Jour. Anat. and Physiol.* vol. xxxvi. p. 257) of undue extension downwards of the nasal bone, which may be perhaps accounted for on the supposition that the lower part is a persistent portion of the premaxilla.

Ossa Suturarum.

Along the line of the cranial sutures and in the region of the fontanelles, isolated bones of irregular form and variable size are occasionally met with. These are the once so-called Wormian bones, named after the Danish anatomist Wormius. They are now called **sutural bones**. They are developed either from distinct ossific nuclei, or, it may be, from division of the primary ossific deposits. Their occurrence may also be associated with certain pathological conditions which modify the development of the bone. They usually include the whole thickness of the cranial wall, but they may involve only the outer or the inner table. They are most frequent in the region of the lambda and the lambdoid suture. They occur commonly about the pterion, and in this situation are called *epipteric bones* (Flower). By their fusion with one or other of the adjacent bones they here lead to the occurrence of a fronto-squamosal suture. Their presence has been noted also along the line of the sagittal suture, and sometimes in metopic skulls in the inter-frontal suture. They are occasionally met with at the asterion and more rarely at the obelion. They appear less frequently in the face, but their presence has been noted around the lacrimal bone, and also at the extremity of the inferior orbital fissure, where they may form an independent nodule wedged in between the great wing of the sphenoid, the zygomatic bone, and the maxilla.

OSSA FACIEI.

Maxillæ.

The two **maxillæ** unite to form the upper jaw. Each consists of a **body** and four projections, named the **zygomatic, frontal, alveolar,** and **palatine processes.**

Corpus.—The **body** is of pyramidal form, and contains within it a cavity called the **maxillary sinus.** It has four surfaces—a facial or antero-lateral, an infra-temporal or posterior, an orbital or superior, and a nasal or medial.

The **antero-lateral surface** is confluent below with the alveolar process. Above, it is separated from the orbital aspect by the **infra-orbital margin,** whilst medially it is limited by the free margin of the **nasal notch,** which ends below in the pointed **anterior nasal spine.** Posteriorly it is separated from the infra-temporal surface by the **zygomatic process.** The facial aspect of the bone is ridged by the sockets of the teeth (**juga alveolaria**). The ridge corresponding to the root of the canine tooth is usually the most pronounced; medial to this, and overlying the roots of the incisor teeth, is the shallow **incisive fossa,** whilst placed laterally, on a higher level, is the deeper **canine fossa,** the floor of which is formed in part by the projecting zygomatic process. Above this, and near the infra-orbital margin, is the **infra-orbital foramen.**

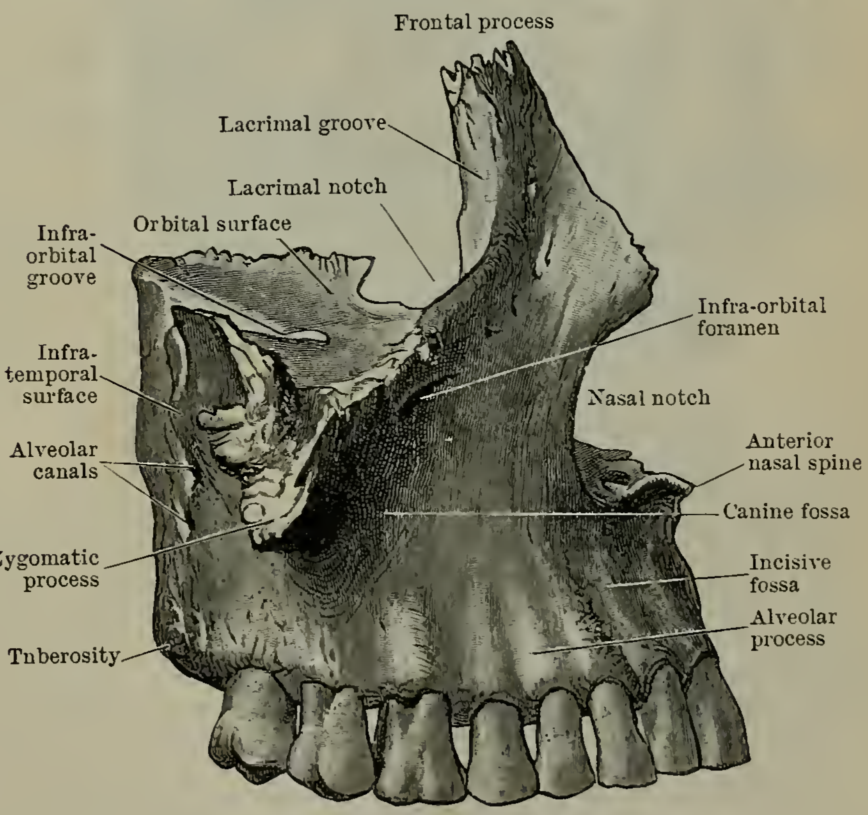

Fig. 182.—The Right Maxilla (Lateral View).

The **infra-temporal surface** is separated above from the orbital aspect by a rounded free edge, which forms the anterior margin of the **inferior orbital fissure** in the articulated skull. Anteriorly it is separated from the antero-lateral surface by the zygomatic process and its free lower border. Medially it is limited by a sharp, irregular margin with which the palatine bone articulates. The surface is more or less convex, and is directed towards the infra-temporal and pterygo-palatine fossæ. In its lower part there are the apertures of the **alveolar canals,** two or more in number, which transmit the nerves and vessels to the molar teeth. Its lower end is called the **maxillary tuberosity.**

The **orbital surface,** smooth and plain, is triangular in outline and forms part of the floor of the orbit. Its anterior edge corresponds to the infra-orbital margin; its posterior border coincides with the anterior boundary of the inferior orbital fissure. Its thin medial edge is notched in front to form the **lacrimal groove,** behind which it articulates with the lacrimal bone for a short distance, then for a greater length with the lamina papyracea of the ethmoid, and terminates posteriorly in a surface for articulation with the orbital process of the palatine bone. Its lateral angle corresponds to the base of the zygomatic process. Traversing its substance is the **infra-orbital canal**, which ends anteriorly in the infra-orbital foramen; posteriorly, however, owing to deficiency of its roof, the canal forms a groove which begins at the margin of the inferior orbital fissure. If the canal is laid open, the orifices of the *middle* and *anterior alveolar canals* will be seen, which transmit the vessels and nerves to the premolar, canine, and incisor teeth.

The **nasal surface** is directed medially towards the nasal cavity. Below, it is confluent with the superior surface of the palatine process; anteriorly it is limited by the sharp edge of the nasal notch; above and anteriorly it is continuous with the medial surface of the frontal process; behind that it is deeply channelled by the **lacrimal groove**, which is converted into the naso-lacrimal canal by articulation with the lacrimal and inferior conchal bones. Behind the groove the upper edge of the nasal surface corresponds to the medial margin of the orbital surface, and articulates from before backwards with the lacrimal, lamina papyracea of the ethmoid, and the orbital process of the palatine bone. The posterior part of the surface, rough for articulation with the palatine bone, is traversed obliquely from above downwards, forwards and slightly medially by a groove, which, by articulation with the palatine bone, is converted into the **greater palatine canal** (canalis pterygo-palatinus). Towards its upper and posterior part the nasal surface displays the irregular, more or less triangular, opening of the **maxillary sinus**. The aperture, which, in the articulated skull, opens into the middle meatus of the nose, is much reduced in size by articulation with the lacrimal, ethmoid, palatine, and inferior conchal bones. In front of the lacrimal groove the nasal surface is ridged horizontally by the **conchal crest**, to which the inferior conchal bone is attached. Below that the bone forms the lateral wall of the inferior nasal meatus.

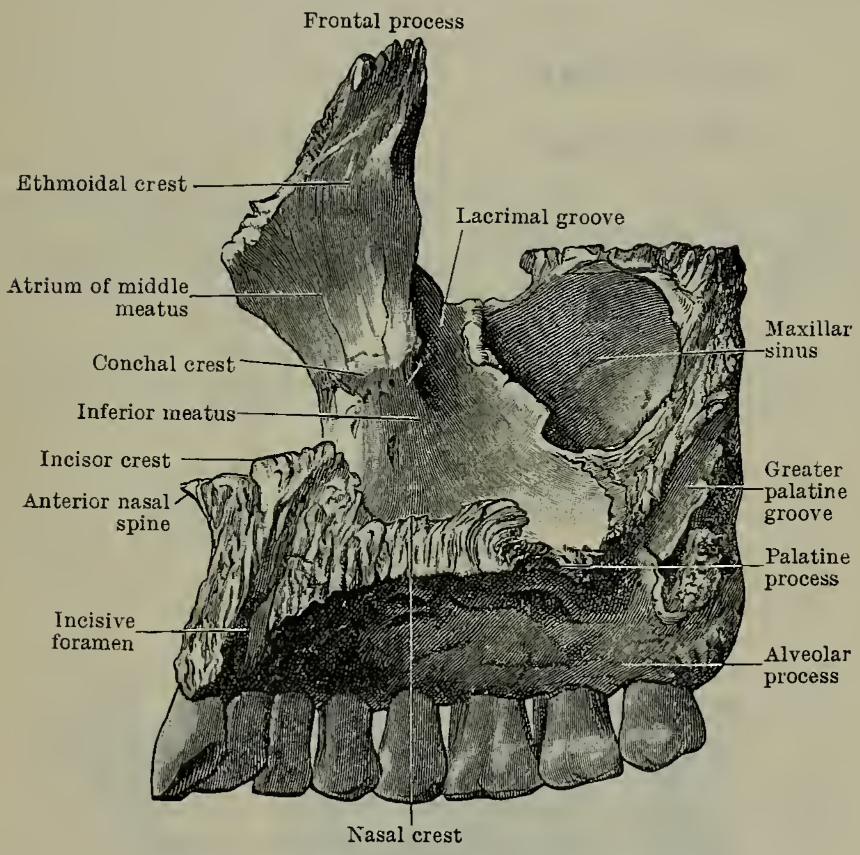

Fig. 183.—The Right Maxilla (Medial Aspect).

Processus Zygomaticus.—The **zygomatic process** projects laterally from the region between the antero-lateral and infra-temporal surfaces, with which its surfaces are continuous; superiorly, it presents an oblique, rough surface which articulates with the zygomatic bone. Inferiorly, its anterior and posterior surfaces meet to form an arched border, which fuses with the alveolar process opposite the root of the first molar tooth.

Processus Frontalis.—The **frontal process** arises from the upper and anterior part of the body. It has two surfaces—a lateral, and a medial. The *lateral surface* is divided into two by a vertical ridge, called the **anterior lacrimal crest**, which is the upward extension of the infra-orbital margin. The narrow strip of bone behind this ridge is hollowed out, and leads into the lacrimal groove below, and by articulation posteriorly with the lacrimal, edge to edge, it completes the **fossa for the lacrimal sac**. In front of the vertical crest the lateral surface is confluent below with the facial surface of the body; one or two vascular foramina may be seen on it. Its anterior edge is rough, or grooved, for articulation with the nasal bone. Superiorly the summit of the process is serrated for articulation with the nasal notch of the frontal bone. The *medial surface* of the frontal process is directed towards the nasal cavity. It is crossed obliquely from below upwards and backwards by a ridge—the **agger nasi** or **ethmoidal crest**—which is considered to be a vestige of the naso-turbinal met with in some mammals. Below the ridge the bone is smooth and forms the side wall of the atrium of the middle meatus, whilst the ridge itself articulates posteriorly with the anterior part of the middle concha.

Processus Alveolaris.—The **alveolar process** projects downwards from the inferior part of the body. Together with its fellow of the opposite side it forms the alveolar arch, in which the roots of the teeth are imbedded in sockets or alveoli; ordinarily in the adult, when dentition is complete, each alveolar process supports eight teeth. Two small vascular foramina are usually visible on the lingual surface behind the incisor teeth. When any or all of the teeth are shed the alveoli become absorbed, and the process may under these circumstances be reduced to the level of the plane of the palatine process. Posteriorly the alveolar process ends in the **maxillary tuberosity**; anteriorly it shares in the formation of the **intermaxillary suture**.

Processus Palatinus.—The palatine process lies in the horizontal plane; it has two surfaces—superior and inferior—and three borders, a straight *medial*, a more or less straight *posterior*, and a curved *lateral*, by which it is attached to the medial side of the body and alveolar process as far back as the interval between the second and third molar teeth. Its *inferior surface*, together with that of its fellow, forms the anterior two-thirds of the hard palate; it is rough and pitted for the palatine glands, and is grooved, near the alveolar margin, by one or two channels which pass forward from the **greater palatine foramen.** Its *superior surface*, smooth and concave from side to side, lies in the floor of the nasal cavity. Its *medial border*, broad and serrated, rises in a ridge superiorly, so as to form, with its fellow of the opposite side, the **nasal crest**, which is grooved to receive the inferior border of the vomer. In front of its articulation with the vomer the ridge rises higher, for articulation with the septal cartilage, and is named the **incisor crest**; its anterior end projects beyond the free border of the nasal notch, and, together with its fellow, forms the projection called the **anterior nasal spine.** At the side of the incisor crest there is the opening of a canal, called the **incisive canal**, which leads downwards, forwards, and a little medially, to open into a broad groove on the medial border of the bone immediately behind the central incisor tooth. When the two maxillæ are articulated, the two grooves form the oval **foramen incisivum**, into which the canal of each side opens, their openings being called the **foramina of Stensen.** The canal represents the channel by which in lower animals the organ of Jacobson opens into the mouth. The *posterior border* of the palatine process, which is sharp and thin, falls in line with the interval between the second and third molar, and articulates with the horizontal part of the palate bone.

Ossification.—The maxillæ (proper) are developed in the connective tissue around the oral aperture of the embryo. Ossification commences from one centre, at the end of the sixth week, in membrane above the canine tooth germ. From that centre ossification extends rapidly upwards on the lateral side of the nasal capsule to form the posterior part of the frontal process, backwards to form the zygomatic process, downwards to form the lateral wall of the alveolar process, and medially to form the palatine process; from the palatine process it extends downwards to form the medial wall of the alveolar process. At first a large gap intervenes between the greater part of the palatine process and the zygomatic process, but bridges of bone ultimately connect the two, separating the various tooth germs, and so forming the tooth sockets. About the fourth month the maxilla invades a small lateral cartilaginous process of the nasal capsule (Mihalkovics), and incorporates it within itself. The infra-orbital nerve is at first placed considerably above the orbital surface of the maxilla, and comes in contact with it only in the second month, when a groove is formed on the bone, which is converted into the infra-orbital canal and foramen to enclose the nerve by the uprising and folding medialwards of its lateral boundary. In the early stages of the development of the bone the alveolar groove, in which the teeth are developed, lies close below the infra-orbital groove; later, they are separated by the maxillary sinus, which first makes its appearance as a shallow fossa to the medial side of the orbito-nasal element about the fourth month.

The **premaxillæ**, which in most vertebrates are independent bones lying in front of the maxillæ, constitute in Man and Apes the portions of the maxillæ which lie in front of the incisive foramen, and carry the incisor teeth. Each premaxilla is ossified from two centres: a **facial**, for the part which ultimately contains the incisor teeth and forms the anterior part of the hard palate, as well as the anterior half of the frontal process of the complete maxilla (Fawcett); and a **palatine centre** (*infra-vomerine* of Rambaud and Renault) which forms the medial wall of the corresponding incisive canal. The facial centre appears early, either before or after that for the maxilla (Mall), and fuses almost at once with the maxilla along the alveolar margin; the palatine centre appears about the twelfth week, and soon fuses with the facial centre. The line of fusion of the premaxillæ with the maxillæ proper can be readily seen in young skulls, and occasionally also in the adult. It corresponds to a suture which passes obliquely laterally and forwards, from the incisive foramen to the interval between the lateral incisor and the canine tooth. In cases of alveolar cleft palate the bones fail to unite along the line of that suture. In some instances, however, the cleft passes between the central and lateral incisor teeth, and this condition suggests that the premaxillary element is derived from two centres—a lateral and a medial. The researches of Albrecht and Warinski support that view. Warinski further observes that the cleavage may lead to a division of the dental germ of the lateral incisor tooth, and so explain the occurrence of the supernumerary incisor which is occasionally met with. In this way the different varieties of cleft palate are readily explained. Median cleft palate

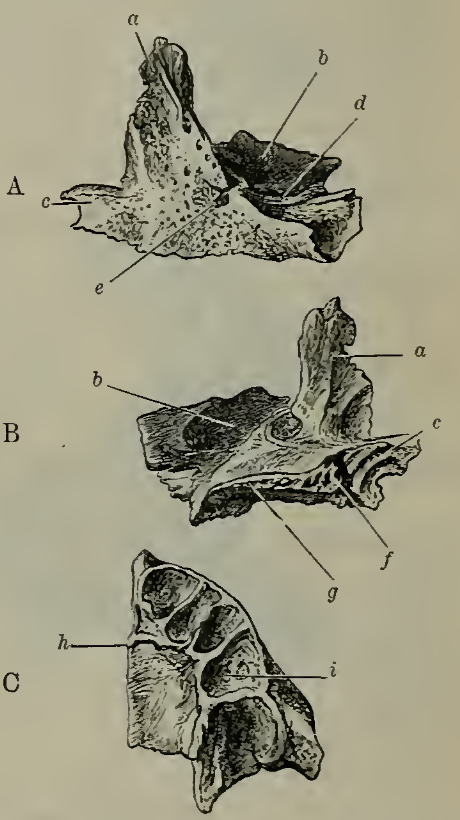

Fig. 184.—Maxilla at Birth.

A, Lateral side; B, Medial side; C, Under side. *a*, Frontal process; *b*, Orbital plate; *c*, Anterior nasal spine; *d*, Infra-orbital groove; *e*, Infra-orbital foramen; *f*, Anterior palatine groove; *g*, Palatine process; *h*, Premaxillary suture; *i*, Alveolar process.

is due to failure of union between the two premaxillary bones. Lateral cleft palate may be of two types: the cleft in one case passing forwards between the central and lateral incisor, and being due to the non-union of the two elements from which the premaxilla is primarily developed; the other, in which the cleft passes between the lateral incisor and the canine, or between the lateral incisor and a supernumerary incisor, owing to the imperfect fusion of the premaxilla with the maxilla.

Variations.—Not infrequently there is a vertical suture in the bar of bone which separates the infra-orbital foramen from the infra-orbital margin. Through imperfections in ossification, the infra-orbital canal may be an open groove. Duckworth records four instances of a spinous process projecting into the apertura piriformis from the lower part of the nasal notch. A case has been described (Fischel) in which there was absence of the premaxillæ, together with the incisor teeth. A not uncommon anomaly is the occurrence of a rounded, elongated ridge extending along the interpalatal or intermaxillary sutures on the lower surface of the hard palate. It is called the *torus palatinus*, and is of interest because it has been regarded as pathological. The sulcus lacrimalis may be constricted towards its centre. A part of the maxillary sinus may be constricted off anteriorly and, owing to its relation to the naso-lacrimal canal, is called the *recessus lacrimalis.* Underwood (*Jour. Anat. and Physiol.* vol. xliv.) records the occurrence of almost complete septa in the maxillary sinus.

Ossa Palatina.

The **palatine bone**, of irregular shape, assists in the formation of the lateral wall of the posterior part of the nasal cavity, the posterior portion of the hard palate, the orbit, the pterygo-palatine, the infra-temporal, and the pterygoid fossæ. It consists of a **horizontal** and a **perpendicular part**, united to each other like the limbs of the letter ᒪ. At their point of union posteriorly there is an irregular projection called the **pyramidal process**; capping the summit of the perpendicular part there are two irregular projections, called the **sphenoidal** and **orbital processes**, which are separated by an interval called the **spheno-palatine notch**.

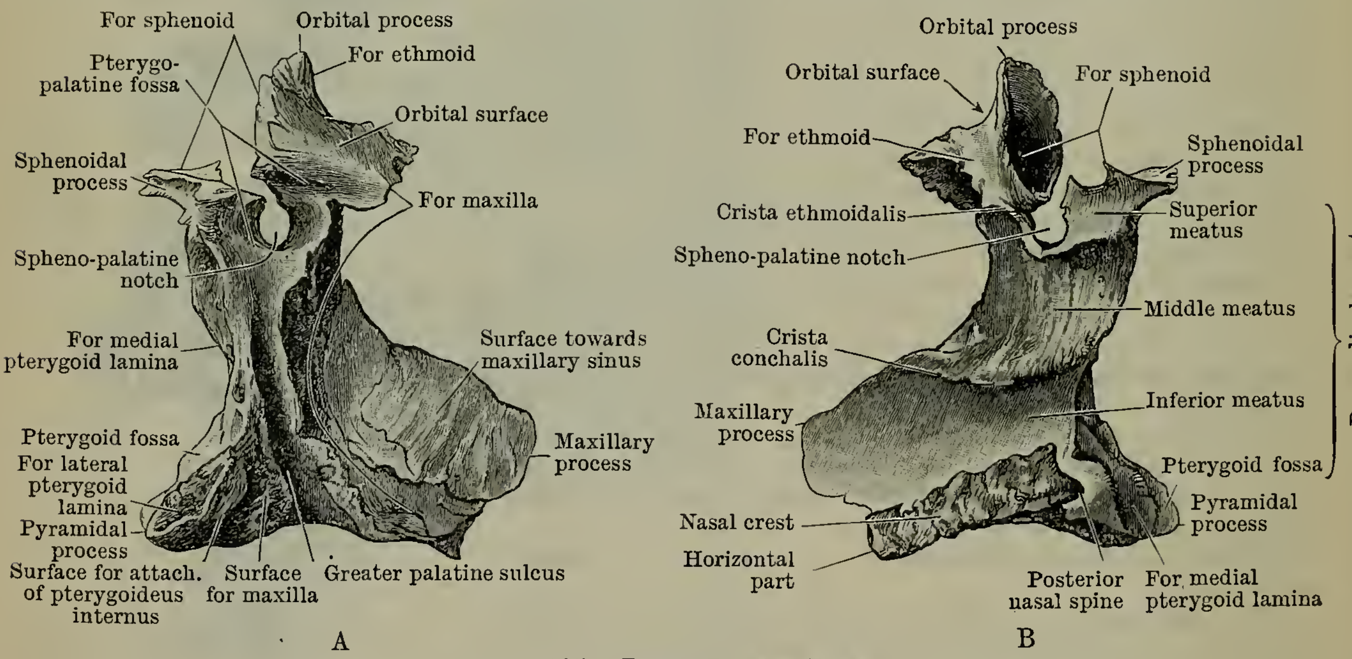

Fig. 185.—Right Palate Bone.

A, As seen from the Lateral Side; B, As viewed from the Medial Side.

Pars Horizontalis.—The **horizontal part** forms the posterior third of the hard palate, and has two surfaces and four borders. Its *superior surface*, which is smooth, is slightly concave from side to side, and forms the floor of the posterior part of the nasal cavity. Its *inferior surface*, rougher, is directed towards the mouth, and, near its posterior edge, often displays a transverse ridge or crest. The *anterior border* is rough, and articulates with the posterior edge of the palatine process of the maxilla. The *posterior margin* is free and is concave from side to side. The *medial border* is upturned, and when it articulates with its fellow of the opposite side it forms superiorly a median crest, continuous in front with the nasal crest of the maxilla; the crest supports the posterior part of the inferior border of the vomer, and, projecting beyond the line of the posterior border, it forms the **posterior nasal spine.** The *lateral border* fuses with the perpendicular part, forming with it a right angle. The posterior extremity of this edge is grooved by the **greater palatine foramen.**

Pars Perpendicularis.—The **perpendicular part** is composed of thin bone, especially at its upper part, and it is very much broader below than above; it also has two surfaces and four borders. Its *medial surface* is crossed horizontally, about its middle, by the **conchal crest**, with which the posterior end of the inferior concha articulates; above and below the crest, the surface forms part of the lateral wall of the middle and inferior meatuses of the nose, respectively. Near the upper end of the surface there is another horizontal ridge, called the **ethmoidal crest**, with which the posterior extremity of the middle concha articulates. The *lateral surface*, which forms the medial wall of the pterygo-palatine fossa, is channelled by an oblique groove which is converted into the **greater palatine canal** (canalis pterygo-palatinus) by articulation with the maxilla; the canal ends inferiorly as the **greater palatine foramen.** The perpendicular part projects forwards to a variable extent, forming a **maxillary process** which helps to close in the maxillary sinus. The *anterior border* is a thin edge, of irregular outline, which articulates above with the ethmoid, with the posterior edge of the maxillary process of the inferior conchal bone about its middle, and below with the maxilla. The *posterior border*, thin above, where it articulates with the anterior part of the medial pterygoid lamina, expands below into the **pyramidal process.** The *inferior border* is confluent with the lateral edge of the horizontal part; posteriorly, and immediately in front of the tuberosity, it is notched by the lower extremity of the greater palatine canal. The *superior border* supports the **orbital** and **sphenoidal processes**, the notch between which is converted into the **spheno-palatine foramen** by the articulation of the palatine bone with the inferior surface of the sphenoid.

Processus Pyramidalis.—The **pyramidal process** is directed backwards and laterally from the junction between the perpendicular and horizontal parts, and presents, on its *posterior surface*, a central smooth vertical groove, bounded on each side by rough articular furrows which unite above in a ∧-shaped manner. The furrows articulate with the anterior parts of the lower portions of the medial and lateral pterygoid laminæ, while the central groove fits into the wedge-like pterygoid fissure, thus entering into the formation of the pterygoid fossa. The *lateral surface* of the pyramidal process is rough above, and is confluent with the lateral surface of the perpendicular part where it articulates with the tuberosity of the maxilla; below, there is a small, smooth, triangular area which appears between the tuberosity of the maxilla and the lateral surface of the lateral pterygoid lamina, and so enters into the medial wall of the infra-temporal fossa. Passing through the pyramidal process in a vertical direction are the **lesser palatine canals**, which open on the inferior aspect of the process as the **lesser palatine foramina.**

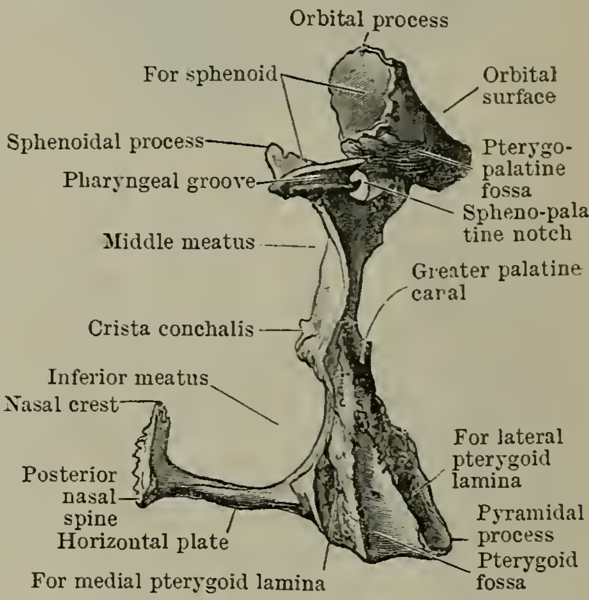

FIG. 186.—THE RIGHT PALATE BONE.
As seen from behind.

Processus Orbitalis.—The **orbital process**, shaped like a hollow cube, surmounts the anterior part of the perpendicular plate. The open mouth of the cube is usually directed backwards and medially towards the anterior part of the body of the sphenoid, with the cavity of which it commonly communicates; the anterior part of the cube articulates with the medial end of the angle formed by the orbital and infra-temporal surfaces of the maxilla. Of the remaining four surfaces, one, directed forwards and medially, articulates with the ethmoid. The others are non-articular: the *superior* forms the posterior part of the floor of the orbit; the *lateral* is directed towards the pterygo-palatine fossa; whilst the *inferior*, which is confluent with the medial surface of the vertical part, is of variable extent, and overhangs the superior meatus of the nose.

Processus Sphenoidalis.—The **sphenoidal process**, much smaller than the orbital, curves upwards, medially, and backwards from the posterior part of the summit of the perpendicular part. Its *superior surface*, which is grooved, articulates with the anterior part of the inferior surface of the body of the sphenoid and the root of the medial pterygoid lamina, thereby converting the groove into the **pharyngeal canal.** Its *lateral surface* forms part of the medial wall of the pterygo-palatine fossa. Its *medial surface* is directed towards the nasal cavity; its medial edge is in contact with the ala of the vomer.

Ossification.—The palatine bone ossifies from one centre which appears during the eighth week in the membrane in the side wall of the nasal cavity. Ossification spreads medially to form the palatine process, upwards to form the sphenoidal and orbital processes, and downwards and backwards to form the pyramidal process. The orbital process may be ossified from an independent centre. Until the third year the antero-posterior width is greater than the vertical height, which increases as the maxillary sinus enlarges.

Structure and Variations.—The greater part of the palatine bone is composed of two thin plates of compact substance, which may be separated, in the horizontal part, by an extension of the maxillary sinus. The lower part of the greater palatine canal may be completely bounded by the palatine bone. The orbital process varies greatly in size, and is not always pneumatic; occasionally it unites with the sphenoidal process and converts the spheno-palatine notch into a foramen, which may be divided into two by a bridge of bone.

Ossa Zygomatica.

The **zygomatic bone** (O.T. **malar**) lies in the most prominent part of the cheek, and is hence often called the *cheek-bone.* Placed below and lateral to the orbit, it forms the sharp lateral border of that cavity, and serves to separate it from the temporal fossa and upper part of the infra-temporal fossa; below, it rests upon and is united to the maxilla; behind, it enters into the formation of the zygomatic arch. The zygomatic bone is described as having three *surfaces*, named the *malar*, the *orbital*, and the *temporal*, two processes, named the *fronto-sphenoidal* and the *temporal*, and two subordinate processes, named the *marginal* and the *orbital*.

The **malar surface** is the largest surface; it is slightly convex and rather uneven; its most elevated part is called the **malar tuberosity**, above which there is a small aperture called the **zygomatico-facial foramen**, which is often double. The lower margin of the surface is free and rough, and is continuous with the lower edge of the zygomatic process of the maxilla. The upper margin is smooth and forms a great part of the infra-orbital margin. The anterior margin is oblique and is united to the zygomatic process of the maxilla. The posterior margin is continuous with the two processes. The **temporal process** projects backwards and articulates by an oblique serrated extremity with the zygomatic process of the temporal bone. The **fronto-sphenoidal process** is a large process which projects upwards; its medial margin is smooth and forms the greater part of the lateral margin of the orbit; its lateral or posterior margin meets the upper border of the temporal process almost at a right angle. About half-way up that margin there is usually a prominence called the **marginal process**. The upper end of the fronto-sphenoidal process articulates with the zygomatic process of the frontal bone; and from its deep aspect a wide, thin, sharp crest projects backwards in the lateral wall of the orbit, between the orbit and the temporal fossa, and articulates by its sharp posterior edge with the great wing of the sphenoid. That crest is continuous inferiorly with a small shelf of bone which projects backwards from the infra-orbital margin, and the two together form a thin, curved lamina which is often called the **orbital process**. The posterior margin of the orbital process is sharp, rough, and uneven; its upper part articulates with the great wing of the sphenoid, as stated above; its lower part articulates with the maxilla; between those two articulations the margin may have a small, smooth notch that forms the anterior end of the inferior orbital fissure.

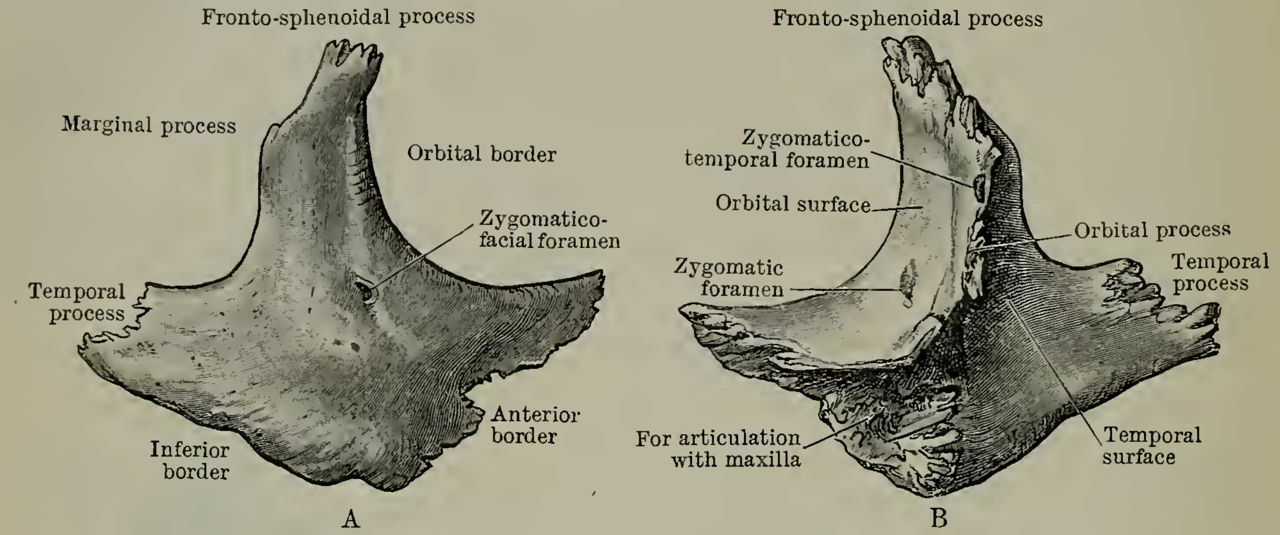

FIG. 187.—THE RIGHT ZYGOMATIC BONE. A, Lateral Side; B, Medial Side.

The **orbital surface** is the smooth, concave area between the posterior edge of the orbital process and the orbital margin, and it lies in the anterior part of the lateral wall and the floor of the orbit; at a varying point on the surface there is an aperture, called the **zygomatic foramen**, which may be double.

The **temporal surface** is a large concave surface which looks towards the temporal and infra-temporal fossæ, and includes the deep aspects of the temporal and fronto-sphenoidal processes. On that part which is formed by the fronto-sphenoidal process there is a small hole called the **zygomatico-temporal foramen.**

Besides those named surfaces there is a wide, rough, triangular area which articulates with the zygomatic process of the maxilla.

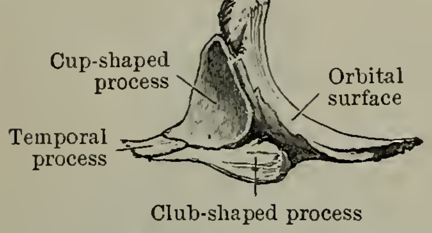

FIG. 188.—MEDIAL SURFACE OF THE ZYGOMATIC BONE AT BIRTH.

Ossification.—The zygomatic bone ossifies in membrane from one centre which appears between the eighth (Mall) and the tenth (Toldt) week. At birth there are narrow grooves or fissures on the temporal surface, produced by the overlapping edges of a cup-shaped and a club-shaped thickening of the bone; in some cases those grooves persist in the adult. Some authorities hold that there are more than one centre of ossification (Rambaud and Renault, Le Double), and that view is supported by the fact that the bone is sometimes divided in the adult.

Structure and Variations.—In structure the zygomatic bone is compact, with little spongy tissue. Together with the zygomatic process of the temporal bone it forms the buttress which supports the maxilla and the lateral wall of the orbit. Additional strength is imparted to the bone by the angular mode of union of its orbital and facial parts.

Cases of division of the zygomatic bone by a horizontal or a vertical suture have been recorded. Owing to the supposed more frequent occurrence of that divided condition in Asiatics the bone has been named the *os Japonicum.* Barclay Smith (*Jour. Anat. and Physiol.*, 1898) describes a case in which the zygomatic bone was divided into an upper and a lower part by a backward extension of the maxilla, which articulated with the zygomatic process of the temporal, thus forming a temporo-maxillary arch. Varieties of a like kind have been described also by Gruber and others. Cases have been noted where, owing to deficiency in the zygomatic bone, the zygomatic arch has been incomplete.

The **mandible** and the **hyoid bone** are described on pp. 177, 182.

BONES OF THE UPPER LIMB.

The **upper limb** or **superior extremity** includes the shoulder, the upper arm, the forearm, and the hand (see Fig. 109, p. 92).

The **shoulder** is not a sharply defined region; it includes not only the familiar prominence at the proximal end of the arm, but also (1) the *scapular region,* that is the parts around the shoulder-blade; (2) the *pectoral region,* that is the parts overlying the upper part of the front of the chest; and (3) the *axilla* or armpit. The bones of the shoulder are the **scapula** or shoulder-blade and the **clavicle** or collar-bone. Those two bones constitute what is called the *shoulder girdle*; they articulate with one another, forming a joint called the *acromio-clavicular joint.* The clavicle articulates with the upper end of the sternum or breastbone, forming with it the *sterno-clavicular joint*; the scapula does not articulate with any part of the axial skeleton, being connected with it only by muscles.

The **upper arm** (brachium) is referred to in anatomical descriptions as the **arm.** The bone of the arm is called the **humerus.** The humerus articulates with the scapula to form the *shoulder joint.*

The **forearm** (anti-brachium) is continuous with the arm at the *elbow* (cubitus); there the humerus articulates with the two bones of the forearm to form the *elbow joint.* The bones of the forearm are called the **radius** and the **ulna**; they articulate with one another at their proximal and distal ends, forming *radio-ulnar joints.*

The **hand** (manus) consists of three parts: (1) the wrist; (2) the hand proper, one surface of which is the palm, and the other surface is the "back of the hand"; (3) the five digits.

The bones of the **wrist** (carpus) are eight small bones, named collectively the **carpal bones**, and each has its own name besides. They are arranged in two rows—a proximal and a distal—four bones in each row. Three of the bones of the proximal row articulate with the radius and with a structure called the *triangular articular disc* to form the *radio-carpal* or *wrist joint*, where the hand joins the forearm. Each carpal bone articulates with the adjoining carpal bones, forming *inter-carpal joints.*

The bones of the **hand proper** (metacarpus) are called **metacarpal bones.** They are five in number, one corresponding to each digit. They are named, **first** metacarpal, **second** metacarpal, etc., beginning with the one which corresponds to the thumb. The metacarpal bones articulate with the distal row of carpal bones, forming *carpo-metacarpal joints*; and they articulate with one another at their proximal ends, forming *inter-metacarpal joints*; their distal ends are the rounded prominences known as the first row of *knuckles.*

Each of the **digits** is named: the thumb or *pollex*; the forefinger or *index*; the middle finger or *digitus medius*; the ring finger or *digitus annularis*; the little finger or *digitus minimus* vel *quintus.* The bones of the digits are called **phalanges.** The thumb has two phalanges, named the **first** or proximal phalanx and the **second** or distal phalanx. Each finger has three phalanges: **first, second,** and **third,** or proximal, middle, and distal. The distal phalanx is sometimes called the *ungual phalanx,* because the *nail* (unguis) is associated with it. The first phalanx of each digit articulates with the distal end of the corresponding metacarpal bone to form a *metacarpo-phalangeal joint.* The ends of the second phalanx articulate with the first and the third phalanx, forming *inter-phalangeal joints.*

Scapula.

The **scapula** is a thin, wide, triangular bone [σκαπάνη (scapanē) = a digging tool] which lies obliquely in the upper part of the back and in the posterior wall of the axilla, opposite the second to the seventh ribs. It is classed as a "flat" bone and possesses a main part or **body** and three processes,[1] named the **spine**, the **acromion**, and the **coracoid process**. At one of its angles the body is greatly thickened and is coated with articular cartilage. The thickened angle is called the **head**, and the part contiguous to the head is called the **neck**. The spine is the large triangular plate attached to the posterior surface of the body; the acromion is the flattened piece of bone which is continuous with the spine at the angle between its two unattached borders; and the coracoid process is the thick, bent piece of bone that projects from the upper part of the head and neck.

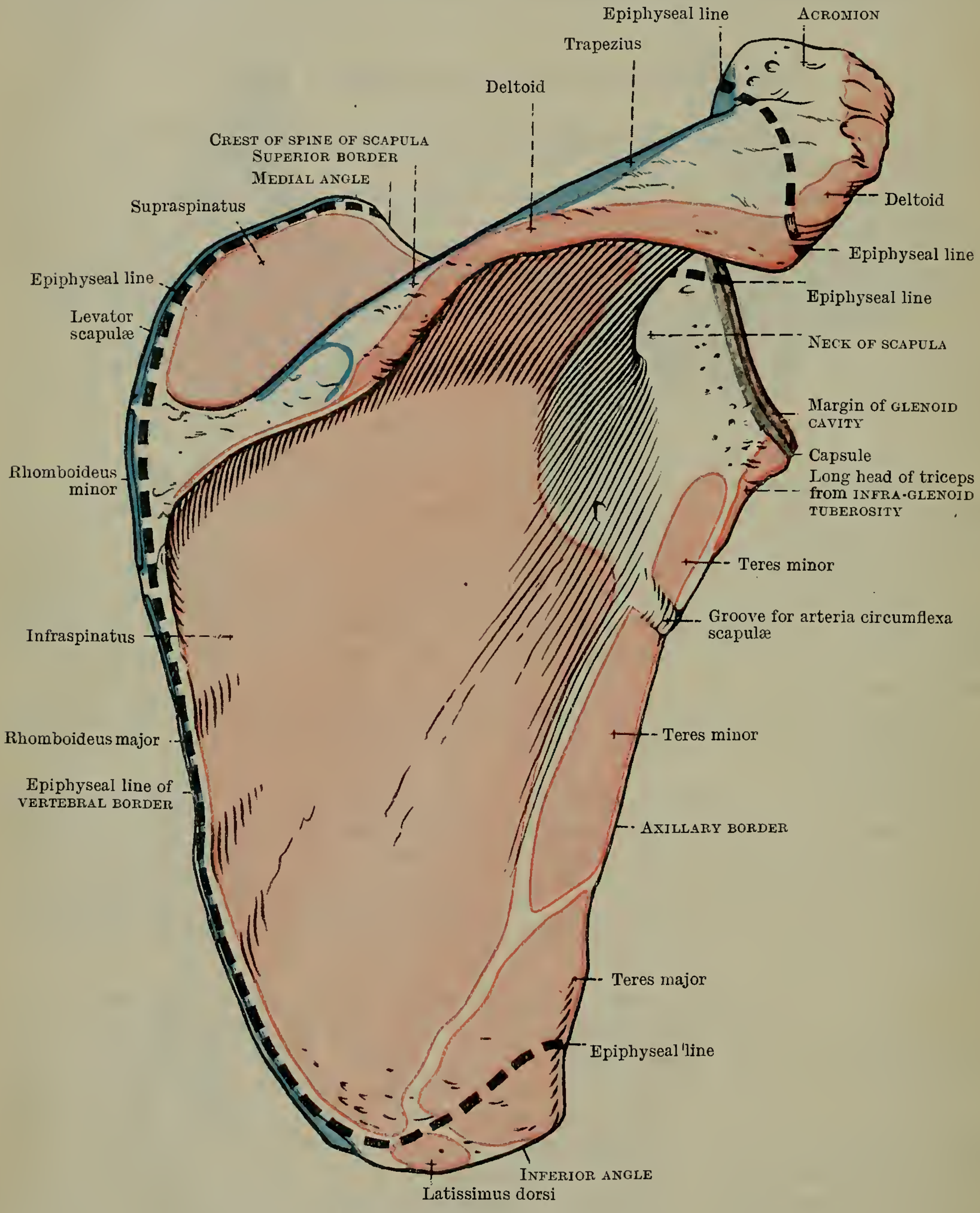

Fig. 189.—Dorsal Surface of Right Scapula.

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[1] Definitions of terms are given on pp. 4 and 87.

The **body** is the blade proper; it is thin and even translucent in places, and is triangular in outline, possessing two surfaces, three borders, and three angles.

The **borders** of the scapula are named *superior*, *vertebral*, and *axillary*.

The **superior border** is the shortest of the three. At its lateral end, close to the root of the coracoid process, there is a notch called the *scapular notch*; it may be wide and shallow, or narrow and deep; it is bridged across by a fibrous band called the *superior transverse ligament*; in some scapulæ the ligament is ossified, so that the notch is converted into a foramen.

The **vertebral border** is the longest of the three, and looks medially and backwards towards the spines of the vertebræ—hence its name. When the shoulder is at rest the border lies two or three finger-breadths from those spines and can be both felt and seen in a thin person. It is divided into three parts: a small part opposite the spine of the scapula, a part above that and a part below, the lowest part being by far the longest.

The **axillary border** looks in a lateral direction and forwards, and lies in the posterior wall of the axilla, where it may be indistinctly felt. It is thick and rough, and extends downwards from the head. Its thickest and roughest part is immediately below the head and is called the *infra-glenoid tuberosity*.

The **angles** of the scapula are named *medial*, *inferior*, and *lateral*.

The **medial angle** is that between the superior border and the vertebral border; it is so thickly covered with muscles that it can scarcely be felt.

The **inferior angle** is that between the vertebral and axillary borders, and is the lowest part of the scapula. It is covered thinly with muscle and is easily felt; it is used as a landmark to locate spines of vertebræ, for, when the arm is hanging at rest, it is on a level with the spine of the *seventh* thoracic vertebra.

The **lateral angle** is that between the axillary and superior borders. It is only nominally an angle, for it is truncated and thickened to form the **head**. The lateral surface of the head is called the **glenoid cavity**; it is concave, smooth, articular, and pear-shaped in outline; it is directed forwards as well as laterally, and it articulates with the head of the humerus to form the shoulder joint [γλήνη (glēnē) = a socket]. The small rough area at the upper end or margin of the glenoid cavity is called the *supra-glenoid tuberosity*.

The **surfaces** of the scapula are named *costal* and *dorsal*.

The **costal surface** looks towards the ribs and is concave; the concavity is often referred to as the **subscapular fossa**, and is deepest opposite the spine. At the medial and lower angles there are usually flat triangular areas marked off by ridges from the rest of the surface, and those two areas are connected by a very narrow raised strip that lies alongside the vertebral border. The areas and the strip are for the insertion of a large muscle called the *serratus anterior*. Nearly all the rest of the costal surface, including the strong smooth ridge which runs downwards from the neck and the groove between that ridge and the axillary margin, gives origin to a muscle called the *subscapularis*. The low ridges that run from the vertebral margin towards the neck give attachment to tendinous fibres in the substance of the subscapularis.

The **dorsal surface** or posterior surface is divided into two unequal parts by the spine; the two parts are not in the same plane, for the scapula is bent at the attachment of the spine. The smaller, supraspinous part and the upper surface of the spine form the boundaries of a space called the **supraspinous fossa**. On the larger, infraspinous part there is a raised oval area, alongside the lower part of the axillary margin, from which a muscle called the *teres major* arises. Above that area there is a raised narrow strip which reaches up to the head of the bone; the *teres minor* muscle arises from the strip, and crossing it there is a narrow, shallow groove produced by an artery called the circumflex scapular artery; occasionally there are two grooves corresponding to branches of the artery. The remainder of the lower part of the dorsal surface forms one wall of a space called the **infraspinous fossa**, while the lower surface of the spine forms the other wall.

The **spine of the scapula** is a triangular plate of bone attached by one of its borders to the dorsum of the scapula. Another border of the spine looks in a lateral direction towards the shoulder joint; it is smooth and rounded, and the wide notch between it and the neck of the scapula is called the **great scapular notch**. A weak fibrous band called the *inferior transverse ligament* bridges across the notch. The third border is called the **crest of the spine**. It is subcutaneous, and can be felt easily in all its length in the living person; it has fairly sharp *upper* and *lower lips* or edges; the prominence or enlargement on the lower lip near the vertebral border is called the **tubercle of the crest**. At the vertebral margin the lips of the crest spread apart to enclose a small smooth triangular area which one can easily feel in the living person by pressing the finger along the crest; it is on a level with the spine of the *third* thoracic vertebra, and is used as a landmark for locating the spines of the vertebræ.

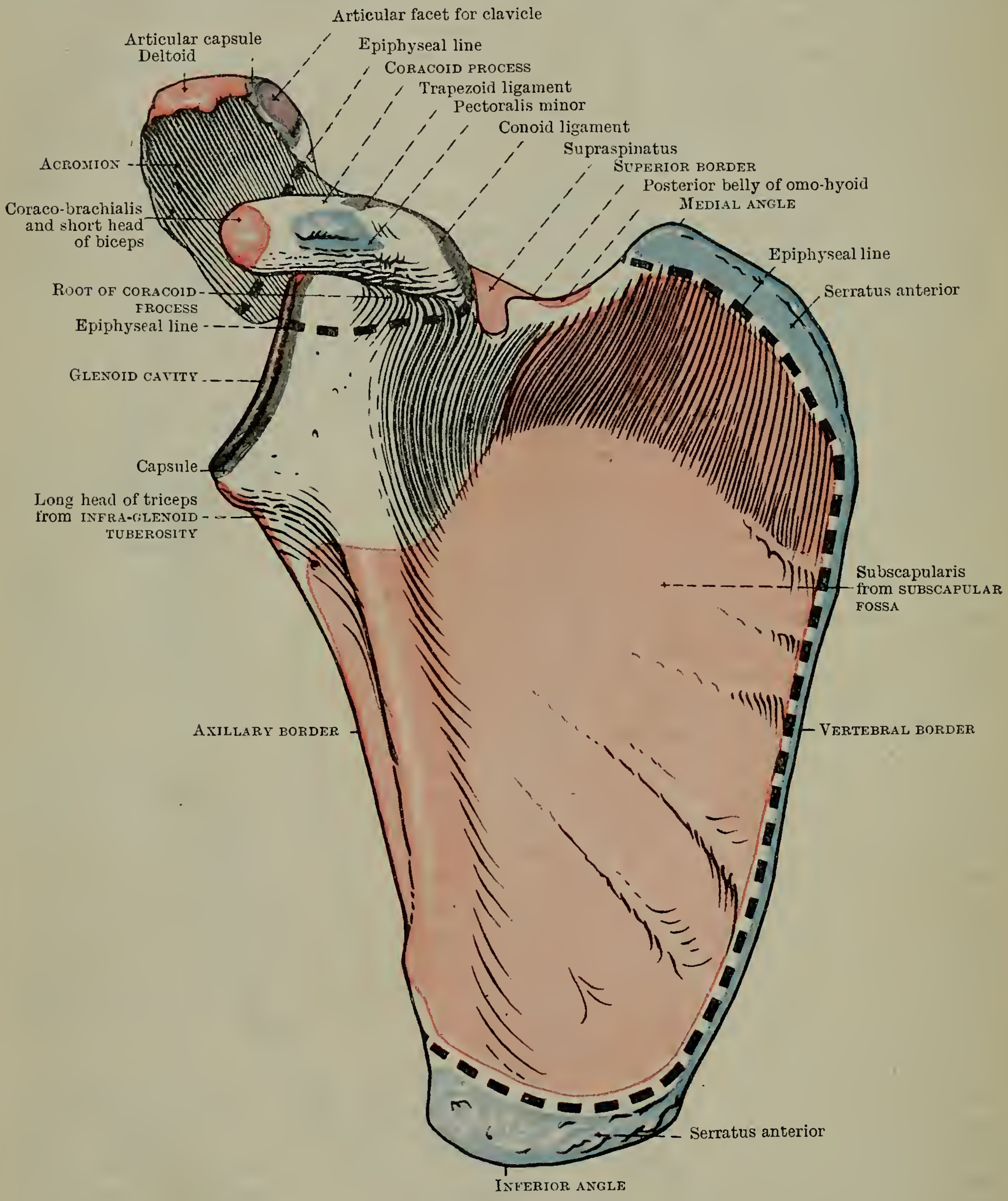


FIG. 190.—COSTAL SURFACE OF RIGHT SCAPULA.

The **acromion** is broad and flattened; it is continuous with the spine at the angle where the crest and the lateral border of the spine meet; it extends in a lateral direction and forwards, and overhangs the shoulder joint above and behind. It lies at the top of the shoulder and is easily felt there, its upper surface being subcutaneous and continuous with the crest of the spine [ἄκρον (acron) = highest point; ὦμος (ōmos) = shoulder (with upper arm)]. Its lateral border is long and is sharply bent to become continuous with the lower lip of the crest. The bend is called the **angle of the acromion**; it is easily located in the living person, and is used as a point from which measurements may be taken and as a guide to the back of the shoulder joint, which lies directly below and in front of it. The medial border of the acromion is short and is continuous with the upper lip of the crest; the anterior and larger part of the medial border is occupied by an oval facet for articulation with the lateral end of the clavicle to form the *acromio-clavicular joint.*

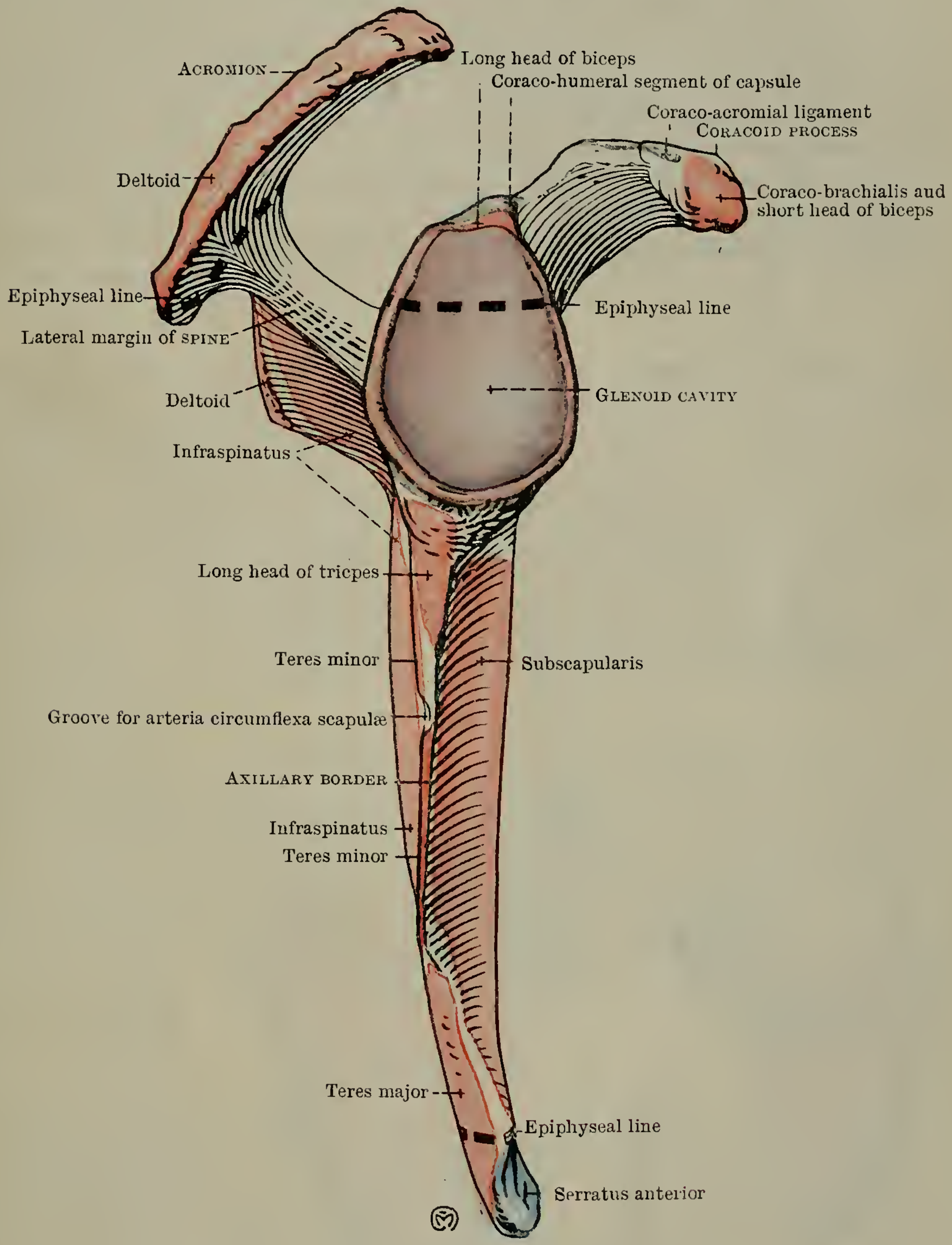


FIG. 191.—LATERAL VIEW OF RIGHT SCAPULA.

The **coracoid process** is the stout, blunt process that projects from the upper margin of the neck and head of the scapula. In shape it has some resemblance to the bill of a bird [κόραξ (corax) = a raven or crow], and it is divisible into a root and a coracoid process proper.

The **root** projects upwards and forwards from the neck and head and is flattened from before backwards, its anterior and posterior surfaces being continuous with the front and the back of the neck; its medial border is the lateral margin of the small scapular notch on the upper border of the scapula; and its lateral border is immediately above the glenoid cavity.

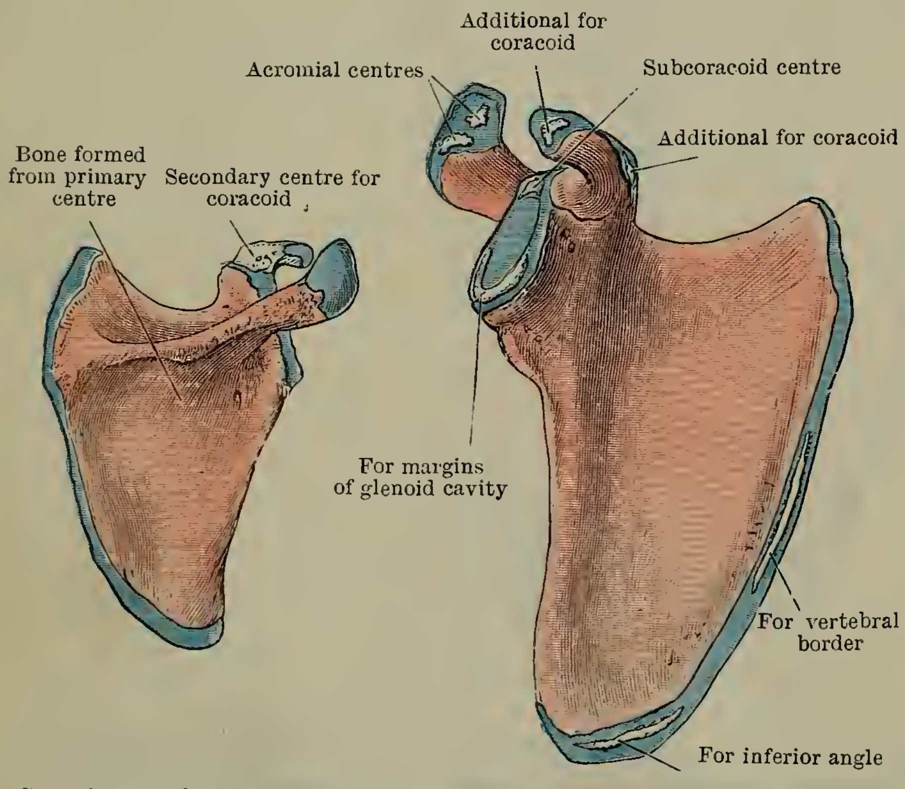
The **coracoid process proper** extends from the top of the root almost horizontally, in a lateral direction and forwards, overhanging the shoulder joint above and in front. Its **borders** are called *lateral* and *medial*, though they look, respectively, backwards and forwards as much as in the directions indicated by their names. The lateral border is connected with the tip of the acromion by a strong, flat triangular band called the *coraco-acromial ligament*; the two processes and the intervening ligament form a wide arch called the **coraco-acromial arch**, which overhangs the shoulder joint and protects it. The **surfaces** of the coracoid process are *upper* and *lower*. The posterior part of the upper surface is roughened for the attachment of a strong *coraco-clavicular ligament* which binds it to the clavicle. The **tip of the coracoid process** is a landmark in the root of the upper limb. It is felt, rather indistinctly, as a hard resisting object in the hollow on the front of the shoulder about an inch below the clavicle.

Nutrient foramina, for the entrance of arteries into the bone and the exit of veins from it, are scattered here and there, and are largest near the attached margin of the spine.

Attachments.—The **upper margin** of the scapula gives attachment to only one small muscle, namely, the posterior belly of the omo-hyoid, which arises from the superior transverse ligament and the adjoining part of the upper margin. The **vertebral border** gives insertion to three muscles: (1) the levator scapulæ, opposite the supraspinous fossa; (2) the rhomboideus minor, opposite the spine; and (3) the rhomboideus major, opposite the infraspinous fossa.

The **costal surface** gives attachment to (1) the serratus anterior, which is inserted into the small areas at the medial and inferior angles and into the narrow strip along the vertebral border between those areas, and (2) the subscapularis, which arises from the whole costal surface except the parts for the insertion of the serratus anterior and a part near the neck; a *bursa* protrudes from the capsule of the shoulder joint and separates the subscapularis from the neck and from the root of the coracoid process, and those parts of the bone are smooth.

The **glenoid cavity** gives attachment by its circumference to the labrum glenoidale (glenoid ligament). The capsule of the shoulder joint is attached to the rim of the cavity outside the labrum glenoidale and to the labrum itself. The tendon of the long head of the biceps arises from the **supra-glenoid tuberosity**, and some of the fibres of the tendon are incorporated in the labrum glenoidale. The tendon of the long head of the triceps arises from the rough area on the **axillary margin** immediately below the glenoid cavity, and that is the only muscle attached to the axillary border.



Scapula at end of First Year. Scapula about the Age of Puberty.

Fig. 192.—Ossification of the Scapula.

On the **dorsal surface** the teres major muscle arises from the oval or *triangular elevated area* near the inferior angle, and the latissimus dorsi muscle receives a small slip of origin from the lowest part of that area; the teres minor arises from the *elongated elevated area* that extends upwards to the head; the infraspinatus muscle arises from the **infraspinous fossa**, except a portion near the neck. The supraspinatus arises from the **supraspinous fossa**, except a part near the neck; as it passes over the shoulder joint towards its insertion into the humerus it is separated from the smooth lower surface of the acromion by a *bursa* called the subacromial bursa.

The *upper* and *lower surfaces* of the **spine** help to bound the supra- and infraspinous fossæ and give origin to some fibres of the supraspinatus and infraspinatus respectively. The inferior transverse ligament stretches from the *lateral margin* of the spine to the back of the **neck** of the scapula. The whole of the *lower lip* of the **crest** and the *lateral margin* of the **acromion** give origin to fibres of the deltoid muscle. The circumference of the *facet* on the medial margin of the acromion gives attachment to the capsule of the acromio-clavicular joint. The coraco-acromial ligament is attached to the *tip* of the acromion in front of the facet. Fibres of the trapezius muscle are inserted into the small part of the *medial margin* behind the facet, and into nearly the whole length of the *upper lip* of the **crest** and the **tubercle** on the *lower lip* of the **crest**; and a tendinous part of the trapezius, before reaching its insertion, plays over the smooth area where the spine joins the vertebral border, and is separated from that area by a small *bursa*.

The **coracoid process** gives attachment to numerous structures. The coraco-humeral ligament is attached to the *lateral margin* of its **root**, and the superior transverse ligament to the *medial margin*. The coraco-brachialis muscle and the tendon of the short head of the biceps muscle arise conjointly from the *tip* of the **process proper**; the coraco-acromial ligament is attached to its *lateral margin*; the costo-coracoid membrane to the posterior part of the *medial margin*, while the pectoralis minor muscle is inserted into the anterior part of the *medial margin* and the adjoining part of the *upper surface*. The coraco-clavicular ligament is attached to the posterior part of the *upper surface*. The *lower surface* does not give attachment to any structure; it is smooth and is in relation with the subscapular *bursa* and muscle.

Ossification.—The **primary** centre appears at the eighth week of fœtal life. At birth the acromion, the coracoid process, the glenoid cavity, the inferior angle, and the vertebral border are still cartilaginous.

Secondary Centre.	Appears at	Epiphysis fuses at	Relation of Epiphyseal line to Capsule of Neighbouring Joint.
For coracoid process (proper)	1st year	Puberty	None.
Subcoracoid, for lateral part of root of coracoid and upper third of glenoid cavity	10th year	Puberty	Partly outside, partly inside.
For margins of glenoid cavity	Puberty	20-25	Inside.
For inferior angle	Puberty	20-25	None.
For vertebral border	Puberty	20-25	None.
Two for acromion	Puberty	20-25	Outside.

Occasionally the epiphysis formed from the two acromial centres fails to fuse with the rest of the bone, and the greater part of *the acromion is* **throughout life a separable bone** united to the rest of the bone by periosteum and a strip of cartilage or by a diarthrodial joint, which appears like a line of fracture in an X-ray photograph; the condition is usually alike on the two sides. Sometimes one or two additional centres appear after puberty on the surface of the coracoid process and form small scaly epiphyses which join about the twentieth year.

Structure and Variations.—Two plates of compact bone separated by spongy tissue in the thicker parts and fused together in the thinner parts. In old people the bone may be absorbed in parts, but the periosteum remains. The coracoid process may be separate, but much more seldom than the acromion. In an infant the scapula is relatively wide.

Clavicula.

The **clavicle** is an elongated, slender curved bone which lies nearly horizontally in front of the upper part of the thorax at the root of the neck, stretching from the upper end of the sternum or breastbone to the acromion of the scapula; it can be felt through the skin from end to end [*clavicula*, diminutive of *clavis* = a key, or of *clavus* = nail or bolt]. It is a long bone and has a shaft or **body** and **two ends**. The **lateral third** of the bone is flattened from above downwards, and therefore the *lateral end* can be distinguished from the *medial end* at once; the lower surface of the lateral third is rougher than the upper surface, and therefore one can determine at a glance which is the *upper surface* and which is the *lower*. The bone as a whole has a double curve like the *italic* letter *f*: the **medial half or two-thirds** of the bone is convex forwards, as may be felt and seen in the living person, and the lateral half or third is concave forwards; the *anterior* and *posterior aspects* of the bone are therefore easily identified.

The **lateral** or **acromial extremity** of the clavicle articulates with the medial margin of the acromion and is occupied by an oval *articular facet*. The margins of the facet are often raised or "lipped," and the ridge at the upper margin may assist one in locating the acromio-clavicular joint in the living person. Its articulation with the acromion is not direct, for an *articular disc* of fibro-cartilage intervenes between the two bones. The articular surface slopes downwards and medially, so that when the bones are dislocated the clavicle overrides the acromion, and is difficult to keep in place once dislocated.

The **medial** or **sternal extremity** is thick. It articulates with the clavicular notch on the upper end of the sternum and with the cartilage of the first rib at the side of the sternum, and the joint is called the *sterno-clavicular joint.* The end of the clavicle is larger than the clavicular notch on the sternum and its upper part can be felt above the level of the sternum; the *articular facet* occupies the lower three-fourths of the end of the clavicle, but it curves also on to the inferior aspect for articulation with the first costal cartilage. In some clavicles the facet has been destroyed during maceration. The articulation with the sternum is not direct, for an *articular disc* separates the clavicle from actual contact with the sternum, though not from the first costal cartilage.

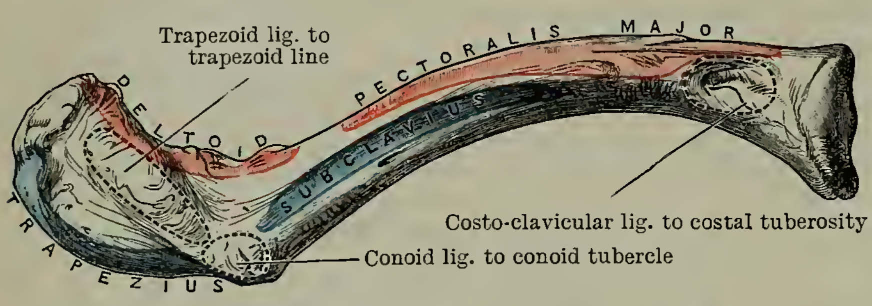

Trapezoid lig. to trapezoid line
PECTORALIS MAJOR
DELTOID
SUBCLAVIUS
TRAPEZIUS
Costo-clavicular lig. to costal tuberosity
Conoid lig. to conoid tubercle

Fig. 193.—Lower Surface of Right Clavicle.

The *anterior* aspect is that on which deltoid and pectoralis major are marked; the medial extremity is the end directed towards the right-hand side of the page.

The **body** of the clavicle is divided, for descriptive purposes, into a lateral third and a medial two-thirds.

The **lateral third** has two surfaces—upper and lower, and two borders—anterior and posterior. The **anterior border** is rough and concave; the **posterior border** is smooth and convex. The **superior surface** is subcutaneous and is usually smooth, but may be rough near the borders, because the muscles attached to the borders sometimes extend their attachments on to the surface. The **inferior surface** is rough. At the posterior border there is a blunt rounded prominence called the **conoid tubercle**; a broad rough ridge, called the **trapezoid ridge**, extends from the tubercle towards the lateral extremity of the clavicle; the tubercle and the ridge, together, form what is called the **coracoid tuberosity**. The lateral third of the clavicle lies above the coracoid process of the scapula, and is attached to it by a strong, important band called the coraco-clavicular ligament, which consists of two parts named from their shape, *conoid* and *trapezoid*, and they give the names to the tubercle and the ridge to which they are attached.

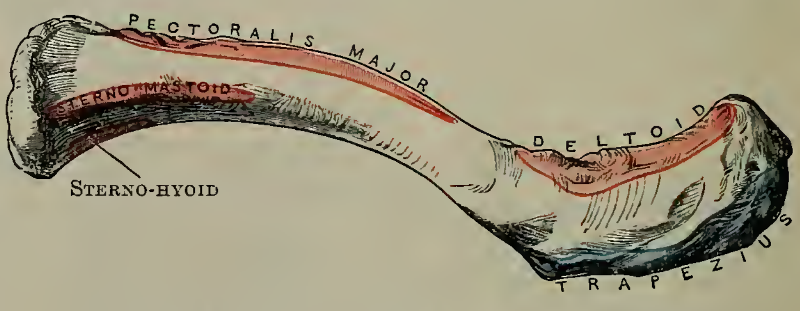


Fig. 194.—Upper Surface of Right Clavicle

The **medial two-thirds** of the clavicle has four surfaces—anterior, posterior, superior, and inferior; they are separated by borders to which it is not necessary to give names.

The **anterior surface** is the convex surface; laterally it narrows down to become continuous with the anterior border of the lateral third. Nearly all of it is occupied by an impression for the origin of part of a large muscle called the *pectoralis major.* The **posterior surface** is the concave surface; it is smooth and is continuous with the posterior border of the lateral third. The **upper surface** is continuous with the upper surface of the lateral third, and is usually smooth and flat. It may be so narrow that it is a mere ridge, or it may be blended with the anterior surface.

Close to the medial end of the **lower surface** there is a rough mark of variable size and character; it may be an elevation or it may be a depression; it is called the **costal tuberosity** because it gives attachment to a strong fibrous band, called the *costo-clavicular ligament*, which binds the clavicle to the first rib. The lateral part of the lower surface of the medial two-thirds is occupied by a shallow furrow, called the **subclavian groove**, which extends as far as the trapezoid ridge. The rest of the surface may be of appreciable width, but in many clavicles it is narrowed down to a mere border.

The **nutrient foramen** is situated on the posterior aspect near the junction of the lateral third with the medial two-thirds, and it is directed towards the lateral end.

The clavicle varies a great deal in different people, and the beginner may have difficulty in identifying the surfaces of the medial two-thirds if he is using a poorly developed bone as a specimen for study.

Attachments.—The capsule of the acromio-clavicular joint is attached to the margins of the *facet* on the **lateral extremity.** Part of the trapezius is inserted into the *posterior border* of the **lateral third**; part of the deltoid arises from the *anterior border*, and the small rough tubercle occasionally present on that border is called the **deltoid tubercle**; the conoid and trapezoid ligaments (*i.e.* the two parts of the coraco-clavicular ligament) are attached to the **conoid tubercle** and the **trapezoid line.**

The capsule of the sterno-clavicular joint is attached to the margins of the *facet* at the **medial extremity**; the capsule, the articular disc and the interclavicular ligament are attached to the rough *area above the facet.* The costo-clavicular ligament is attached to the **costal tuberosity.** The subclavius muscle is inserted into the **subclavian groove,** and the costo-coracoid membrane, which splits to enclose the subclavius, is attached to the *margins of the groove.* Part of the pectoralis major muscle arises from the *anterior surface* of the **medial two-thirds.** Part of the sterno-mastoid muscle arises from the *upper surface* of the medial third. Fibres of the sterno-thyreoid and sterno-hyoid muscles arise from the *posterior surface* near the medial extremity.

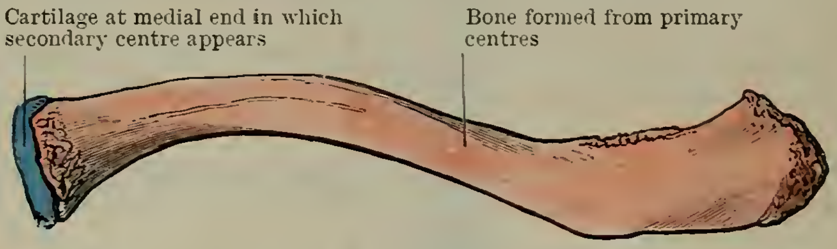

Cartilage at medial end in which secondary centre appears
Bone formed from primary centres

Fig. 195.—Ossification of the Clavicle.

Ossification.—The clavicle is the first bone in the body to begin to ossify. Two **primary** centres appear in the fifth week of fœtal life; they soon coalesce, and from them almost the whole bone is ossified.

Secondary Centre.	Appears at	Epiphysis fuses at	Epiphyseal Line is inside
For medial end	20th year	25	Capsule of sterno-clavicular joint.

Structure and Variations.—The clavicle, though a long bone, has no medullary cavity. It consists of spongy tissue surrounded by a shell of compact bone which is thickest in the middle.

The clavicle in women is shorter and more slender than in men, and the curvatures are less marked; its acromial end is at a lower level than the sternal end, while in men the ends are at the same level or the acromial end is the higher. Occasionally the clavicle is perforated by one of the supraclavicular nerves. In rare cases the clavicle is incompletely developed or is absent. Cases have been recorded recently in which (*a*) the medial end of the clavicle was freely movable (*Anat. Record*, Vol. xvi.), and (*b*) there was bifurcation of the lateral part of the clavicle (*Jour. Anat.*, July 1921).

Humerus.

The **humerus** is the bone of the upper arm; its length is about one-fifth of the height of the person; though nearly all thickly covered with muscles it can be felt by deep palpation in all its length. It is a long bone, possessing a shaft or **body** and **two ends.**

It is necessary first to distinguish the ends and ascertain the general direction of its surfaces. The **proximal** or upper end is the thick, rounded end, while the distal end is compressed from before backwards; there is a wide, deep hollow on the **posterior** aspect of the distal end; the smooth hemispherical part of the proximal end looks in a **medial** direction.

The **proximal end** includes the head, the anatomical neck, the greater tubercle, the lesser tubercle, and part of the inter-tubercular sulcus.

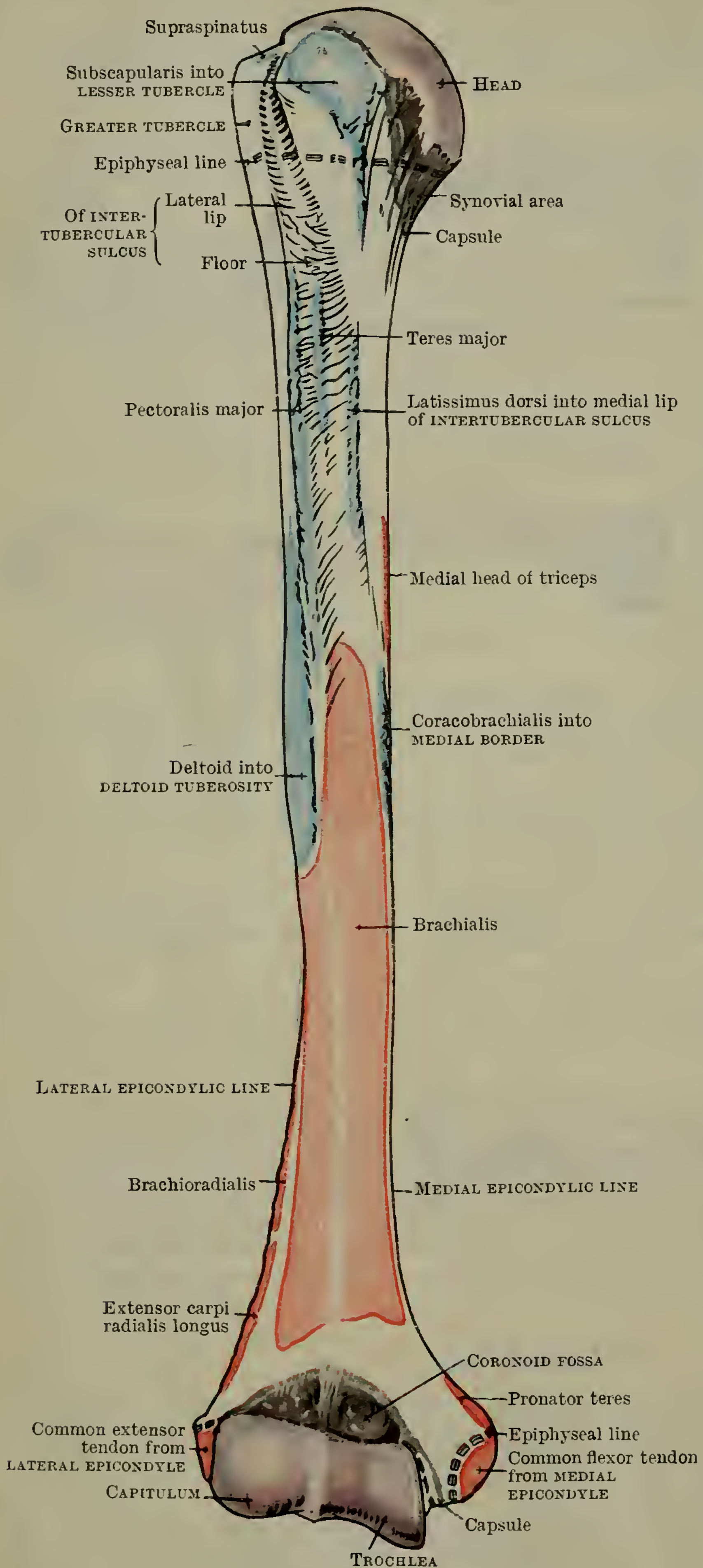

Supraspinatus
Subscapularis into LESSER TUBERCLE
GREATER TUBERCLE
Epiphyseal line
Of INTER-TUBERCULAR SULCUS
Lateral lip
Floor
HEAD
Synovial area
Capsule
Teres major
Pectoralis major
Latissimus dorsi into medial lip of INTERTUBERCULAR SULCUS
Medial head of triceps
Coracobrachialis into MEDIAL BORDER
Deltoid into DELTOID TUBEROSITY
Brachialis
LATERAL EPICONDYLIC LINE
Brachioradialis
MEDIAL EPICONDYLIC LINE
Extensor carpi radialis longus
CORONOID FOSSA
Pronator teres
Epiphyseal line
Common extensor tendon from LATERAL EPICONDYLE
Common flexor tendon from MEDIAL EPICONDYLE
CAPITULUM
Capsule
TROCHLEA

FIG. 196.—FRONT OF RIGHT HUMERUS.

The **head** is the large, convex, smooth articular part which is directed not only medially but also upwards, and, when the arm is hanging naturally by the side, it looks backwards as well. It articulates with the glenoid cavity of the scapula; and it may be indistinctly felt by the fingers pushed well up into the axilla.

The **lesser tubercle** is the well-marked prominence on the anterior surface of the proximal end; the part of it nearest the head has an impression, usually smooth, for the insertion of the tendon of the subscapularis. The lesser tubercle can be felt in the front of the shoulder just lateral to the coracoid process (and may be mistaken for it) when the arm is hanging comfortably by the side, but at a little distance from that process when the limb is rotated so that the palm of the hand looks forwards.

The **greater tubercle** is the prominence on the lateral aspect of the proximal end. Though larger than the lesser tubercle it is not so clearly defined, for its lateral surface shades off into the lateral aspect of the body of the bone. Its upper surface or border and its posterior surface have smooth impressions for the insertion of certain muscles. The greater tubercle forms the "point of the shoulder," *i.e.*, its most projecting lateral part, and may be felt there a little below the lateral margin of the acromion.

The **intertubercular sulcus** is the clean-cut groove between the two tubercles, and it is prolonged for two inches or more on to the body, where it is not so sharply defined. The tendon of the long head of the biceps, after it emerges from the shoulder joint, lies in the groove.

The **anatomical neck** is the narrow strip that encircles the margins of the head; its upper part is the narrow and shallow depression between the head and the tubercles.

Collum Chirurgicum.—The **surgical neck** is the region immediately distal to the head and tubercles where the proximal end and the body join. It does not have sharp limits, and may be reckoned as about a finger's breadth in extent all round the bone. The name is given because the bone is often fractured there.

The **distal end** includes the capitulum, the trochlea, the radial, coronoid and olecranon fossæ, and the lateral and medial epicondyles.

The **capitulum** is the smooth, rounded knob placed near the lateral part of the distal end. It is situated partly on the front and partly on the distal aspect, but not at all on the back. It articulates with the head of the radius.

The **radial fossa** is the shallow depression immediately above the capitulum; the margin of the head of the radius comes into close relation with it when the forearm is fully bent.

The **trochlea** is the wide, smooth, pulley-shaped surface at the medial side of the capitulum [τροχιλία (trochilia) = the sheave of a pulley]. It is situated both on the front and back and distal aspect, and its medial lip stands out as a prominent rim. It articulates with the wide semilunar notch, on the front of the proximal end of the ulna.

The **coronoid fossa** is the depression on the anterior aspect just above the trochlea. It is related to the coronoid process of the ulna when the forearm is fully flexed.

The **olecranon fossa** is the large depression in a corresponding position on the back; the olecranon of the ulna fits into it when the forearm is straightened out. The bony substance between the coronoid and olecranon fossæ is very thin.

The **medial epicondyle** is the prominent projection on the medial side of the distal end. It is easily felt at the medial side of the elbow and can be gripped between finger and thumb. Its anterior surface has impressions on it for the origin of muscles; its posterior surface is smooth and has a shallow groove which lodges the *ulnar nerve* as it passes from the arm to the forearm; the nerve can be felt and rolled between the finger and the bone.

The line or ridge (often poorly marked) which extends from the epicondyle on to the body of the bone for two or three inches is called the **medial epicondylic line.**

The **lateral epicondyle** is the projection on the lateral side of the distal end; it is not nearly so prominent as the medial epicondyle. Its anterior surface is small and is occupied by an impression for the origin of muscles. Its posterior surface is broad and smooth and subcutaneous; it can be felt on the back of the arm just above the lateral part of the elbow joint, that part of the joint being recognisable as a transverse depression.

The strong ridge which extends on to the shaft from the lateral epicondyle is called the **lateral epicondylic line**; it is easily felt when the elbow joint is in the bent position and the muscles are relaxed.

When the upper limb hangs comfortably by the side with the palm looking towards the thigh, the arm is then rotated so that the lateral epicondyle is felt on the antero-lateral aspect of the limb, and the medial epicondyle on the postero-medial aspect.

Corpus Humeri.—The **body** or **shaft** of the humerus is more or less cylindrical in its proximal half, but is rather compressed from before backwards in its distal part; it is described as having three borders and three surfaces. The **borders** are anterior, medial, and lateral; the **surfaces** are posterior, antero-lateral, and antero-medial.

The **anterior border** begins at the anterior margin of the greater tubercle, runs along the front of the bone, and ends near the radial and coronoid fossæ; its proximal third is the lateral margin or lip of the intertubercular groove.

The **medial border** begins at the lesser tubercle and ends at the medial epicondyle. It is not nearly so well marked as the anterior border. Its proximal third is the medial lip of the intertubercular sulcus; its distal third is the medial epicondylic line; in bones in which muscular markings are well seen its middle part is roughened for the insertion of a muscle called coraco-brachialis.

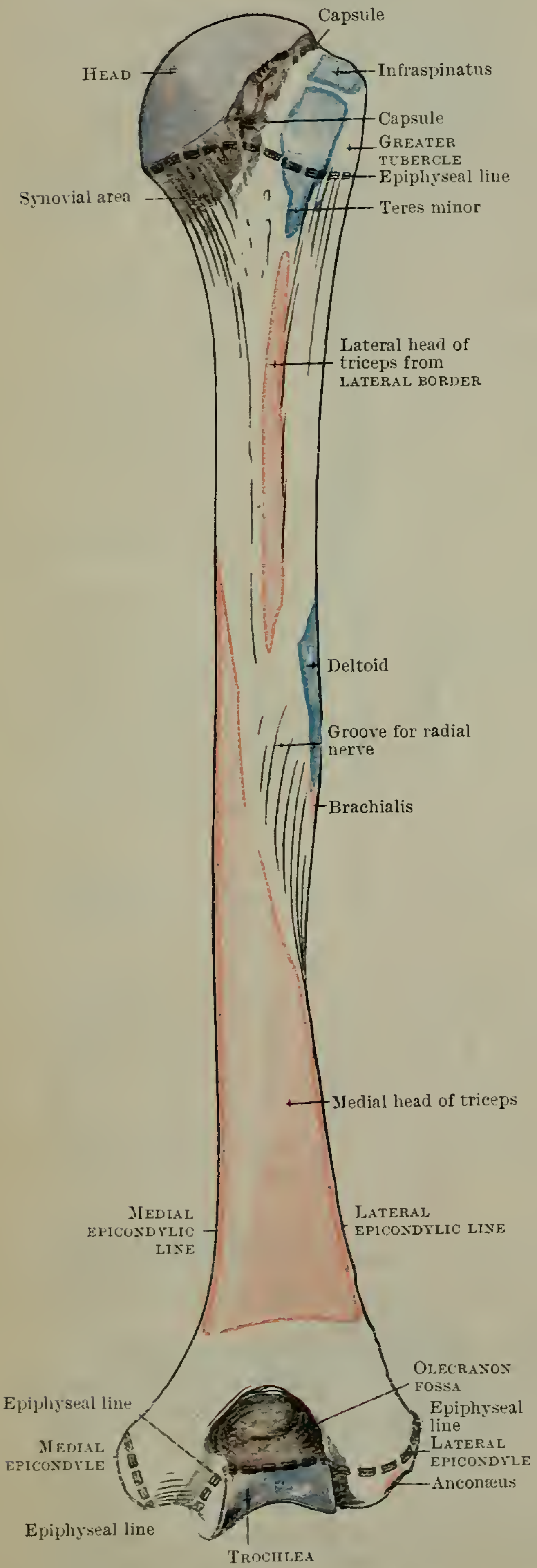


FIG. 197.—BACK OF RIGHT HUMERUS.

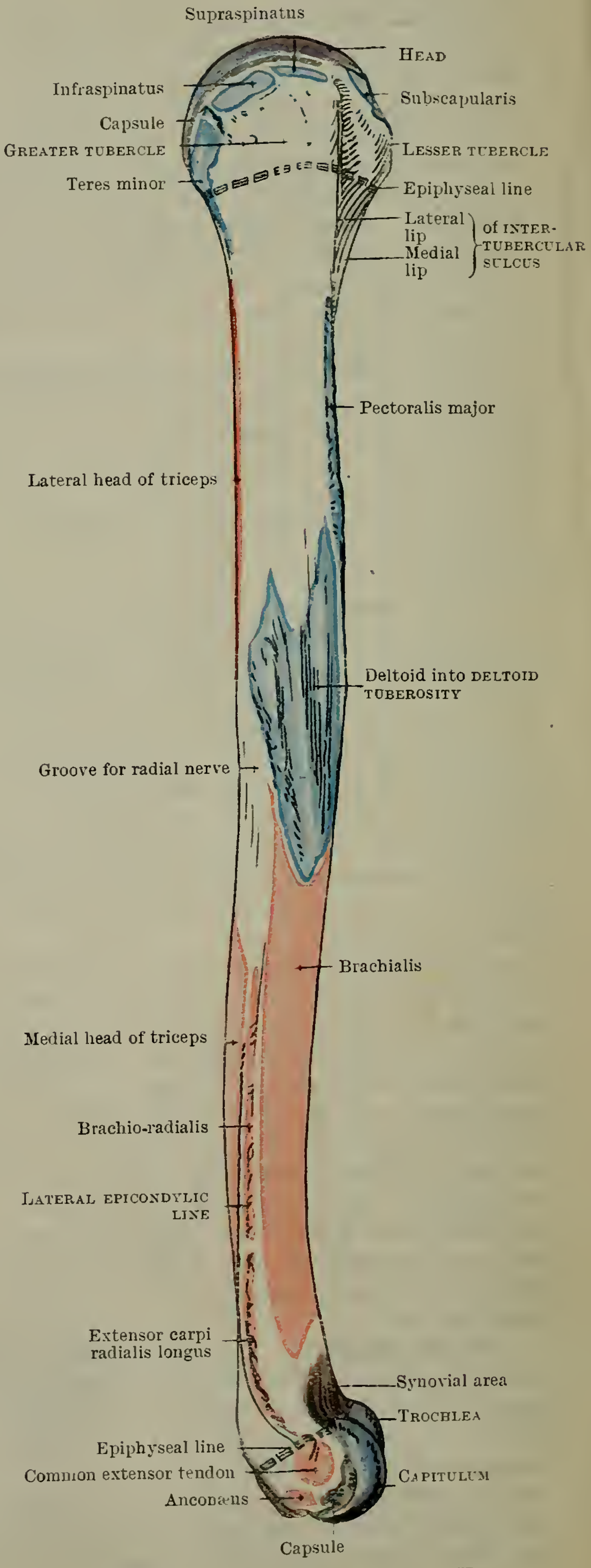


FIG. 198.—LATERAL ASPECT OF RIGHT HUMERUS.

The **lateral border** begins at the posterior surface of the greater tubercle and ends at the lateral epicondyle. Its distal third is the lateral epicondylic line; its proximal third is an indistinct ridge which descends from the back of the greater tubercle; it is interrupted in its middle third by a broad shallow groove which extends obliquely across it. The groove begins on the back of the bone and is directed downwards and forwards on to the front; the radial nerve, winding round the humerus, lies in it along its posterior or distal margin, and it is named accordingly the **groove for the radial nerve.**

The **posterior surface** is the area between the lateral and medial borders.

The **antero-lateral surface** is the area between the anterior and lateral borders. Its proximal part is continuous with the lateral surface of the greater tubercle. About its middle it is occupied by a rough, V-shaped mark called the **deltoid tuberosity,** so named because the deltoid muscle is inserted into it. The anterior margin of the V is part of the anterior border of the humerus, and its posterior margin is one of the boundaries of the groove for the radial nerve, for that groove is just behind and distal to the tuberosity. The tuberosity can usually be made out in the living person by deep pressure on the middle of the lateral aspect of the arm.

The **antero-medial surface** is the area between the anterior and medial borders. Its proximal part is narrow, for it is merely the floor of that part of the intertubercular groove which extends on to the shaft.

The distal halves of the antero-lateral and antero-medial surfaces are often spoken of together as the distal half of the anterior aspect of the humerus, in order to simplify the description of the brachialis muscle, which arises from the whole of that region.

The principal **nutrient foramen** is almost always situated just in front of the medial border, not far from its middle, and is directed towards the distal end. Sometimes it is in the proximal part of the groove for the radial nerve; and there may be a foramen in both places.

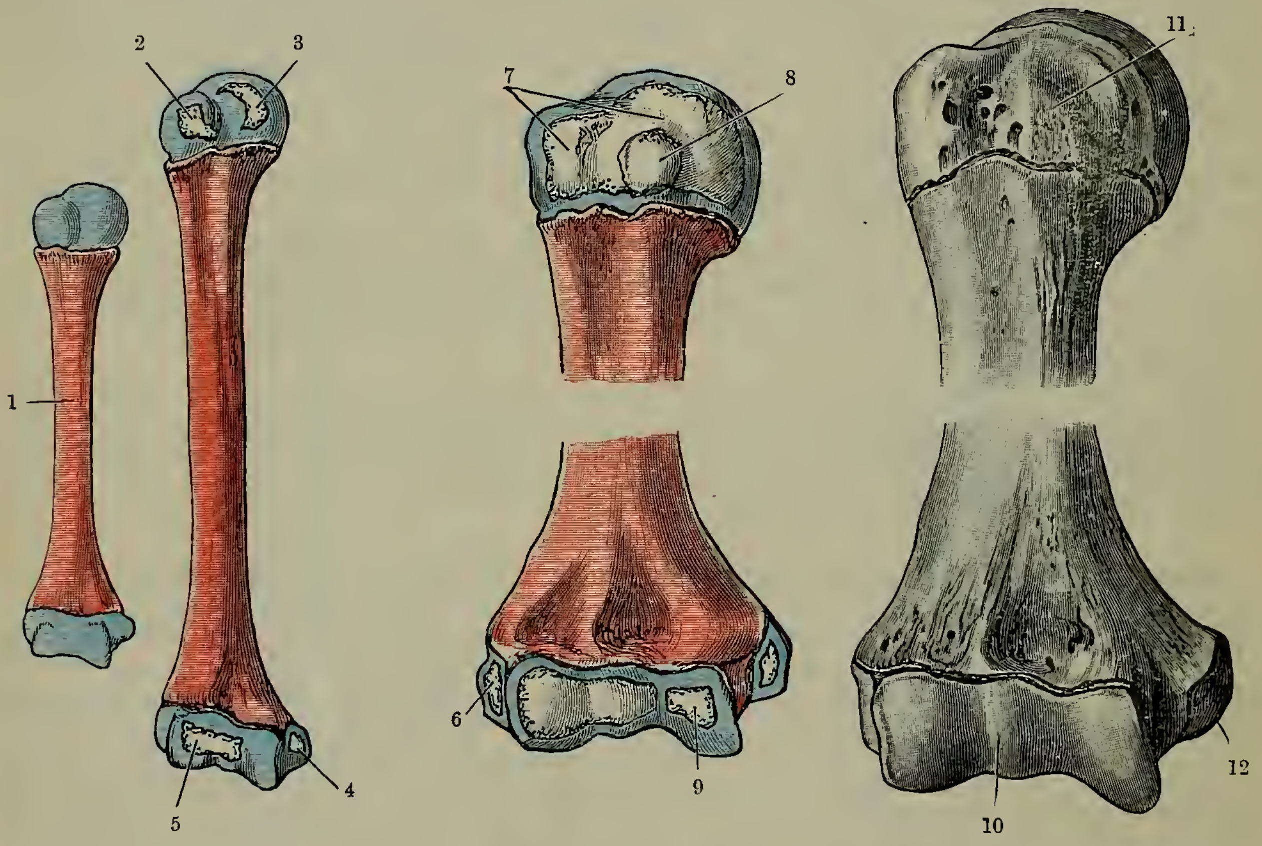
Attachments.—The capsule of the shoulder joint is attached to the **anatomical neck** above and in front and behind, but is attached to the bone nearly a finger's breadth below the head on the medial side, so that the medial part of the bone, just below the head, is covered with synovial membrane; the coraco-humeral ligament is attached to the anatomical neck at the anterior and upper part of the greater tubercle. The supraspinatus is inserted into the anterior impression on the top of the **greater tubercle**, the infraspinatus into the impression behind that, the teres minor into the impression on the back and into a strip below that for half an inch; the subscapularis into the **lesser tubercle** and into the surface below for half an inch. The transverse ligament of the humerus is attached to *both tubercles* and bridges across the proximal end of the **intertubercular groove**, holding the tendon of the long head of the biceps in place; further down, on the shaft, the pectoralis major is inserted into the *lateral lip* of the groove, the teres major into the *medial lip*, and the latissimus dorsi into *its floor*; the tendon of the long head of the biceps lies in the groove, enclosed in a sheath of synovial membrane, which is prolonged from the synovial lining of the capsule of the shoulder joint and envelops the tendon and lines the groove; deep to that sheath a little artery, a branch of the anterior circumflex, runs upwards in the groove to the shoulder joint.

The common extensor tendon (the combined tendons of origin of the extensores carpi radialis brevis, digitorum communis, digiti quinti and carpi ulnaris) arises from the *front* of the **lateral epicondyle**; the radial collateral ligament is attached to its *distal margin*, while the tendon of the anconeus arises immediately behind the attachment of the ligament, leaving the large posterior surface smooth. The common flexor tendon (the combined tendons of origin of the flexores carpi radialis, palmaris longus, digitorum sublimis and carpi ulnaris) arises from the impressions on the lower part of the *front* of the **medial epicondyle**, the pronator teres from the flatter, upper part and adjoining lower end of the epicondylic line; the ulnar collateral ligament is attached to the *distal margin* of the epicondyle. The anterior ligament of the elbow joint is attached to the *proximal margins* of the **radial** and **coronoid** fossæ and to the front of the epicondyles near the capitulum and trochlea. The posterior ligament is attached to the *floor* of the **olecranon fossa**, to its margins on each side, and to the backs of the epicondyles close to the margins of the trochlea.

The deltoid is inserted into the **deltoid tuberosity**; the coraco-brachialis into the middle of the **medial border.** The medial intermuscular septum is attached to the *edge* of the **medial epicondylic line**; the lateral intermuscular septum to the *edge* of the **lateral epicondylic line**; the brachio-radialis arises from the proximal two-thirds of the *anterior aspect* of the lateral line, and the extensor carpi radialis longus from its distal third. The lateral head of the triceps arises from the *proximal third* of the **lateral border**; the medial head from the *whole width* of the **posterior surface** below the groove for the radial nerve; the brachialis from the distal half or two-thirds of the **anterior aspect** of the body of the humerus.

Ossification.—The primary centre appears at the eighth week of fœtal life. At birth only the ends are cartilaginous.

Secondary Centre	Appears at	Epiphysis fuses at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For head	1st year	20-25	Medial part inside, remainder outside.
For greater tubercle	3rd ,,		
For lesser tubercle	5th ,,		
For capitulum and lateral half of trochlea	3rd ,,	17	Lateral extremity outside, remainder inside.
For medial half of trochlea	12th ,,		
For lateral epicondyle	12th ,,		
For medial epicondyle	5th ,,	18	Outside.



At birth. About 5 years. About 12 years. About 16 years.

FIG. 199.—OSSIFICATION OF THE HUMERUS.

1. Body, from primary centre.
2. Centre for greater tubercle.
3. Centre for head.
4. Centre for medial epicondyle.
5. Centre for capitulum and lateral half of trochlea.
6. Centre for lateral epicondyle.
7. 8. Centres for head and tubercles coalesced.
9. Centre for medial half of trochlea.
10. =5, 6, and 9 coalesced.
11. Proximal epiphysis.
12. Epiphysis of medial epicondyle.

The centres for the head and the two tubercles coalesce in the seventh year to form one epiphysis. The centres for the capitulum, trochlea, and lateral epicondyle coalesce to form one epiphysis.

Structure and Variations.—The structure is that of a typical long bone; the walls of the medullary cavity are thickest just below the middle of the bone. In some cases, more often in lower races, the thin bone of the floor of the olecranon fossa is perforated. In rare cases a small projection is found about two inches above the medial epicondyle, with which it is connected by a fibrous band; the median nerve and brachial vessels, taking an unusual course, pass under cover of the band. The humerus normally appears twisted, so that while the articular surface at the proximal end looks mainly in a medial direction, the articular surfaces at the distal end look backwards and forwards; the twist is more marked in adults than in children and fœtuses, and in modern Europeans than in more primitive races or in prehistoric Europeans.

Ulna.

The **ulna** is the medial and longer bone of the forearm [from ὠλένη (ōlenē) = forearm or elbow]. It is easily felt on the back of the forearm in its whole length.

It is a long bone, about one-sixth of the body length, and has a **body** or shaft and **two extremities.**

The **proximal** end is the larger end, and has two large projections which give it a resemblance to a spanner and enable the beginner to pick the ulna out from among other bones. The wide, deep concavity between those two projections is directed **forwards.** The lateral aspect can be distinguished from the medial because the **lateral** border of the body is the sharpest and most outstanding of the three borders.

The **proximal end** includes the olecranon, the coronoid process, the semilunar notch, the radial notch, and the tuberosity of the ulna.

The **olecranon** is the larger of the two projections and is the most proximal part of the ulna [ὠλένη—see p. 230; κρανίον (cranion) = head]; it is the prominence felt at the back of the elbow, and is the part which rests on the table when one leans on the elbow. It is in line with the body of the bone, and though stout and strong it is sometimes broken off. It has proximal, anterior, and posterior surfaces, and lateral and medial borders or surfaces. The **posterior** surface is smooth and subcutaneous, and nearly triangular in outline with the apex pointing downwards. The **anterior** surface is smooth and coated with articular cartilage. The **proximal** surface is the very end of the bone, and the tendon of the triceps muscle is inserted into its posterior part. The **lateral** and **medial** borders are thick, and are rough for the attachment of ligaments and muscles.

The **coronoid process** is the projection that juts forward from the proximal part of the shaft and has a fancied resemblance to the beak of a bird [κορώνη (corōnē) = a sea crow]. Its *proximal* surface is smooth and coated with articular cartilage; its volar or *anterior* surface is rough for the insertion of a muscle called brachialis; on its *medial* side there is a rounded tubercle for the attachment of part of the ulnar collateral ligament of the elbow joint; the tubercle can be felt about a thumb's breadth below the medial epicondyle of the humerus, and the ulnar nerve, as it passes into the forearm, can be felt and rolled over the tubercle by the finger.

The **radial notch** is the shallow, smooth hollow on the lateral surface of the coronoid process; it is coated with articular cartilage and articulates with the side of the head of the radius. Immediately distal to the notch, on the body of the bone, there is a rough, shallow hollow, triangular in outline with its base at the notch; it is named the *supinator fossa,* and its posterior margin, which is often a strong ridge, is named the *supinator crest,* for the supinator muscle arises from both.

The **semilunar notch** is the wide concavity between the coronoid process and the olecranon. The trochlea of the humerus fits into it; therefore both olecranon and coronoid process articulate with the trochlea, and their articular surfaces are the reverse of a pulley, being elevated in the middle and sloping to the sides. If the humerus and the ulna are placed together properly, the olecranon fits into the olecranon fossa when the bones are in line, *i.e.,* when the forearm is extended; and the coronoid process comes into relation with the coronoid fossa when the two bones make an acute angle, *i.e.,* when the forearm is fully flexed. Where the olecranon and the coronoid process join each other the semilunar notch has little rough patches at its sides; those patches may meet, forming a rough narrow strip across the notch, separating the front of the olecranon from the proximal surface of the coronoid process.

The **tuberosity** of the ulna is a rough mark at the distal end of the volar or anterior surface of the coronoid process, and is continuous with that surface; but it is on the body rather than on the proximal end of the ulna.

The **distal end** of the ulna is small, and includes the head and the styloid process.

The **head** is the larger, rounded part. It should be noted that in the ulna the part called the *head* is at the *distal* end. When the hand is held with the palm looking downwards, the head of the ulna can be seen as a knob on the back of the forearm just above the wrist on the ulnar side (that is, the side in line with the little finger). The *lateral* and *volar aspects* of the head are smooth and convex, and articulate with the distal end of the radius, the radius articulating with the lateral aspect when the limb is in the position in which the thumb is directed away from the body, and with the volar aspect when the thumb is directed medially. The *distal surface* of the head also is smooth; it articulates not with a bone but with a triangular plate of fibro-cartilage, called the *triangular articular disc*, which separates the head from the bones of the wrist.

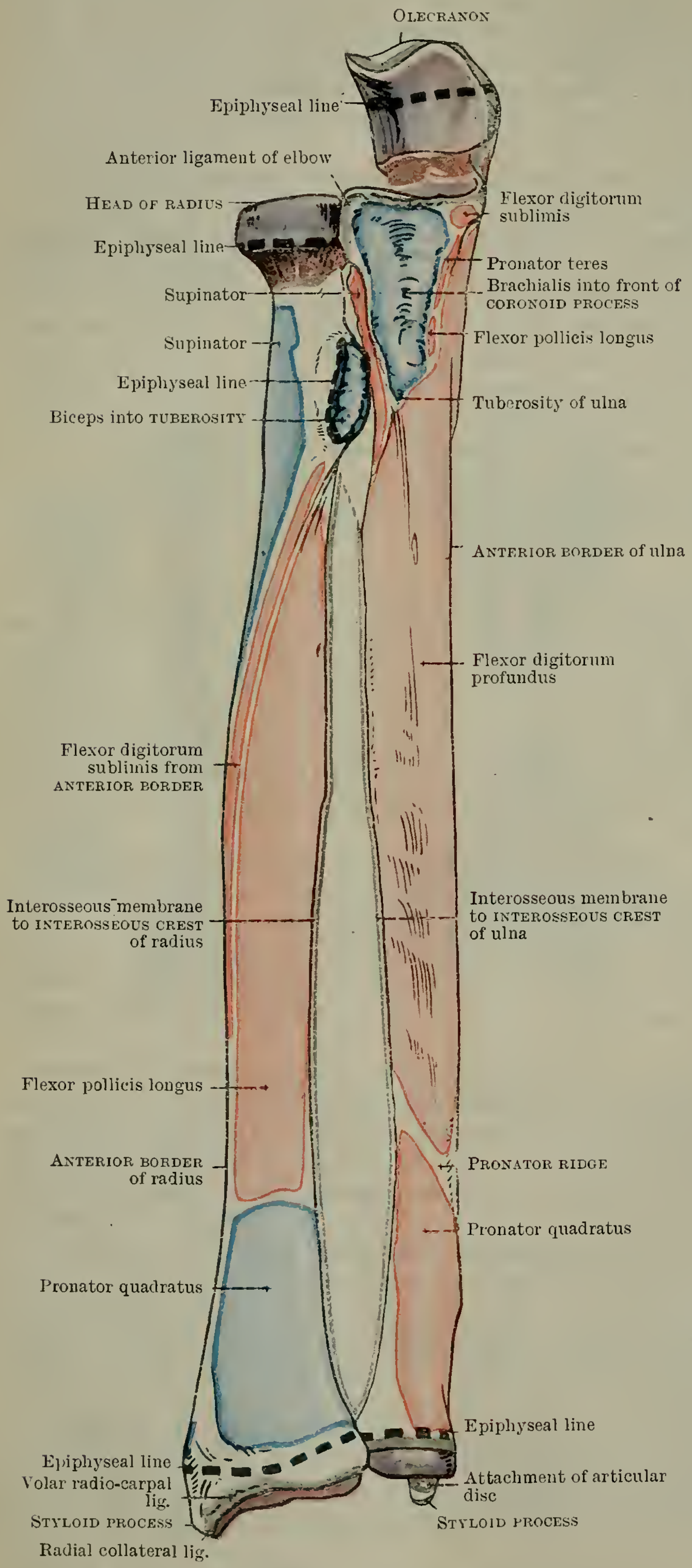


FIG. 200.—VOLAR SURFACE OF RIGHT RADIUS AND ULNA.

The **styloid process** is the small, conical projection that juts downwards towards the wrist from the postero-medial aspect of the distal end. Between the base of the styloid process and the distal surface of the head there is a small rough patch to which the apex of the articular disc is attached. On the *back of the bone*, between the styloid process and the head, there is a well-marked **groove** which lodges the tendon of a muscle called the *extensor carpi ulnaris*.

When the hand is in the position in which the palm looks towards the shoulder (the elbow being bent) the styloid process, along with the tendon of the extensor carpi ulnaris, can be felt as a ridge on the ulnar border of the back of the forearm, but the head of the ulna is scarcely palpable. When the hand is held palm downwards the head of the ulna appears as a round knob at the ulnar border of the back of the forearm, and the styloid process is then felt on the ulnar surface of the limb. The apparent differences in position are not due to movements of the ulna, but to movements of the radius called *supination* and *pronation* (p. 237).

Corpus Ulnæ.—The **body** or shaft of the ulna diminishes in thickness from above downwards. It has three **borders**, named volar, dorsal, and lateral, and three **surfaces**, named dorsal, volar, and medial.

The *volar* or **anterior border** is smooth and rounded. It begins at the tuberosity of the ulna and ends at or near the base of the styloid process.

The **dorsal border** begins at the distal angle of the back of the olecranon, extends sinuously along the body, and fades away near the distal end. It is felt as a sharp subcutaneous ridge on the back of the forearm.

The **lateral border** is a sharp, salient ridge. It begins at the distal angle of the supinator fossa, becomes very prominent in the middle of the bone, and fades away near the distal end. It is called also the **interosseous crest**, because a strong, wide, fibrous sheet, called the *interosseous membrane,* stretches across from it to the radius.

The *volar surface* or **anterior surface** lies between the volar margin and the interosseous crest; and the tuberosity of the ulna is situated at its proximal end. It is usually hollowed out longitudinally in its proximal two-thirds or more, and the distal end of the hollow is limited by an oblique ridge, called the *pronator ridge* because part of the pronator quadratus muscle arises from it.

The **dorsal surface** lies between the dorsal margin and the interosseous crest. In a well-marked bone an oblique ridge runs from the back of the radial notch to a point on the dorsal border about an inch below the distal end of the back of the olecranon. A muscle called the anconæus is inserted into the area above the ridge. Below the ridge a vertical line maps off a long, flat strip between itself and the dorsal border. The strip does not give attachment to any muscle, but the extensor carpi ulnaris lies upon it; nearly all the rest of the dorsal surface is mapped out by faint oblique ridges into areas for the origin of muscles.

The **medial surface** is the smooth, slightly convex surface between the volar and dorsal borders. Its proximal part is covered with muscle, but its distal third is subcutaneous and therefore easily felt.

The **nutrient foramen** is situated on the volar surface about the junction of the proximal and middle thirds, and is directed towards the proximal end.

Attachments.—The tendon of the triceps is inserted into the posterior part of the *proximal surface* of the **olecranon**, and the posterior ligament of the elbow joint is attached to the anterior edge of the surface, while a small *bursa* lies between them on the intervening part; the posterior ligament is attached also to the rough *lateral surface* or border, and the anconæus is inserted into that surface behind the ligament; the posterior band of the ulnar collateral ligament of the elbow joint is attached to the *medial surface* or border, and fibres of the flexor carpi ulnaris and of the flexor digitorum profundus arise from it behind the ligament.

The anterior band of the ulnar collateral ligament is attached to the *tubercle* on the *medial border* of the **coronoid process**, some fibres of the flexor digitorum sublimis arise from it, while slips of the pronator teres and flexor pollicis longus arise from the ridge which descends from the tubercle, and fibres of the flexor profundus from the hollow behind that ridge; the anterior ligament of the elbow joint is attached to the sharp *volar margin* of the process, and the brachialis is inserted into the *volar surface* and also into the **tuberosity** immediately below. The annular ligament which surrounds the head of the radius is attached to the *volar* and *dorsal margins* of the **radial notch**, and the ligamentum quadratum to its *distal margin*.

The capsule of the distal radio-ulnar joint is attached to the *front* and *back* of **head**, and a septum of the dorsal carpal ligament to the radial border of the **groove** on the back; the ulnar collateral ligament of the wrist to the tip of the **styloid process**, and the apex of the triangular articular disc to the small rough mark between its base and the head.

On the **body** or shaft, the chorda obliqua, as well as part of the brachialis, is attached to the **tuberosity.** The supinator arises from the **supinator crest** and **fossa.** The interosseous membrane is attached to the **interosseous crest**. The flexor carpi ulnaris arises by a wide aponeurosis from the proximal three-fourths of the *dorsal border*, besides having a small origin from the lateral surface of the olecranon. By means of the same aponeurosis part of the extensor carpi ulnaris arises from the middle third of the dorsal border. The anconæus is inserted into the proximal part of the *dorsal surface*; parts of the abductor pollicis longus, extensor pollicis longus, and extensor indicis proprius arise from the lateral part of the dorsal surface, in that order from above downwards. The pronator quadratus arises from the **pronator ridge** and the distal fourth of the *volar surface*, and the flexor digitorum profundus from the two-thirds or three-fourths of the *volar* and *medial surfaces*, extending up to the medial surfaces of the coronoid process and olecranon.

Ossification.—The **primary centre** appears at the eighth week of fœtal life, and from it the body, the coronoid process, and nearly the whole of the olecranon are ossified, though at birth a great part of the olecranon, as well as the distal end, is cartilaginous.

Secondary Centre.	Appears at	Epiphysis joins at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For distal end	6th year	21	Outside.
For top of olecranon	10th ,,	Puberty	Outside; anterior part sometimes inside.

Structure and Variations.—The structure resembles that of the humerus and other long bones. The medullary canal extends from the root of the coronoid process to the distal fifth of the bone. The weakest parts are at the junction of the olecranon and the coronoid process, and the junction of the middle and distal thirds of the shaft.

In rare cases the ulna is incompletely developed or is absent. In one recorded case the olecranon was a separate bone.

Radius.

The **radius** is shaped like the spoke of a wheel—hence its name. It is the lateral and shorter bone of the forearm, and can be felt in all its length, though deep pressure is necessary at its middle. It is a long bone with a **body** or shaft and **two ends.**

The **proximal** end is the smaller end. The distal end is a block of bone; it is slightly bent forwards, and its **anterior** or volar surface is broad, concave, and fairly smooth; from the **lateral side** of the distal end a short, thick, pointed process projects downwards.

The **proximal end** includes the head, the neck, and the tuberosity.

The **head** is a circular disc, cupped on its proximal surface, and that surface is smooth and articulates with the capitulum of the humerus. The circumference of the head is smooth; it articulates with the radial notch of the ulna and with the inner surface of a fibrous band, called the *annular ligament* of the radius, which encircles five-sixths of the head of the radius and is attached by its ends to the volar and dorsal margins of the radial notch of the ulna; the ligament and the notch, together, constitute a complete ring within which the head of the radius rotates during the movements of supination and pronation (p. 237). The head of the radius can be felt, through the ligament, on the back of the limb towards the lateral side, immediately distal to the lateral epicondyle of the humerus.

The **neck** is the cylindrical, slightly constricted part of the bone that supports the head.

The **tuberosity** of the radius is the broad, low prominence on the medial side, just distal to the neck. The tendon of the biceps is inserted into it.

When the humerus and radius are fitted together properly the proximal surface of the head of the radius articulates with the distal part of the capitulum of the humerus when the bones are in line; it comes into full articulation with the capitulum when they are at right angles; and its edge comes into relation with the radial fossa of the humerus in extreme flexion. The radius only touches the capitulum, while the semilunar notch of the ulna grips the trochlea; the ulna is therefore much the more important constituent of the elbow joint, and the stability of the joint depends on it, the radius offering no bar to dislocation. The grip of the ulna is least secure when the forearm is extended, *i.e.* in line with the arm; the ulna can then slip backwards off the humerus. But the olecranon is a positive bar to forward dislocation until the forearm is becoming acutely flexed.

The **distal end** of the radius has five surfaces and a styloid process. The surfaces are volar, dorsal, medial, lateral, and distal or carpal.

The *volar surface* or **anterior surface** is broad and slightly concave; at its distal margin there is a broad, rough ridge that can be felt on the front of the forearm about an inch above the ball of the thumb; it indicates the position of the distal epiphyseal line, and is also a guide to the position of the wrist joint, which is immediately distal to it.

The **dorsal surface** is more uneven, being occupied by grooves and ridges. The most prominent ridge is about the middle of the surface; it is called the **dorsal tubercle**, and can usually be felt in the living limb. On the lateral side of the tubercle there is a shallow groove, more than half an inch wide, on which two thick tendons lie; they are the tendons of the extensor carpi radialis longus and brevis muscles, and when the closed fist is bent slightly backwards they can be seen as they pass off the radius on to the back of the wrist. On the medial side of the tubercle there is a narrow, oblique, clean-cut groove for the tendon of the extensor pollicis longus, which can be seen reaching almost to the thumb nail when the thumb is outstretched. The rest of the dorsal surface, *i.e.* the part medial to the narrow groove, is a broad shallow groove which lodges the tendons of the extensor digitorum communis and extensor indicis proprius.

The **lateral surface** is less than half an inch wide; it is occupied by a shallow groove for the tendons of the abductor pollicis longus and extensor pollicis brevis, and is separated from the volar surface by a sharp ridge which is easily felt in the living limb.

The lateral part of the distal end of the radius is prolonged downwards as the short, thick **styloid process**. When the thumb is outstretched a hollow is seen on the radial side of the wrist, called by the French

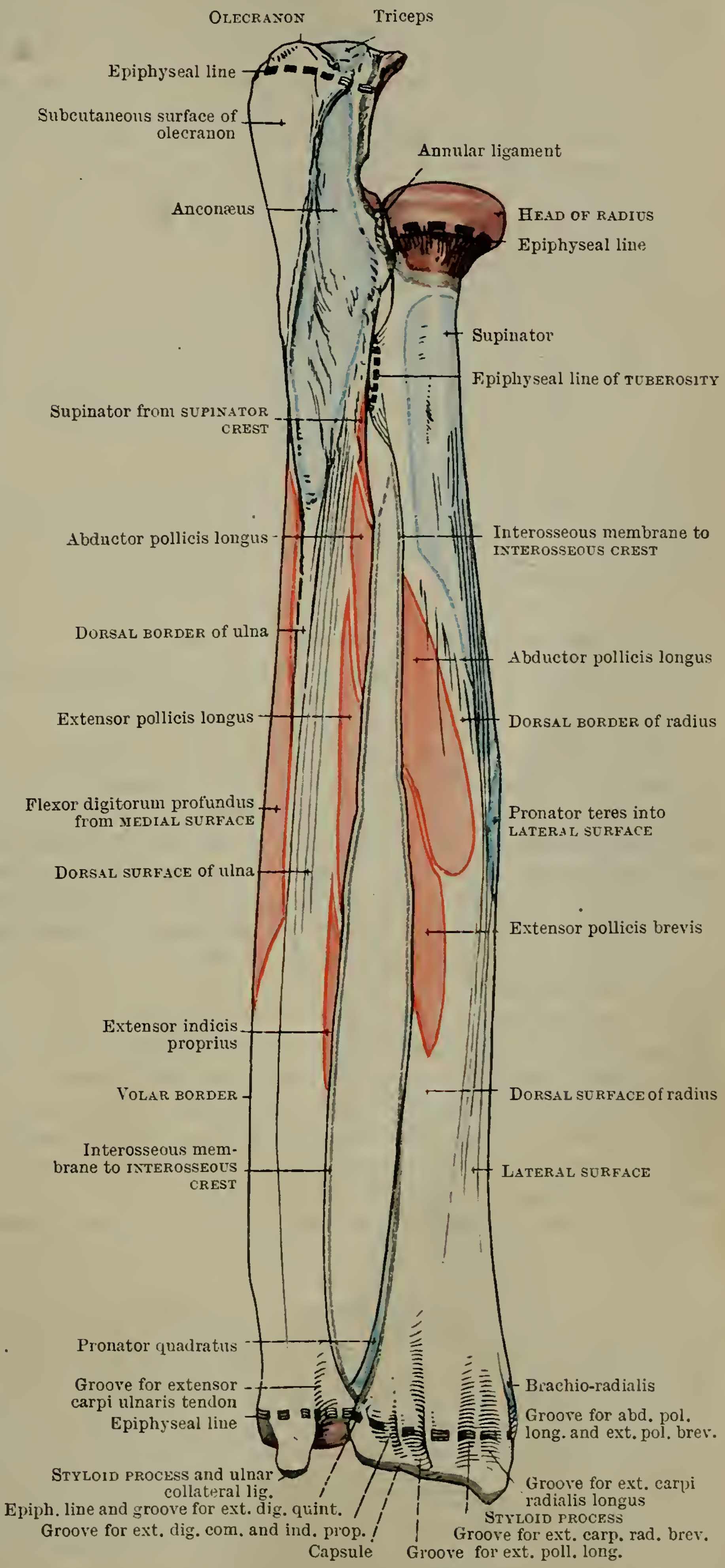

Olecranon
Triceps
Epiphyseal line
Subcutaneous surface of olecranon
Annular ligament
Anconæus
Head of radius
Epiphyseal line
Supinator
Epiphyseal line of tuberosity
Supinator from supinator crest
Abductor pollicis longus
Interosseous membrane to interosseous crest
Dorsal border of ulna
Abductor pollicis longus
Extensor pollicis longus
Dorsal border of radius
Flexor digitorum profundus from medial surface
Pronator teres into lateral surface
Dorsal surface of ulna
Extensor pollicis brevis
Extensor indicis proprius
Volar border
Dorsal surface of radius
Interosseous membrane to interosseous crest
Lateral surface
Pronator quadratus
Groove for extensor carpi ulnaris tendon
Brachio-radialis
Epiphyseal line
Groove for abd. pol. long. and ext. pol. brev.
Styloid process and ulnar collateral lig.
Groove for ext. carpi radialis longus
Epiph. line and groove for ext. dig. quint.
Styloid process
Groove for ext. dig. com. and ind. prop.
Groove for ext. carp. rad. brev.
Capsule
Groove for ext. poll. long.

FIG. 201.—DORSAL SURFACE OF RIGHT RADIUS AND ULNA.

the *anatomical snuff-box* (Tabatière anatomique); its dorsal boundary is the tendon of the extensor pollicis longus; its volar boundary is the tendons of the abductor pollicis longus and extensor pollicis brevis, which lie close together and make a ridge between the front of the wrist and its lateral surface; the styloid process is the bone felt in the proximal part of the floor of the hollow. Its position should be compared with that of the styloid process of the ulna; the radial styloid process is at a more distal level than that of the ulna; in the common variety of fracture of the distal end of the radius that relationship may be reversed.

The **medial surface** is small, concave, and smooth; it is sometimes called the **ulnar notch**, for it articulates with the head of the ulna and rotates round it during the rotatory movements of the forearm and hand (pronation and supination).

The *distal* or **carpal surface** is concave and smooth, and articulates with bones of the wrist or carpus. It is divided into two areas: a medial area nearly quadrilateral, and a lateral area nearly triangular, the apical part of which extends on to the styloid process. Between the carpal surface and the medial surface there is a sharp edge to which the base of the triangular articular disc is attached. The dorsal and lateral boundaries of the distal surface project downwards more than the others, and in a fall on the hand the dorsal and lateral part of the distal end is liable to be chipped off.

Corpus Radii.—The **body** or shaft of the radius increases in girth from above downwards, but is most often broken near the distal end; it has three borders and three surfaces. The **borders** are volar, dorsal, and medial; the **surfaces** are dorsal, volar, and lateral.

The **medial border** is the most definite and sharpest of the three, and it is called also the **interosseous crest**, because the interosseous membrane is attached to it. It begins near the tuberosity; towards its distal end it divides into two ridges which diverge slightly and become continuous with the margins of the ulnar notch.

The *volar* or **anterior border** begins at the tuberosity and ends at the ridge between the volar and lateral surfaces of the distal end of the bone. Its proximal part is well marked and oblique; its distal part is rounded and indistinct.

The **dorsal border** is most distinct in the middle third of the bone; the proximal part is an indistinct line stretching from the middle third obliquely towards the back of the tuberosity; the distal part is a smooth indistinct ridge which runs from the middle third to the dorsal tubercle on the distal end.

The **volar** and **dorsal surfaces** lie between the interosseous crest and the volar and dorsal margins.

The **lateral surface** lies between the volar and dorsal margins. It is roughened at its middle for the insertion of the pronator teres muscle. Its proximal part encroaches greatly on the volar and dorsal aspects of the bone owing to the obliquity of the proximal parts of the volar and dorsal margins; the distal part of the surface also encroaches on the dorsal aspect, and is continuous not only with the lateral surface of the distal end but also with the groove on the dorsal surface lateral to the dorsal tubercle.

The **nutrient foramen** is situated on the volar surface about the junction of its proximal and middle thirds, and it is directed towards the proximal end.

Attachments.—The distal margin of the annular ligament and the lateral margin of the lig. quadratum are attached round the **neck** *loosely*, so as not to interfere with the rotatory movements of the radius. The tendon of the biceps is inserted into the rough posterior part of the **tuberosity**, and is separated by a *bursa* from the smooth anterior part.

At the **distal end**, the volar ligament of the wrist joint (volar radio-carpal lig.) is attached to the distal margin of the *volar surface*; the radial collateral ligament to the **styloid process**; the dorsal ligament of the wrist joint to the distal edge of the *dorsal surface*; the capsule of the distal radio-ulnar joint to the volar and dorsal margins of the **ulnar notch**; the base of the triangular articular disc to the border between the notch and the *carpal surface*; the lateral end of the dorsal carpal ligament to the *sharp border* between the lateral and volar surfaces, and its septa to the ridges bounding the grooves on the *dorsal surface*; the tendon of the brachio-radialis is inserted into the proximal part of the *lateral surface*.

On the **body**, the chorda obliqua is attached to the bone just distal to the tuberosity; the interosseous membrane to the **interosseous crest** and to the more dorsal of the two ridges into which the distal end of the crest divides. Part of the flexor digitorum sublimis arises from the proximal half of the *volar margin*, and the flexor pollicis longus from the proximal three-fourths of the *volar surface*; the pronator quadratus is inserted into the distal fourth of the volar margin and volar surface, into the volar surface of the distal end, and into the narrow triangular area above the ulnar notch. The pronator teres is inserted into the rough mark on the middle of the *lateral surface*; the supinator into the proximal third, including its encroachments on the volar and dorsal aspects. Parts of the abductor pollicis longus and extensor pollicis brevis arise from the *dorsal surface*, the abductor just above the middle of the bone, and the extensor just below.

The radius is slightly curved so that it is convex in a medial direction in its proximal quarter, and in a lateral direction in the distal three-quarters; the biceps and the pronator teres are inserted into the maximum points of the curves, so that their value as supinator and pronator, respectively, is increased.

Ossification.—The **primary centre** appears at the eighth week of fœtal life. At birth only the distal end, the head, and the tuberosity are cartilaginous.

Secondary Centre.	Appears at	Epiphysis fuses at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For distal end	2nd year	21	Outside.
For head	6th ,,	Puberty–20	Inside.
For tuberosity	Puberty	Shortly after puberty	Outside.

Structure and Variations.—The medullary canal reaches the neck but does not reach the distal part of the body. The neck of the bone is the most slender part of the bone, but the commonest seat of fracture is near the distal end, for that part of the bone bears the impact of a fall on the hand. Absence of the radius has been recorded more than once, and in some of those cases the thumb also was absent.

Supination and Pronation.

The terms *supination* and *pronation* refer to position and movements of the forearm and hand, though in ordinary circumstances supination and pronation of the forearm are always supplemented by rotation of the upper arm.

The **supine position** is that in which the two bones of the forearm are parallel and the thumb is directed away from the side of the body (Fig. 109); in that position the palm of the hand looks forwards when the limb hangs by the side, upwards when the elbow is flexed to a right angle [*supinus* = lying on the back], and backwards when the elbow is acutely flexed.

The **prone position** is that in which the thumb is directed towards the side of the body, and the two bones of the forearm are crossed; the proximal end of the radius is still lateral to the ulna, but the radius is crossed in front of the ulna so that its distal end is on the medial side; the palm looks backwards or downwards or forwards according to the state of the elbow joint [*pronus* = inclined downwards, here referring to the palm when the elbow is flexed to a right angle].

When the upper limb hangs free and naturally by the side the palm of the hand looks towards the thigh as though the forearm were in a position midway between supination and pronation; but it is nearer the supine position than the prone; in the natural pendent position of the limb the whole limb is rotated in a medial direction at the shoulder joint, and that makes the forearm appear more prone than it really is; ready evidence of the rotation at the shoulder joint is afforded by the lateral epicondyle of the humerus; the epicondyle is felt, in that position, well round towards the front, instead of on the lateral aspect of the limb. When the forearm is brought into the position of complete supination, the medial rotation at the shoulder is at the same time undone, and the epicondyle is felt on the lateral aspect. The position of complete supination is, however, an unnatural one, and soon becomes uncomfortable; none the less, the structures are all described on the assumption that the limb is in the supine position, because, the radius and ulna being then parallel, the relations of all the other structures in the forearm can be more simply stated.

The **movement of supination** is the movement by which the forearm and hand are rotated from the position of pronation, or from the intermediate position, into the position of supination; and the **movement of pronation** is the reverse. The movement of supination is the stronger; and screws and screwing instruments are made so as to be manipulated by supination of the right forearm.

When the upper arm is rotated the forearm rotates with it, but in the movements of simple supination and pronation the ulna remains practically stationary. It is the radius that is moved, and the hand is moved with the radius. The head of the radius rotates within the ring composed of the annular ligament and the radial notch of the ulna, while the distal end of the radius rotates round the head of the ulna and carries the hand with it. The actual movements in the living limb are not only greatly supplemented by rotation of the humerus at the shoulder joint, but are also slightly added to by movement at the wrist joint and intercarpal joints.

Carpus.

The skeleton of the **carpus** or **wrist** consists of *eight* small bones closely held together by ligaments, and arranged in two rows—a proximal and a distal. From lateral to medial side, the names of those in the **proximal row** are: os naviculare, os lunatum, os triquetrum, os pisiforme; and in the **distal row**: os multangulum majus, os multangulum minus, os capitatum, os hamatum.

The **pisiform bone** is the hard knob at the medial border of the front of the wrist. It is rather loosely attached and can be moved slightly from side to side if the hand is held slack; the sinew which can be seen and felt descending to it, along the medial border of the forearm, is the tendon of the flexor carpi ulnaris muscle.

The **other bones** of the wrist are so tightly bound together that, until the ligaments are cut, they form **one compact mass** with *six* surfaces—volar, dorsal, medial, lateral, proximal, and distal. (See Fig. 283, p. 333.)

The *proximal surface* is smooth, convex, and elongated from side to side; it articulates with the radius and the articular disc to form the radio-carpal or wrist joint. The *distal surface* is uneven and elongated from side to side; it articulates with the bases of the five metacarpal bones to form the carpo-metacarpal joints. The *medial surface* is small, and can be felt on the medial side of the wrist. The *lateral surface* also is small; it is partly palpable in the "anatomical snuff-box," and is partly hidden by the tendons in the volar boundary of that hollow; an artery, called the radial artery, crosses it obliquely, under cover of those tendons.

The *dorsal surface* is large and rough; it is convex from side to side, and is to a large extent concealed by tendons. The *volar surface* is large, and is concave from side to side; the concavity is greatly deepened by, and, indeed, is largely owing to, the shape and position of the bones at the sides. On the medial side there is the prominence due to the pisiform bone, and, distal to that, a hook-like process projects forwards from the os hamatum [*hamatus* = hooked]. On the lateral side a tubercle on the navicular bone and a ridge on the os multangulum majus project forward. The deep concavity is called the **carpal groove**; it is bridged across and converted into a **carpal canal** or tunnel by a very strong fibrous band, called the *transverse carpal ligament*, which holds the tendons proceeding to the thumb and fingers in their place in the groove.

Those projections can all be felt in the living hand. The **pisiform bone** has been referred to already. The **hook of the os hamatum** can be felt if deep pressure is made by the thumb of the other hand on the ball of the little finger, *i.e.* the fleshy eminence on the medial side of the palm; the pressure should be made at a point 15-25 mm. from the pisiform bone and on a line drawn from the pisiform towards the centre of the palm. A nerve can often be felt slipping from side to side on the hook; that is the ulnar nerve as it enters the palm.

The **tubercle of the navicular bone** can always be felt and often is a visible projection. The guide to its position is a tendon. In the distal half of the front of the forearm, about midway from side to side, the tendons of the palmaris longus and the flexor carpi radialis can be seen, close together, extending to the wrist; the tendon of the flexor carpi radialis is the more lateral of the two, and sometimes, of the two, it alone is present. Where it passes out of sight at the wrist the tubercle of the navicular bone can be felt, partly under cover of the tendon and partly lateral to it, just proximal to the ball of the thumb.

The **ridge on the os multangulum majus** is not so easily felt. It is situated just distal to the tubercle of the navicular in the medial edge of the ball of the thumb, and pressure should be made there with the hand bent backwards; the bony resistance encountered there is the ridge; it may be felt as a prominence separate from the tubercle of the navicular, but the two often are felt as one continuous bony resistance.

If the student has a skeleton of the hand in which the carpal bones are strung or wired together he will be able to identify them from their position. If they are separate he may require the aid of a demonstrator, but should try himself to identify them by means of their chief characters, beginning with those that are more easily recognised.

The **pisiform bone** is the smallest of all. It resembles a large pea with a slice cut off [*pisum* = a pea].

The **os hamatum** has a large, compressed, curved process that juts forwards from its volar surface.

The **os capitatum** is usually the largest. Its proximal surface or end is smooth and rounded, resembling a head.

The **navicular** is one of the larger bones. It is somewhat comma-shaped, the tubercle being the bent, narrower end of the comma. Of its *articular* surfaces two are convex and one is concave in each direction, fitting the tip of a finger. The bone is called the "navicular" from a far-fetched resemblance to a boat given to it by that concave surface.

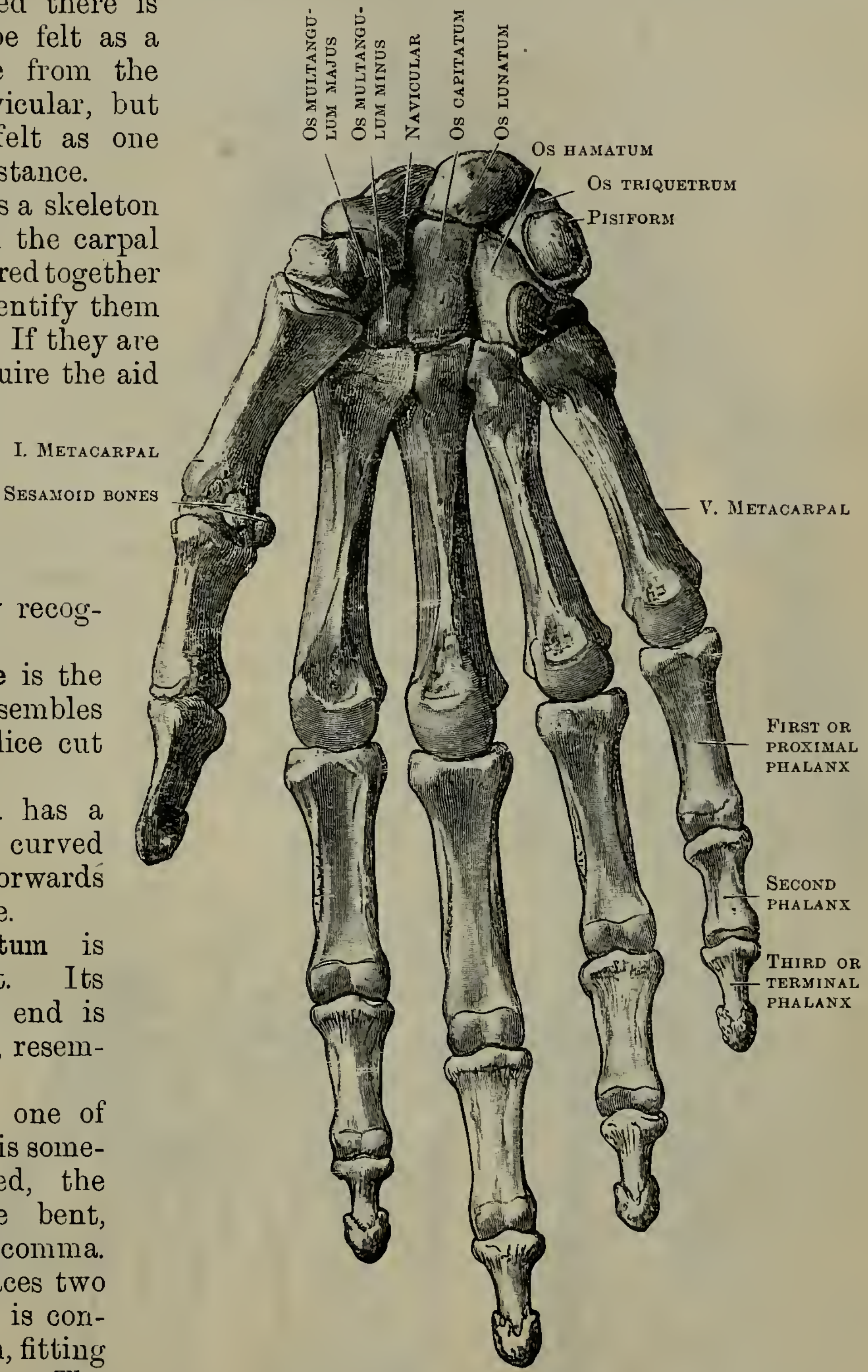


Fig. 202.—Volar Aspect of Bones of Right Hand.

The **os lunatum** is one of the smaller bones. Its distal surface is markedly concave in one direction and fits the tip of a finger. On another surface (the lateral) it has an articular facet, shaped like a crescent moon, which gives the bone its name.

The **os multangulum majus** is medium in size. One of its articular surfaces is saddle-shaped; one of its non-articular surfaces has the prominent ridge mentioned before, with a groove alongside the ridge.

The os triquetrum and the os multangulum minus are the only two left. The **os triquetrum** is more or less pyramidal in shape [*triquetrus* = three-cornered], and on one of its surfaces it has a circular, flat facet which occupies a great part of that surface but not the whole of it. The **os multangulum minus**, though very distinctive and very unlike the others, has no outstanding characters. It has four definite articular surfaces set almost at right angles to each other, and two non-articular surfaces, one of which is considerably larger than the other; when it is placed on that larger surface it has a fanciful resemblance to a Chinese boot.

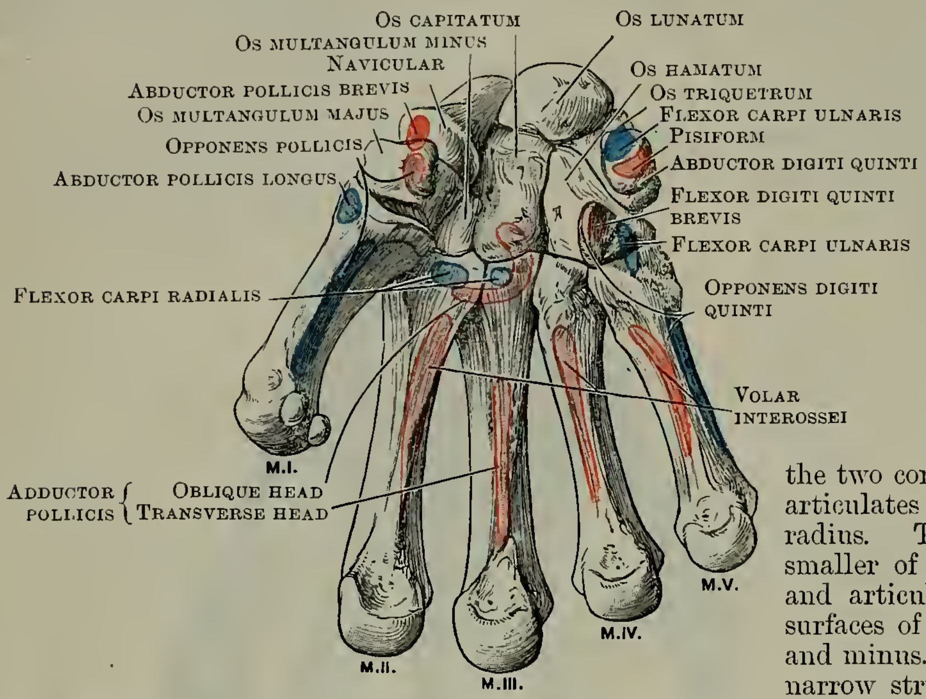


Fig. 203.—Volar Aspect of Bones of the Right Carpus and Metacarpus with Muscular Attachments mapped out.

Each of the carpal bones has six surfaces—proximal, distal, volar, dorsal, lateral, and medial.

Os Naviculare Manus.—The *proximal surface* is the larger of the two convex articular surfaces; it articulates with the distal end of the radius. The *distal surface* is the smaller of the two convex surfaces, and articulates with the proximal surfaces of the multangulum majus and minus. The *dorsal surface* is the narrow strip between the proximal and the distal surface, and is rough for the attachment of ligaments. The *medial surface* has a smooth area, concave in each direction, for articulation with the lateral surface of the head of the os capitatum, and above that there is a semilunar strip which articulates with the lateral surface of the os lunatum. The *lateral surface* is greatly reduced and is represented by the **tubercle.** The *volar surface* is concave in one direction and is the concave side of the comma; the concavity lodges the tendon of the flexor carpi radialis.

Os Lunatum.—The *distal surface* is the concave surface and articulates with the top of the head of the os capitatum. The *proximal surface*, directly opposite, is convex, and articulates with the distal end of the radius. The *lateral surface* is that which is shaped like a crescent moon, and it articulates with the navicular bone. The *medial surface*, directly opposite, is flat and nearly quadrilateral and articulates with the base or lateral surface of the os triquetrum. Between the medial and the distal surface there is usually a narrow strip which articulates with the upper edge of the os hamatum. The *volar* and *dorsal surfaces* give attachment to ligaments; the volar surface is convex and is larger and smoother than the dorsal surface.

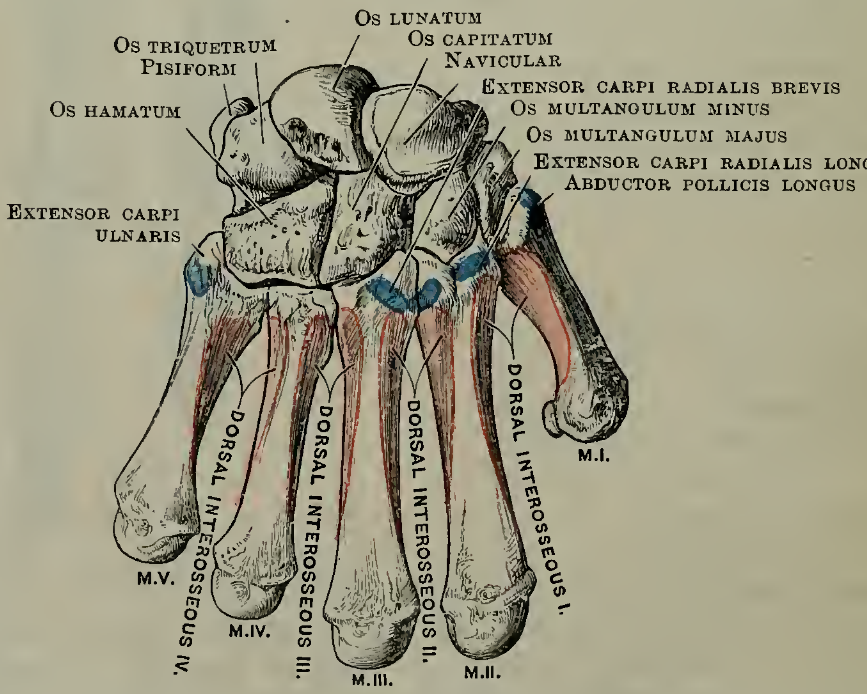


Fig. 204.—Dorsal Aspect of Bones of the Right Carpus and Metacarpus with Muscular Attachments mapped out.

Os Triquetrum.—The *volar surface* is nearly flat; its medial two-thirds is covered with a flat, circular facet which articulates with the pisiform bone. The *distal surface* is concavo-convex or undulating, and articulates with the medial surface of the os hamatum. The *lateral surface* is the base of the pyramid and articulates with the os lunatum. The *medial surface* is the blunted apex of the pyramid, and can be felt on the side of the wrist distal to the styloid process of the ulna and behind the pisiform bone. The *proximal* and *dorsal surfaces* are confluent, making one uneven convex surface ; its lateral part has a facet which articulates with the triangular articular disc.

Os Pisiforme.—The *dorsal surface* articulates with the os triquetrum. The other surfaces are confluent, and give attachment to muscles and ligaments.

Os Multangulum Majus.—The *distal surface* is saddle-shaped and articulates with the base of the first metacarpal bone. The *proximal surface* is the small, smooth, concave surface opposite ; it articulates with the navicular bone. The *medial surface* has a large facet which is separated by a smooth ridge from the proximal surface, and articulates with the lateral surface of the os multangulum minus ; lower down there is a small facet for articulation with the base of the second metacarpal bone. The *volar*, *dorsal*, and *lateral surfaces* are non-articular ; the volar surface has an upstanding ridge at the lateral margin, and along the medial side of the ridge there is a well-defined narrow groove which lodges the tendon of the flexor carpi radialis. The lateral surface is continuous with the lateral aspect of the ridge, and the dorsal surface is directly opposite the volar.

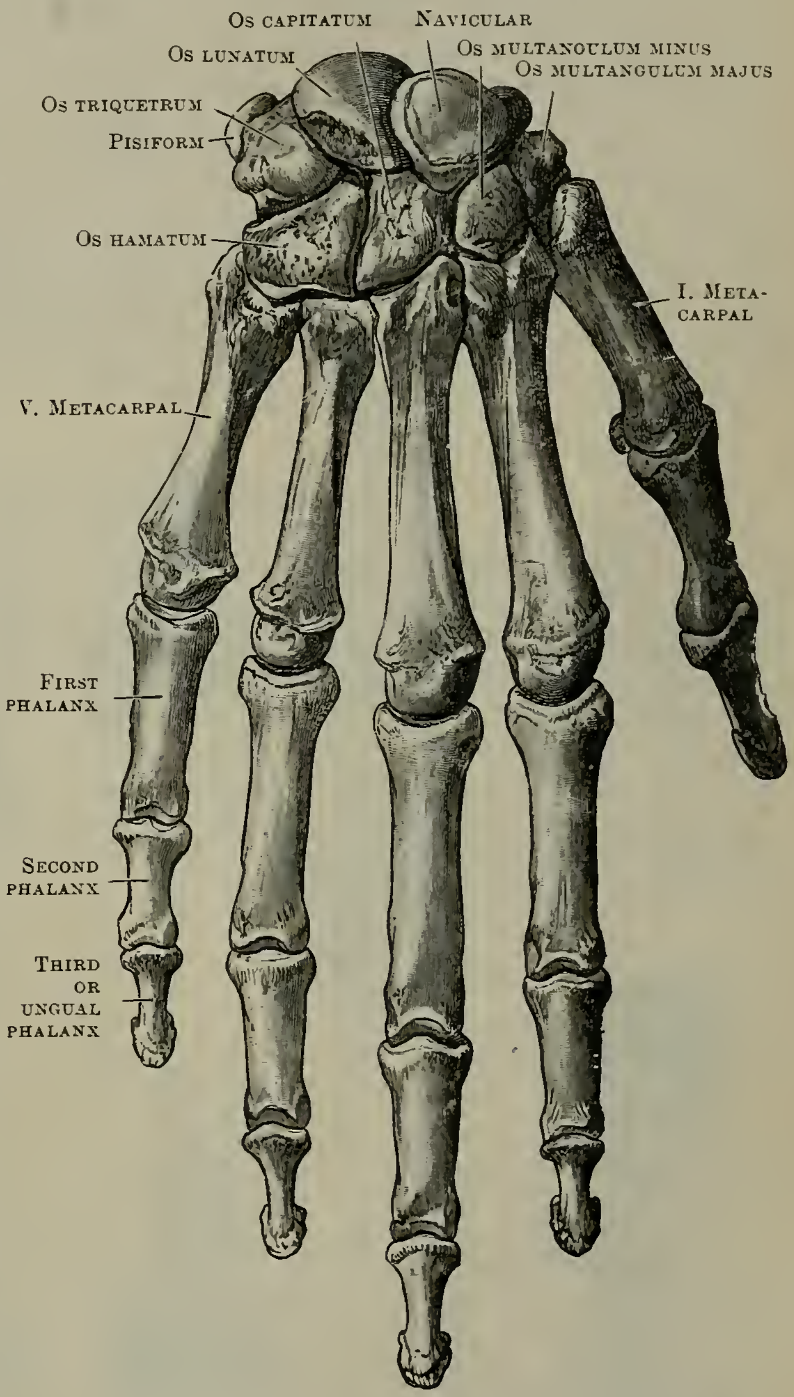


Fig. 205.—Dorsal Aspect of Bones of Right Hand.

Os Multangulum Minus.—Beginners find difficulty in identifying its surfaces. The *dorsal* and *volar surfaces* are both non-articular ; the volar surface is much the smaller. The other four surfaces are articular. The *distal surface* is the largest of those four ; it is concave from before backwards and convex from side to side ; it articulates with the base of the second metacarpal bone. From the volar surface a rough strip, which may be V-shaped, passes backwards between the distal and lateral surfaces, and so the *lateral surface* can be identified ; it articulates with the os multangulum majus. The *proximal surface*, opposite the distal, articulates with the navicular bone. The *medial surface* articulates with the lateral surface of the os capitatum.

Os Capitatum.—The *proximal surface* is the rounded top of the head, and articulates with the concave surface of the os lunatum. The *distal surface* is the base ; its greater part articulates with the base of the third metacarpal bone, but at the sides it articulates also with the second and the fourth. The *volar surface* is rough and protuberant. The *dorsal surface* also is non-articular, but is nearly flat. The *lateral surface* of the head is convex and articulates with the concave facet of the navicular bone ; lower down, on the lateral surface of the body, there is a facet for articulation with the medial surface of the os multangulum minus. The *medial surface* has a large facet, which includes the medial side of the head, for articulation with the lateral surface of the os hamatum.

Os Hamatum.—The hook juts forwards from the distal and medal part of the volar surface ; the concave side of the hook looks in a lateral direction. The body of the bone is shaped somewhat like a wedge. The base of the wedge is the *distal surface* ; it is concave from before backwards and convex from side to side ; it articulates with the bases of the fourth and fifth metacarpal bones, and usually an indication of subdivision into two corresponding parts can be made out. The *proximal surface* is reduced to a blunt border between the medial and lateral surfaces and is the edge of the wedge ; it articulates with the os lunatum. The distal and volar part of the *lateral surface* is rough ; the remainder is covered with a large facet for articulation with the os capitatum. The *medial surface* is wholly articular except at its distal margin, and is undulating ; it articulates with the distal surface of the os triquetrum, which is correspondingly concavo-convex. The *dorsal surface* is non-articular and fairly flat. The *volar surface*, also non-articular, bears the hook.

Attachments.—The pisiform is attached to the front of the os triquetrum by an articular capsule. The other seven bones are closely bound together by (1) volar intercarpal ligaments attached to their *volar* surfaces, (2) dorsal intercarpal ligaments attached to their *dorsal* surfaces, (3) interosseous intercarpal ligaments attached to the rough areas and edges of *contiguous surfaces*, and (4) ulnar and radial collateral intercarpal ligaments attached to the surfaces on the *ulnar and radial borders of the wrist.* The ulnar and radial collateral ligaments of the wrist joint also are attached to those surfaces, while the volar ligament of the wrist joint (volar radio-carpal) is attached to the volar surfaces of the *navicular bone* and *os lunatum*, and the dorsal ligament to the dorsal surfaces of the *navicular, lunatum*, and *triquetrum.* The *distal row* of bones is closely bound to the bases of the medial four metacarpal bones by dorsal and volar carpo-metacarpal ligaments, while the *os multangulum majus* is more loosely attached to the base of the first metacarpal bone by a separate articular capsule.

One end of the transverse carpal ligament is attached to the *pisiform* bone and the *hook* of the os hamatum, and the other end to the *tubercle of the navicular* bone and the volar surface of the *os multangulum majus*; an additional band called the volar carpal ligament connects the front of the transverse ligament with the *pisiform.* The dorsal carpal ligament stretches obliquely from the distal end of the radius to the *os triquetrum* and the *pisiform bone.*

The tendon of the flexor carpi ulnaris is inserted into the *pisiform bone*, but many of the tendinous fibres are continued onwards to the *hook* of the os hamatum and the base of the *fifth metacarpal* as two distinct strong bands called the piso-hamate and piso-metacarpal ligaments. The abductor digiti quinti muscle arises partly from the *pisiform bone.* The flexor digiti quinti brevis and the opponens digiti quinti arise partly from the *hook* of the os hamatum. The abductor pollicis brevis arises in great part from the *tubercle of the navicular* and the *ridge* on the *os multangulum majus*; and portions of the flexor pollicis brevis and opponens pollicis also arise from that ridge. A portion of the oblique head of the adductor pollicis arises from the volar surfaces of the *multangulum majus* and *minus* and *capitatum.*

Metacarpus.

The **metacarpus** is the skeleton of the hand proper [μετά (meta) = next after; καρπός (carpos) = wrist]. It consists of five separate bones, called **metacarpal bones**, one corresponding to each digit. They are named by number, *first*, *second*, etc., beginning with the one corresponding to the thumb. Each of them is a miniature long bone, possessing a **body** or shaft and **two extremities.** Each is slightly concave lengthwise on the volar or **palmar** surface; the **distal end** is the rounded end and is called the *head*; the

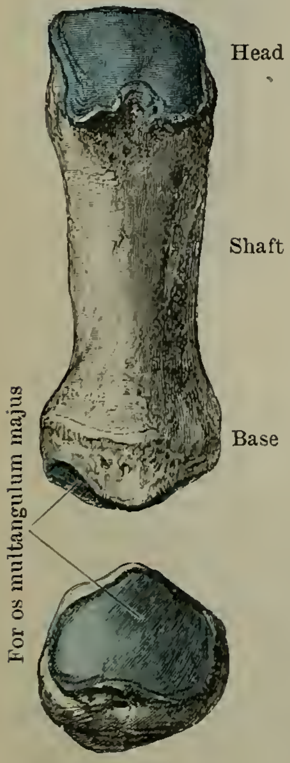


Fig. 206.—First Right Metacarpal Bone.

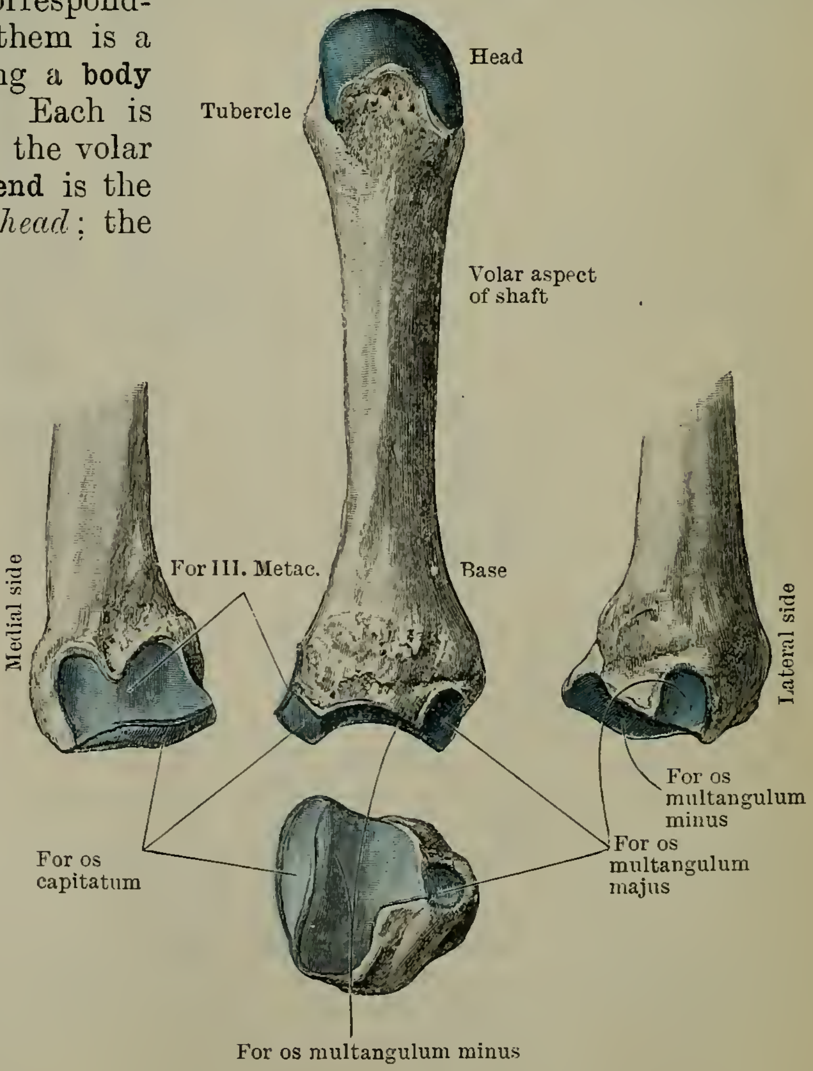


Fig. 207.—Second Right Metacarpal Bone.

proximal end is called the *base.* The lateral surface can be distinguished from the medial after the base is examined.

The corresponding bones of the **foot** are called *metatarsal bones*; they are not at all unlike the metacarpals, and a beginner may mistake the one for the other if they are loose and mixed. The metacarpals are between two and three inches long, and are rather shorter than the metatarsals, but are relatively thicker and less compressed; they have on the dorsal surface an elongated, nearly flat, triangular area with its base at the distal end of the bone; and the distal end is larger, conforming to the larger size of the finger. Those distinctions do not apply to the first metacarpal and metatarsal, but the first metacarpal is the shortest of all those bones, and the first metatarsal is the thickest. A beginner may also mistake the *proximal phalanx* of a finger for a metacarpal bone; but the phalanx is smaller, smoother, and more regular in contour, and its smaller end or head is distinctly pulley-shaped.

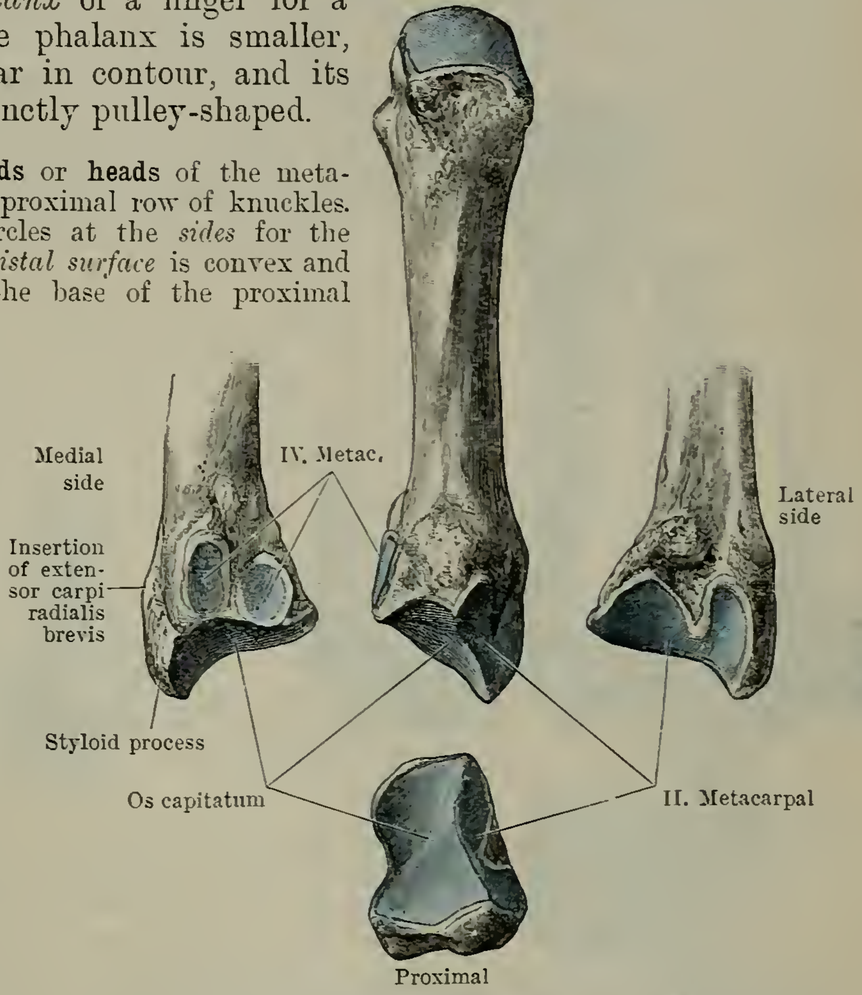


Fig. 208.—Third Right Metacarpal Bone.

Note.—The whole bone shows its volar aspect.

Capitulum.—The **distal ends** or **heads** of the metacarpal bones are familiar as the proximal row of knuckles. Each head has pits and tubercles at the *sides* for the attachment of ligaments; the *distal surface* is convex and smooth for articulation with the base of the proximal phalanx when the digit is straightened; the articular surface extends much further on to the palmar or volar surface than on to the dorsal, for when a digit is *flexed*, as when the hand is closed, the phalanx articulates with the palmar surface of the head. When a finger is *extended* it is in straight line with the hand, and the phalanx articulates with the distal surface of the head. The degree to which the finger can be *dorsiflexed*, *i.e.*, bent backwards beyond the straight line, varies considerably in different people, and the greater the degree of dorsiflexion possible the more does the articular surface extend on to the dorsal aspect of the head of the metacarpal bone.

Corpus.—The **body** or shaft is slightly curved so that it is concave towards the palm. It has a *dorsal surface* which can be felt on the back of the hand, and a *medial* and a *lateral surface.* The blunt *volar border*, which separates the lateral and medial surfaces, broadens out into a surface near each end.

Basis.—The **proximal end** or **base** of a metacarpal bone articulates with the carpus by its *proximal surface*, which is therefore smooth; the bases of the medial four articulate with each other by their *sides*, and therefore there are articular facets on the sides. The readiest means of identifying the individual metacarpal bones is found in the base, and in the medial four the base provides the means of distinguishing the lateral from the medial surface.

The **first** metacarpal bone is shorter than the others. It is slightly compressed from before backwards, so that the surfaces of the **body** are usually regarded as two—a *dorsal* and a *palmar*; but the palmar surface is divided by a blunt ridge into a radial and an ulnar half, of which the radial or *lateral* half is slightly the larger. The **base** has no facets on its *sides*; its *proximal surface* is saddle-shaped and articulates with the saddle-shaped distal surface of the os multangulum majus. The *volar surface* of the **head** has two shallow grooves which articulate with the sesamoid bones (p. 247).

The **second** metacarpal has a wide groove or *notch* on the *proximal surface* of its **base.** The notch articulates with the os multangulum minus. The ridge forming the medial boundary of the notch articulates with the os capitatum; the pointed tubercle on the *lateral side* articulates with the os multangulum majus. There is a facet on the *medial side* of the base for articulation with the lateral surface of the base of the third metacarpal.

The **third** metacarpal has a thick pointed projection, called its **styloid process**, which juts upwards from the junction of the *dorsal* and *lateral* surfaces of the **base**, and by that the **lateral** side can be recognised. The *proximal surface* of the base articulates with the os capitatum, and on the sides there are facets for articulation with the second and fourth metacarpals.

The **fourth** metacarpal has a cubical **base**. Its *proximal surface* is nearly flat and articulates chiefly with the os hamatum and slightly with the os capitatum. There are two nearly circular facets on the *lateral surface* of the base for articulation with the third metacarpal, and a single facet on the *medial surface* for articulation with the fifth.

The **fifth** metacarpal, being the bone on the side of the hand, has a facet on only one side of the **base**, and that is on the *lateral surface* for articulation with the fourth; there is a tubercle on the *medial surface*, while the *proximal surface* is convex from before backwards and slightly concave from side to side, and articulates with the os hamatum.

Attachments.—The **base** of the *first metacarpal* is attached to the os multangulum majus by an articular capsule. The *other four* are bound to the carpus by volar and dorsal carpo-metacarpal ligaments attached to their volar and dorsal surfaces; they are bound to each other by volar and dorsal ligaments and by interosseous ligaments attached to the rough parts of their sides; the **base** of the *fifth* has two additional ligaments—the piso-metacarpal attached to the volar surface, and an ulnar collateral stretching from the side of the carpus to the tubercle on the medial side. The **head** of each metacarpal is attached to the proximal phalanx by an articular capsule; the fibrous layer of the capsule is thickened at the sides to form radial and ulnar collateral ligaments, which are attached to the *sides* of the head, and it is thickened in front to form what is called the volar accessory ligament, which is attached loosely to the *volar surface* just proximal to the smooth articular part, while, on the back, the fibrous layer is either fused with or is replaced by the extensor tendon overlying the joint.

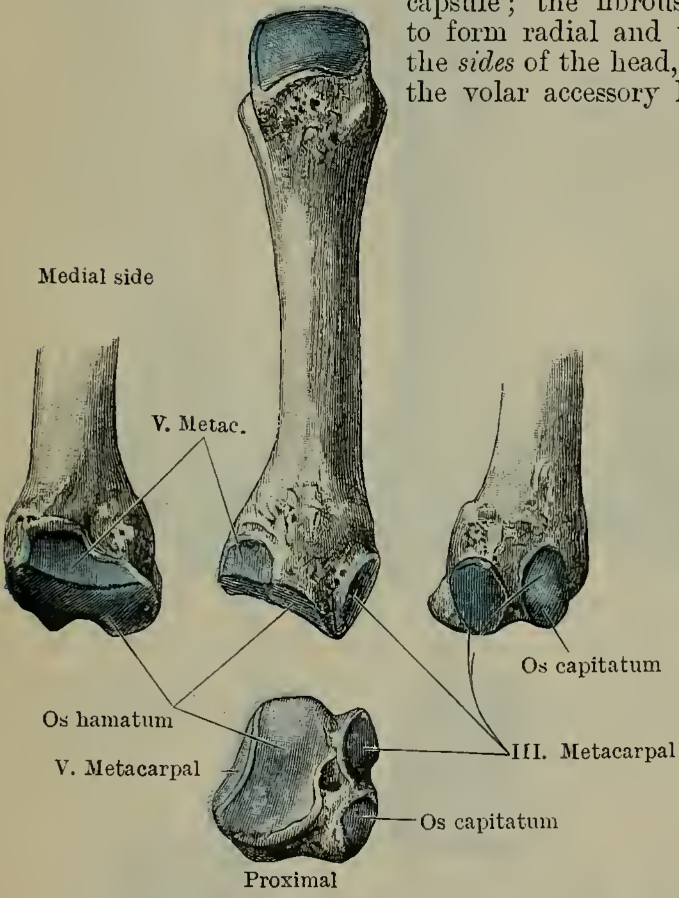


FIG. 209.—FOURTH RIGHT METACARPAL BONE.

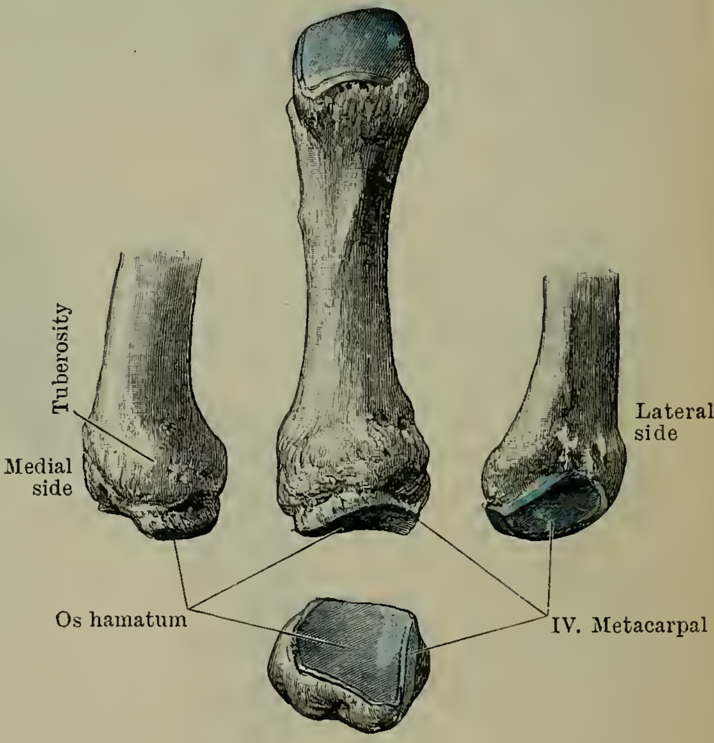


FIG. 210.—FIFTH RIGHT METACARPAL BONE.

NOTE.—The whole bone presents its volar surface.

The abductor pollicis longus tendon is inserted into the radial and volar surfaces of the **base** of the *first*; the flexor carpi radialis tendon into the volar surface of the base of the *second* and slightly into the base of the *third* also; the extensor carpi radialis longus tendon into the radial part of the back of the base of the *second*; the extensor carpi radialis brevis tendon into the radial part of the base of the *third* at the root of the *styloid process*, and slightly also into the base of the *second*; the extensor carpi ulnaris tendon into the back and ulnar side of the *fifth*. The interosseus primus volaris arises from the ulnar side of the base of the *first*; part of the oblique head of the adductor pollicis from the volar surfaces of the *second*, *third*, and *fourth*.

The opponens pollicis is inserted into the radial half of the volar surface of the **body** of the *first*; the opponens digiti quinti into the ulnar surface of the *fifth*. The four dorsal interosseous muscles lie between the metacarpal bones and are attached to *all* of them; each arises by two heads which spring from the adjacent sides of the two metacarpal bones between which the muscle lies. The three volar interosseous muscles lie in front of the dorsal interosseous; they arise by single heads from the *second*, *fourth*, and *fifth*. The transverse head of the adductor pollicis arises from the volar border of the *third*.

The structures attached to each individual metacarpal bone are as follows:—

First Metacarpal Bone.—**Base**: Articular capsule; abductor pollicis longus; interosseus primus volaris. **Body**: Opponens pollicis; first dorsal interosseous. **Head**: Volar accessory and collateral ligaments.

Second.—**Base**: Carpo-metacarpal and intermetacarpal ligaments; flexor carpi radialis, extensor carpi radialis longus and brevis; oblique head of adductor pollicis. **Body**: First and second dorsal interosseous, first volar interosseous. **Head**: Volar accessory and collateral ligaments. (Volar interossei are differently numbered in chapter on Muscles, p. 397.)

Third.—**Base**: Carpo-metacarpal and intermetacarpal ligaments; flexor carpi radialis, extensor carpi radialis brevis; oblique head of adductor pollicis. **Body**: Second and third dorsal interosseous, transverse head of adductor pollicis. **Head**: Volar accessory and collateral ligaments.

Fourth.—**Base**: Carpo-metacarpal and intermetacarpal ligaments; oblique head of adductor pollicis. **Body**: Third and fourth dorsal interosseous, second volar interosseous. **Head**: Volar accessory and collateral ligaments.

Fifth.—**Base**: Carpo-metacarpal (including piso-metacarpal and ulnar collateral) and intermetacarpal ligaments; extensor carpi ulnaris. **Body**: Fourth dorsal interosseous, third volar interosseous; opponens digiti quinti. **Head**: Volar accessory and collateral ligaments.

Phalanges Digitorum Manus.

Each **phalanx** is a miniature long bone possessing a **body** or shaft and **two ends** [φάλαγξ (phalanx) = a round log or roller]. The **proximal** end is the larger end and is called the *base*; the **distal** end is called the *head*. The **body** is markedly *convex* from side to side on its *dorsal* surface and nearly flat on the *palmar* surface. There is little distinction between the lateral and medial sides of a phalanx.

The **first** phalanx of a digit is the largest; the proximal surface of its **base** is hollowed out as a single concavity, and its **head** is pulley-shaped. The **head** of the **second** also is pulley-shaped, but its **base**, since it articulates with the head of the first, is the reverse of a pulley, having two shallow concavities with a low intervening ridge; that distinguishes the second phalanx of a large hand from the first phalanx of a small hand. The **base** of the **third** phalanx also is the reverse of a pulley, but the third phalanx is the smallest and its **head** is non-articular.

The **thumb** has only *two* phalanges. They are shorter and broader than those of the fingers; the **first** resembles the first of a finger, but the **second** resembles the third phalanx of a finger.

The phalanges of the toes should not be mistaken for those of the fingers. The first phalanx of a toe is about the same length as the second phalanx of a finger, but its body is much thinner and its base is relatively large. Both of the phalanges of the big toe are so thick, and the second and third phalanges of the other toes are so short, that they cannot be mistaken.

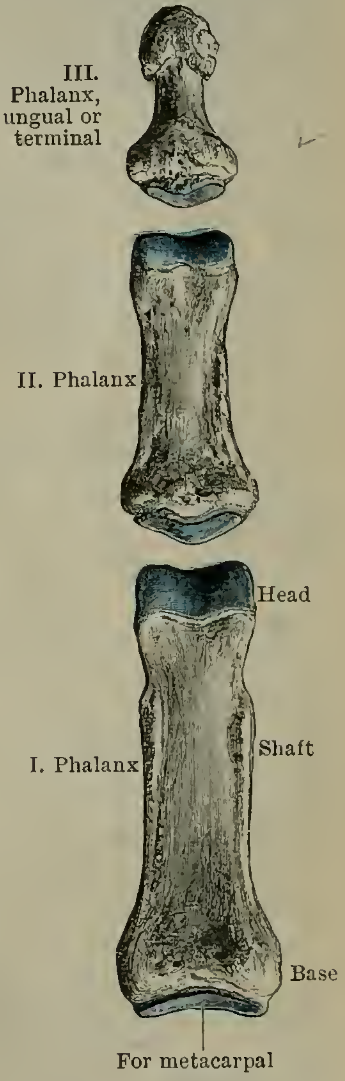


Fig. 211.—Phalanges of a Finger (Volar Aspect).

The **first phalanx** of a finger measures 35-45 mm. in length, and is curved so that it is slightly concave lengthwise on its *volar* surface. The concave *proximal surface* of its **base** articulates with the convex head of the metacarpal; the *sides* of the base are slightly enlarged and give attachment to muscles and ligaments. The convex *dorsal surface* of the **body** is separated from the flat *palmar surface* by sharp margins. The pulley-shaped **head** articulates with the base of the second phalanx; the articular surface extends much further on to the volar aspect than on to the dorsal, just as on the head of a metacarpal bone and for the same reason. The *sides* of the head show shallow pits for the attachment of ligaments.

The **second phalanx** measures 25-30 mm. Its **body** and **head** resemble those of a first phalanx, but the **base** differs in the way already mentioned. The **third phalanx** is very small and is not curved. Its **base** is relatively large, and resembles that of a second phalanx. The **body** is short. The **head** is slightly expanded sideways, is non-articular, and is very rough on its volar surface.

Attachments.—The base of the *first* phalanx is attached to the metacarpal bone by a joint capsule, the characters of which are briefly indicated in the account of the metacarpals; the volar accessory ligament is attached firmly to the volar surface of the base, and the collateral ligaments to its sides. The *second* phalanx is attached to the first and the third by similar capsules. Each of the four tendons of the extensor digitorum communis spreads out on the back of a first phalanx to form an *extensor expansion* which is inserted into the back of the base of the *second* and *third* phalanges of a finger; the tendon of the extensor indicis proprius joins the tendon of the communis for the forefinger, and the tendon of the extensor digiti quinti proprius joins that for the little finger; the tendons of the interossei and of the lumbricales are inserted partly into the sides of the base of the *first* phalanx, but chiefly into the extensor tendon of a finger; therefore each *extensor expansion* is made up of several tendons. Each of the four tendons of the flexor digitorum sublimis is inserted into the margins of the **body** of a *second* phalanx. Each of the four tendons of the flexor digitorum profundus is inserted into the volar surface of the **base** of a *terminal* phalanx. The abductor digiti quinti and the flexor digiti quinti brevis are inserted into the ulnar side of the **base** of the *first* phalanx of the *little finger*.

The tendons of the long flexors of a digit are held in place along its volar surface by a fibrous strap, called the fibrous flexor sheath, the edges of which are attached to the margins of the **body** of the *first* phalanx of the *thumb* and of the *first* and *second* phalanges of the *fingers*, while its distal extremity is attached to the volar surface of the *terminal* phalanx, just beyond the insertion of the flexor tendon.

The structures attached to the individual phalanges are as follows:—

First phalanx.—Of forefinger. Articular capsules; flexor sheath; first dorsal and first volar interosseous, first lumbrical.—**Of middle finger.** Capsules; sheath; second and third dorsal interosseous, second lumbrical.—**Of ring finger.** Capsules; sheath; second volar and fourth dorsal interosseous, third lumbrical.—**Of little finger.** Capsules; sheath; third volar interosseous, fourth lumbrical, abductor digiti quinti, and flexor digiti quinti brevis.

Second phalanx of each finger.—Articular capsules; flexor sheath; extensor expansion, flexor digitorum sublimis.

Third phalanx of each finger.—Articular capsule; flexor sheath; extensor expansion; flexor digitorum profundus.

Thumb.—The extensor pollicis brevis is inserted into the *dorsal* surface of the **base** of the **first phalanx**; the flexor brevis and abductor brevis together into the *radial* side of the base; the adductor and interosseus primus volaris into the *ulnar* side. The extensor longus into the *dorsum* of the **base** of the **second phalanx**; and the flexor longus into the *volar* surface. The fibrous flexor sheath is attached to the *margins* of the **body** of the **first phalanx** and the *volar surface* of the **second.** Articular capsules, like those of the fingers, connect the first phalanx with the metacarpal bone and the second phalanx.

Ossification of Bones of Hand.—The **carpus** is cartilaginous at birth. Each carpal bone has **one** centre; ossification is completed between 20 and 25.

	Capitatum.	Hamatum.	Triquetrum.	Lunatum.	Naviculare.	Multangulum majus.	Multangulum minus.	Pisiforme.
Centre appears	1st year	1st	3rd	5th	5th	5th	7th	10th

Metacarpus.—The *primary* centre, one for each metacarpal bone, appears in the ninth week of fœtal life. The metacarpal bones are well ossified at birth.

Secondary Centre.	Appears at	Epiphysis joins at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For base of first	3rd year	20	Outside.
For head of others	3rd ,,	20	Outside.

The **first** differs from the others in having the epiphysis at the base instead of at the head, possibly because movement is more free at the carpo-metacarpal joint of the thumb than at the metacarpo-phalangeal joint, while the reverse is the case at the joints of the other metacarpal bones. In rare cases an epiphysis appears in the head of the first at the seventh year; and the base of the second may have an epiphysis.

Phalanges.—The *primary* centre for each appears between the eighth and the twelfth week of fœtal life. At birth the phalanges are well formed.

Secondary Centre.	Appears at	Epiphysis fuses at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For base	3rd year	Rather before 20	Outside.

The **ungual phalanges** are the first bones of the hand to ossify, and their primary centres appear near their distal ends instead of in the middle.

Structure and Variations of Bones of Hand.—**Carpal bones** have the typical structure of short bones. **Metacarpal bones** and **phalanges** have the structure of long bones.

Occasionally one of the carpal bones is divided, giving rise to an additional bone in the carpus. The **os centrale**, though normally a separate bone in the carpus of most mammals, and represented by a separate cartilage in the earlier months of fœtal life, is almost always fused with the navicular bone, but sometimes it is a separate ossicle on the back of the carpus between the navicular, the capitatum, and the multangulum minus. X-ray photographs sometimes reveal what appear to be small additional nodules in the carpus. Diminution of the number of carpal bones is usually due to fusion caused by disease. The *styloid process* of the third metacarpal bone may have an epiphyseal centre, and may be a separate bone, or may be fused with the os capitatum or the os multangulum majus, instead of with the metacarpal.

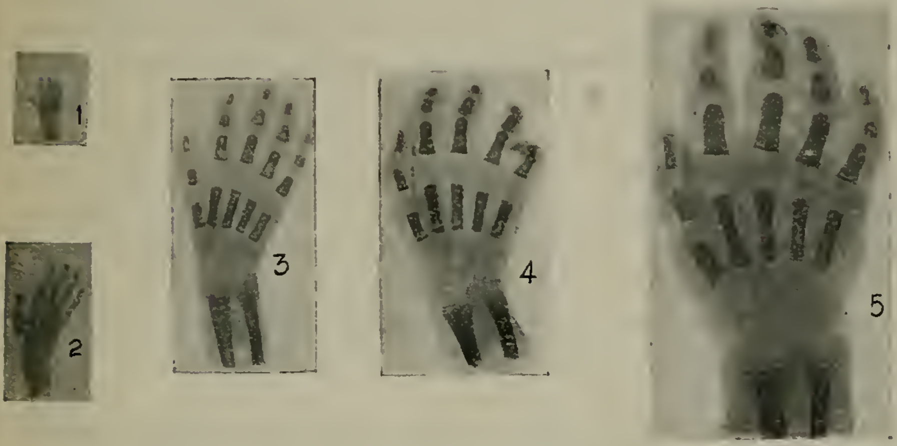


Fig. 212.—Radiographs of Fœtal Hands.

1. About 10 weeks. The centres for terminal phalanges and medial four metacarpal bones are seen.
2. A little later. The centres for the first metacarpal, for the proximal row of phalanges, and for the second phalanx of middle and ring fingers are seen.
3. During the 3rd month. All the primary centres for metacarpal bones and phalanges are seen.
4. About the fourth to fifth month. 5. About the sixth to seventh month.

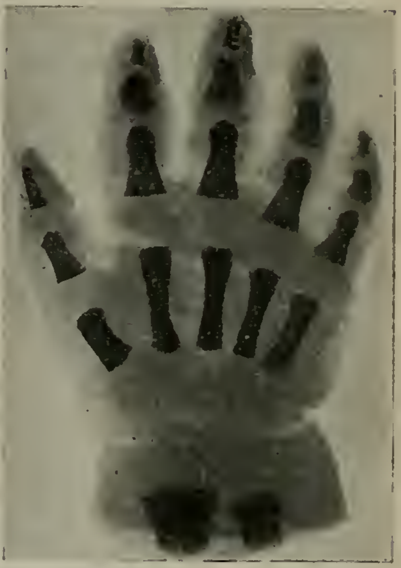


Fig. 213.—At Birth.

Carpus is still entirely cartilaginous.

Compare this with the tarsus at birth, in which the tarsus is shown in part already ossified.

Sometimes an *ungual phalanx* is bifurcated. The thumb may have three phalanges. Occasionally a phalanx is absent or has been absorbed by another phalanx. A case has been recorded in which the first phalanx had an epiphysis at its head as well as at its base.

Ossa Sesamoidea.

The **sesamoid bones** of the hand are two very small nodules that lie in the tendons of insertion of the flexor pollicis brevis and the adductor pollicis. They are blended with the volar accessory ligament of the metacarpo-phalangeal joint, and play against the volar surface of the head of the metacarpal bone. Occasionally little nodules are found also in the volar accessory ligament of the other metacarpo-phalangeal joints and in the interphalangeal joint of the thumb.

BONES OF THE LOWER LIMB.

The **lower limb** or **inferior extremity** includes the hip and buttock, the thigh, the leg, and the foot (Figs. 109, 110, pp. 92 and 93).

The **hip** (*coxa*), above and at the side, and the **buttock** (*natis*), below and behind, make up the **gluteal region**, which extends from the waist and the small of the back down to the level of the horizontal crease that limits the buttock below; the crease is called the *gluteal fold*; the interval between the buttocks is called the *natal cleft* [γλουτός (glūtos) = *natis* = buttock]. The lower end of the trunk, between the thighs and between the buttocks, is called the *perineum* [περίνεος (perineos) = the perineum: derivation uncertain].

The skeleton of the hip and buttock of each side is a single bone called the **hip bone** or os coxæ. It forms part of the framework of the trunk also, for the right and left hip bones, together with the sacrum and the coccyx, form the bony walls of the pelvis; and the hip bone is sometimes referred to as the *pelvic girdle.* (The sacrum and coccyx are the lowest subdivisions of the backbone; the pelvis is the lower subdivision of the abdomen or belly, and the perineum is included in the pelvis.)

The **thigh** (*femur*) extends from the gluteal region to the knee. On the lateral[1] side it is continuous with the hip; posteriorly it joins the buttock at the gluteal fold; on the medial side it joins the perineum, which separates it from the other thigh; anteriorly it joins the anterior wall of the abdomen and reaches a higher level than it does behind; the depression between the front of the thigh and the front of the abdomen is the *groin* or *inguinal region* [*inguen* = groin, from *inquinare* = to stain].

The bone of the thigh is called the **femur.** At its proximal end the femur articulates with the hip bone to form the *hip joint.* At the knee joint the distal end of the femur articulates (1) with the tibia or shin bone, which is the larger of the two bones of the leg, and (2) with the patella or knee cap—the small bone that lies in the front of the knee joint. The hollow at the back of the knee is the ham or *popliteal fossa* [*poples* = the hough; the ham of the knee].

The term **leg** (*crus*) is often applied to the whole free part of the lower limb, but in Anatomical text-books it is limited strictly to the segment between the knee joint and the ankle joint. The two bones of the leg are called the **tibia** and the **fibula.** They articulate with each other at their proximal and distal ends, and the joints so formed are called the *tibio-fibular joints.* The tibia articulates with the femur at the *knee joint,* but the fibula does not do so; the tibia and fibula both articulate with one of the bones of the foot, called the talus, to form the *ankle joint.*

The **foot** (*pes*) is joined to the leg at the ankle joint. It consists of the foot proper and the toes. The **foot proper** includes all the region from the point of the heel to the roots of the toes. Its upper surface is called the *dorsal surface* or *dorsum* of the foot; the *sole* is often called the *plantar surface* [*planta* = the sole]. The foot proper consists of (1) the *tarsus,* which is the hinder half of the foot proper, and corresponds to the carpus or wrist, and (2) the *metatarsus,* which is the half next the toes, and corresponds to the metacarpus or hand proper.

The bones of the **tarsus** are seven in number; they are named collectively the **tarsal bones,** and each has its own name besides; they articulate with one another, forming *inter-tarsal joints.* They are arranged in two rows—two bones in the first row and four bones in the second row—and an intermediate bone between the rows. The bones of the second row are placed side by side; the bones of the first row are placed one above the other, and the upper one—the talus—articulates with the bones of the leg at the *ankle joint.*

The bones of the **metatarsus** are called **metatarsal bones.** There are five of them, placed side by side, one corresponding to each toe. They are named by number: **first** metatarsal, **second,** etc., beginning with the one that corresponds to the big toe. The proximal or posterior ends of the metatarsal bones articulate (1) with the second row of tarsal bones, forming *tarso-metatarsal joints,* and (2) with each other, side by side, forming *inter-metatarsal joints.*

Toes or Digits.—The great toe is called the **hallux** [probably from *allex* = thumb or great toe]. The other toes are usually designated by number—**second, third,** etc.

The bones of the toes are called **phalanges.** The great toe has two phalanges, named the proximal or **first** phalanx and the distal or **second** phalanx. Each of the other toes has three phalanges—proximal, middle, and distal, or **first, second,** and **third.** The distal phalanx is sometimes called the *ungual phalanx,* because the nail (*unguis*) is associated with it. The first phalanx of a digit articulates with the distal end of the corresponding metatarsal bone to form a *metatarso-phalangeal joint*; and the second phalanx articulates with the first and the third, forming *inter-phalangeal joints.*

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[1] Definitions of terms are given on pp. 4, 5, 87.

Os Coxæ.

The **hip bone** is the broadest bone in the skeleton. It is large, expanded, and unevenly compressed. On one side of it there is a deep cup or cavity with a broken rim; the cavity is called the **acetabulum**, and near it there is a large aperture called the **obturator foramen**.

The hip bone lies in the side wall and the anterior wall of the pelvis. In the anterior wall it articulates with its fellow of the opposite side to form a joint called the *symphysis pubis*; posteriorly the hip bone articulates with the side of the sacrum, which lies in the back wall of the pelvis between the two hip bones, and the joint is called the *sacro-iliac joint.*

The hip bone consists of three originally distinct bones which in the adult are fused together at the acetabulum. The three bones or parts are named the os ilium, the os ischii, and the os pubis, but those names are usually shortened to *ilium, ischium,* and *pubis.*

The **ilium** is the largest and broadest of the three parts. It is the uppermost part of the hip bone; and the bone should be held in the hand so that this broad part is uppermost, and the deficient side of the acetabulum looks directly downwards. The **ischium** is the thick, three-sided part below and behind the acetabulum and behind the obturator foramen; from the lower end of the ischium a broad, fairly flat bar of bone, called the *ramus of the ischium,* projects forwards, forming the lower boundary of the obturator foramen, and joins the pubis. The **pubis** is the remaining part of the hip bone, and forms the other boundaries of the obturator foramen. The pubis has three main parts: (1) an expanded part in front, commonly called the *body* of the pubis; (2) a compressed bar of bone, called the *inferior ramus* of the pubis, which extends backwards from the body and fuses with the ramus of the ischium; (3) a thicker bar, called the *superior ramus,* which extends from the body to the acetabulum.

The position of parts is roughly as follows: the ilium is the upper part; the ischium is the lower and posterior part; the pubis is the lower, anterior, and medial part; the acetabulum is on the lateral surface; the obturator foramen is below and medial to the acetabulum.

Os Ilium.—The **ilium** is "the bone of the flank" [*ilia* (plural) = the flank]. It lies below the waist in the uppermost part of the hip. It is large, compressed, and fluted, and possesses two ends, three borders, and three surfaces.

The two **ends** are upper and lower. The **lower end** forms the upper part of the acetabulum, and is fused there with the ischium and the pubis.

The **upper end** is scarcely recognisable as an end, for the ilium in Man is so expanded that the upper end is drawn out like the wide end of an open fan and resembles a border; it is called the **iliac crest.** The crest is curved like the *italic* letter *f*; the curve of the anterior half is convex in the lateral direction, and the curve of the posterior half is convex in the medial direction. The anterior and posterior ends of the crest are named, respectively, the **anterior superior iliac spine** and the **posterior superior iliac spine.** The margins of the crest are called its *outer* and *inner lips*; the interval between the lips is called the *intermediate line.* Two or three inches behind the anterior superior spine the crest is thicker than it is elsewhere; the thickening affects the outer lip, producing a low prominence on it called the **tubercle of the crest.**

The iliac crest can be felt from end to end in the living body, along the lower boundary of the waist. By tracing the crest forwards one can locate the anterior superior spine, and can almost grip it between finger and thumb when the muscles attached to it are relaxed—as they are when one is sitting. The tubercle of the crest is easily felt, two or three inches behind the anterior spine. The posterior superior spine is not distinctly palpable in the living body like the anterior spine, but its position can always be recognised by a dimpling of the skin overlying it; the dimple is seen above the buttock about two finger-breadths from the median plane, and the spine is the bone felt in its floor; it is on a level with the second spine of the sacrum and the middle of the sacro-iliac joint. The highest point of the crest is about its middle point, one or two inches behind the tubercle of the crest, and is on a level with the fourth lumbar vertebra; the tubercle of the crest is the highest point that can be seen when the body is examined from the front, and is on a level with the fifth lumbar vertebra.

The **borders** of the ilium are anterior, posterior, and medial.

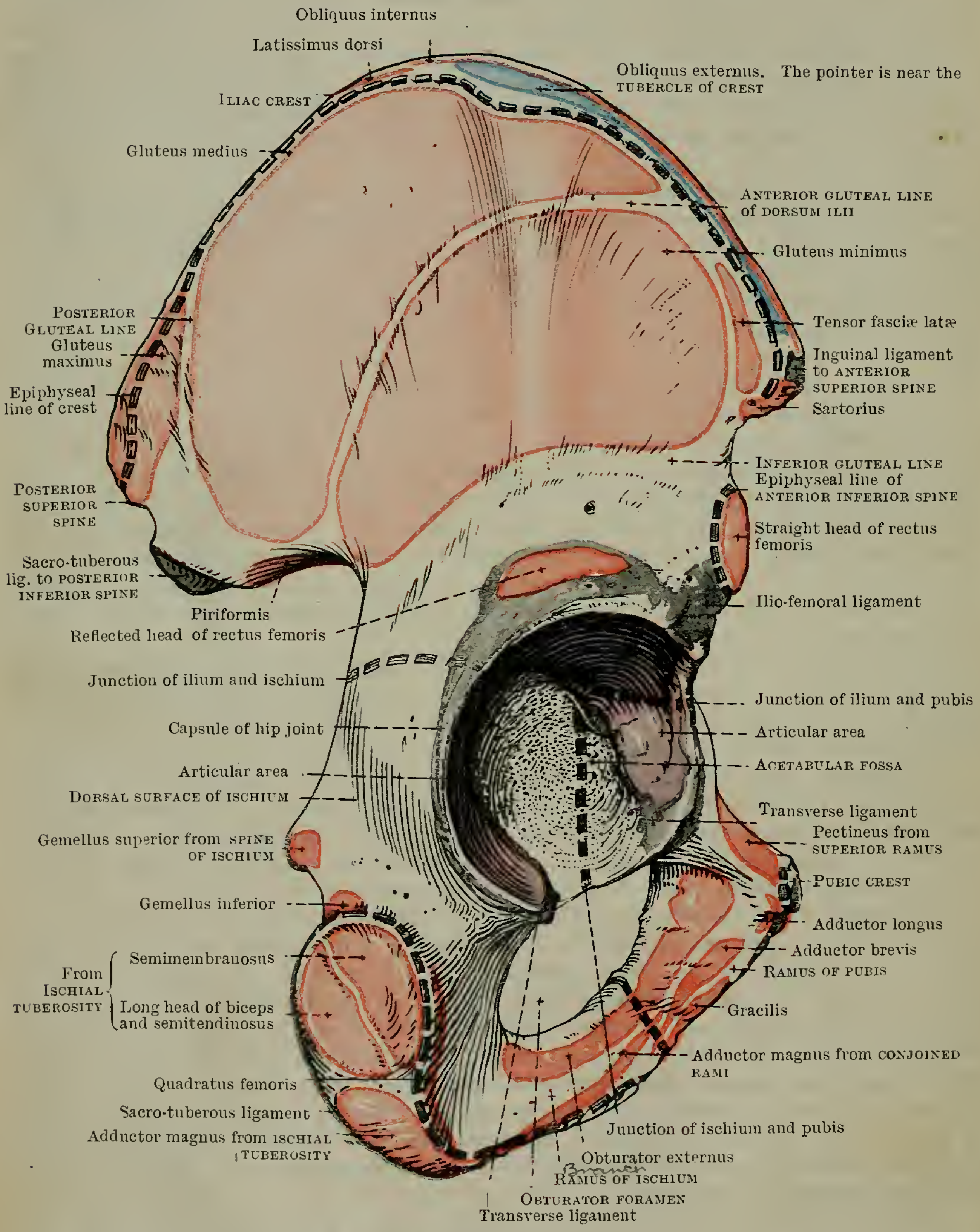

Obliquus internus
Latissimus dorsi
Iliac crest
Obliquus externus. The pointer is near the tubercle of crest
Gluteus medius
Anterior gluteal line of dorsum ilii
Gluteus minimus
Posterior gluteal line
Gluteus maximus
Tensor fasciæ latæ
Inguinal ligament to anterior superior spine
Epiphyseal line of crest
Sartorius
Inferior gluteal line
Epiphyseal line of anterior inferior spine
Posterior superior spine
Straight head of rectus femoris
Sacro-tuberous lig. to posterior inferior spine
Ilio-femoral ligament
Piriformis
Reflected head of rectus femoris
Junction of ilium and ischium
Junction of ilium and pubis
Capsule of hip joint
Articular area
Articular area
Acetabular fossa
Dorsal surface of ischium
Transverse ligament
Pectineus from superior ramus
Gemellus superior from spine of ischium
Pubic crest
Gemellus inferior
Adductor longus
Adductor brevis
Ramus of pubis
From ischial tuberosity
Semimembranosus
Long head of biceps and semitendinosus
Gracilis
Adductor magnus from conjoined rami
Quadratus femoris
Sacro-tuberous ligament
Junction of ischium and pubis
Adductor magnus from ischial tuberosity
Obturator externus
Ramus of ischium
Obturator foramen
Transverse ligament

Fig. 214.—Lateral Aspect of Right Hip Bone.

The **anterior border** begins at the anterior superior spine and extends downwards and backwards to end at the anterior margin of the acetabulum. On the anterior border, a little above the acetabulum, there is a considerable prominence called the **anterior inferior iliac spine.** About an inch medial to the lower end of the anterior border, in front of the acetabulum, there is a low diffuse swelling called the *ilio-pectineal eminence*; it marks the region where ilium and pubis fuse.

The **posterior border** begins at the posterior superior spine and runs in an undulating manner downwards and forwards to end just above the level of the middle of the acetabulum, where it becomes continuous with the posterior border of the ischium. At a point about an inch below the posterior superior spine, the posterior border makes an abrupt bend forwards; that point is called the **posterior inferior iliac spine.** The wide notch which is bounded by the part of the posterior border below the inferior spine and by the adjoining part of the posterior border of the ischium is called the **greater sciatic notch.**

The **medial border** is a ridge on the medial aspect of the ilium. It begins at the crest at the point where the posterior half of the crest is most convex, and it ends at the ilio-pectineal eminence. Its *lower half* is smooth and blunt; its *upper half* separates a rough region behind from a smooth, concave region in front.

The three **surfaces** of the ilium are the dorsal or lateral, the sacro-pelvic, and a third surface moulded into a large concavity called the iliac fossa.

The **iliac fossa** is situated between the anterior and medial borders. It is smooth and concave and lodges a large muscle called the iliacus.

The **sacro-pelvic surface** is the region between the posterior and medial borders. Its uppermost and largest part is very rough for the attachment of muscles and ligaments, and is called the **iliac tuberosity.** The middle part usually has a sharply defined outline, and is called the **auricular surface,** because its shape resembles that of an ear (though turned the wrong way); it articulates with a corresponding "auricular" surface on the sacrum to form the *sacro-iliac joint,* but though it is an articular surface it is uneven and rather rough; the lobe of the "ear" is the posterior inferior iliac spine. The lowest part of the sacro-pelvic surface is smooth; it is the area between the lower smooth part of the medial border and the bottom of the greater sciatic notch; it forms part of the side wall of the pelvis minor, which is the basin-like, lower part of the pelvis.

The **dorsal or lateral surface** of the ilium, often called the **dorsum ilii,** is the wide, concavo-convex or undulating surface above the acetabulum, between the anterior and posterior borders. It is divided into areas by three curved ridges, called gluteal lines, which vary in distinctness with the muscularity of the subject. The *inferior gluteal line* begins at the anterior border above the anterior inferior spine and curves backwards, about an inch above the acetabulum, towards the greater sciatic notch. The *anterior gluteal* line begins at the crest about an inch behind the anterior superior spine and arches across the middle of the surface towards the greater sciatic notch. The *posterior gluteal line* begins at the crest two or three inches in front of the posterior superior spine and curves downwards to the greater sciatic notch.

Os Ischii.—The **ischium** is the thick prismatic part of the hip bone below and behind the acetabulum. In the upright sitting posture the body rests on the two ischia [ἰσχίον (ischion) = buttock. The adjective *ischiadic* has been reduced by time to *sciatic*].

The ischium has two ends, three borders, three surfaces, and a ramus.

The two **ends** are upper and lower. The **upper end** forms part of the acetabulum and is fused with the ilium and the pubis. The **lower end** is free and rough; the rough lower extremity of the ischium, together with the rough lower part of its dorsal surface, is called the **ischial tuberosity.** The **ramus** of the ischium is the compressed bar of bone that projects from the lower end of the ischium and fuses with a ramus of the pubis below the obturator foramen.

The **borders** of the ischium are anterior, posterior, and lateral. The **anterior border** forms one of the boundaries of the obturator foramen. The **posterior border** is continuous with the posterior border of the ilium at the lower part of the greater sciatic notch and extends to the lower end of the ischium; near its upper end a sharp triangular process, called the **ischial spine,** juts backwards and medially from it. The spine forms the lowest part of the boundary of the greater sciatic notch and the upper boundary of the **lesser sciatic notch,** which is the smooth shallow concavity between the ischial spine and tuberosity. The **lateral border** extends from the posterior margin of the acetabulum to the lower end of the ischium; its lower part is the lateral margin of the tuberosity; between the tuberosity and the acetabulum it is almost obliterated by a short, wide, horizontal groove.

The **surfaces** of the ischium are dorsal, pelvic, and femoral. The **dorsal surface** is continuous with the dorsal surface of the ilium across the back of the acetabulum, and its lower part is occupied by the rough tuberosity. The **pelvic surface** is the large smooth area between the anterior and posterior borders; it forms part of the side wall of the cavity of the pelvis minor, and is continuous superiorly with the sacro-pelvic surface of the ilium. The **femoral surface** is the flat area below the acetabulum; it looks towards the thigh.

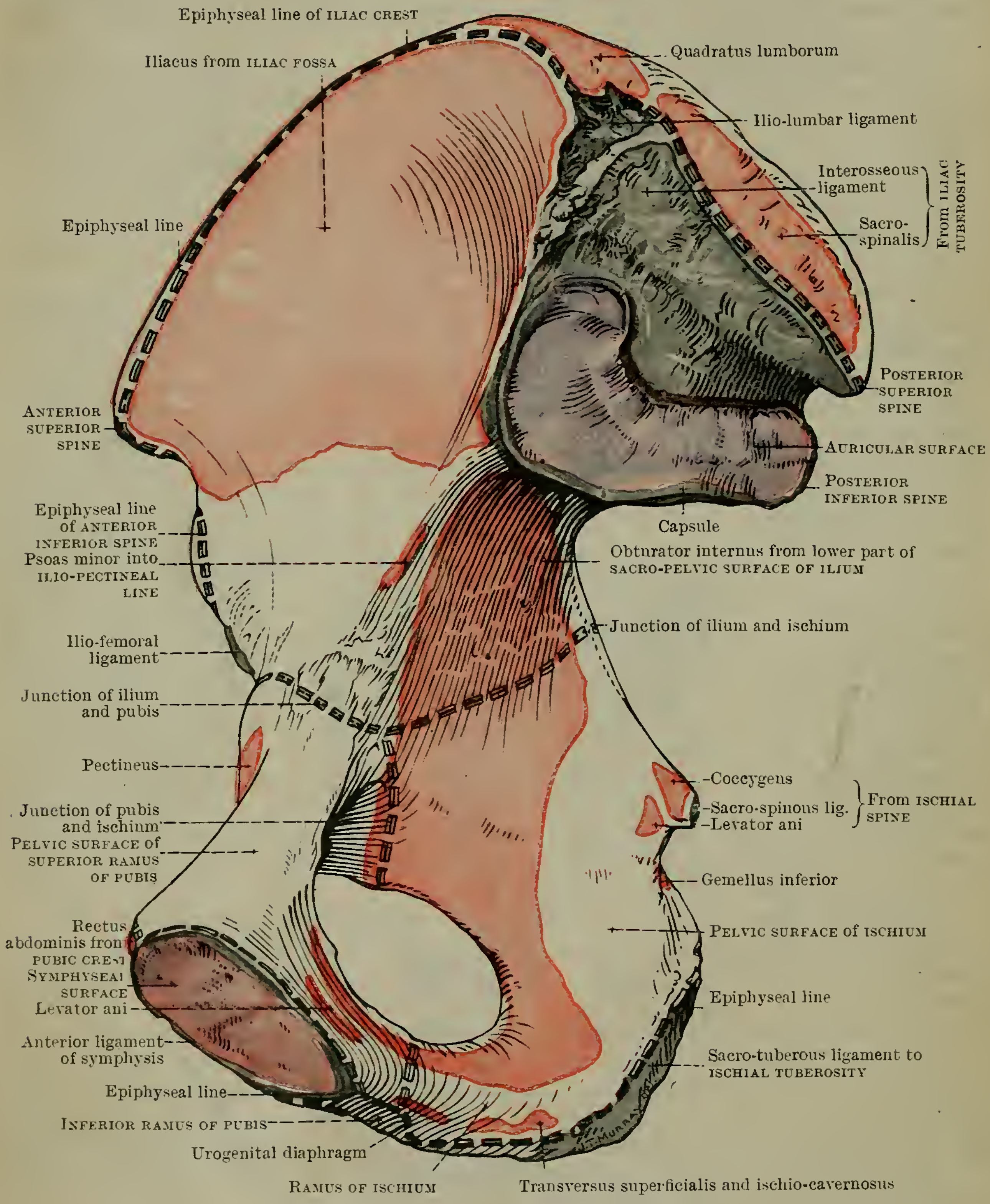

Epiphyseal line of ILIAC CREST
Iliacus from ILIAC FOSSA
Quadratus lumborum
Ilio-lumbar ligament
Interosseous ligament
Sacro-spinalis
From ILIAC TUBEROSITY
Epiphyseal line
POSTERIOR SUPERIOR SPINE
ANTERIOR SUPERIOR SPINE
AURICULAR SURFACE
POSTERIOR INFERIOR SPINE
Capsule
Epiphyseal line of ANTERIOR INFERIOR SPINE
Psoas minor into ILIO-PECTINEAL LINE
Obturator internus from lower part of SACRO-PELVIC SURFACE OF ILIUM
Junction of ilium and ischium
Ilio-femoral ligament
Junction of ilium and pubis
Pectineus
Coccygeus
Sacro-spinous lig.
Levator ani
From ISCHIAL SPINE
Junction of pubis and ischium
PELVIC SURFACE of SUPERIOR RAMUS OF PUBIS
Gemellus inferior
PELVIC SURFACE of ISCHIUM
Rectus abdominis from PUBIC CREST
SYMPHYSEAL SURFACE
Levator ani
Epiphyseal line
Anterior ligament of symphysis
Sacro-tuberous ligament to ISCHIAL TUBEROSITY
Epiphyseal line
INFERIOR RAMUS OF PUBIS
Urogenital diaphragm
RAMUS OF ISCHIUM
Transversus superficialis and ischio-cavernosus
T. MURRAY

FIG. 215.—MEDIAL ASPECT OF RIGHT HIP BONE.

Os Pubis.—The **pubis** lies in the anterior or lower wall of the pelvis, and can be felt at the lowest part of the front of the abdomen and at the upper end of the thigh where the medial side and the front of the thigh merge into each other. It is named from the region in which it lies. [The *pubis* is the region covered with hair at the lowest part of the front of the abdomen: from *pubes* = the hair that appears at puberty.]

The pubis is divisible into an expanded compressed piece of bone, usually called the *body*, and two bars of bone called the *rami*, superior and inferior.

The **body** lies alongside the median plane in the pubic region, articulating with the body of the other pubis; the two are joined by a plate of fibro-cartilage, and the joint is called the symphysis pubis; the articulating border is called the *symphyseal border*. The body has two surfaces—anterior and posterior. The *posterior* or *pelvic surface* is smooth; it looks upwards into the cavity of the pelvis rather than backwards, and is closely related to the urinary bladder. The *anterior* or *femoral surface* looks downwards into the thigh rather than forwards, and is roughened for the attachment of thigh muscles. The upper border of the body is raised and bent forwards and downwards, and is called the **pubic crest.** The medial end of the crest, which joins the symphyseal border at an angle, is called the *pubic angle*; the lateral end is called the **pubic tubercle.** The upper part of the symphysis, the pubic crest, and the pubic tubercle can all be felt at the lower part of the abdomen; the tubercle is rather more than an inch from the median plane, and is often referred to as a landmark. When the hip bone is held in the position it occupies in the erect body, the pubic tubercle and the anterior superior iliac spine lie in one vertical plane, so that the hip bone is in its proper position when it is placed against a wall with only those two points touching, and the defective side of the acetabulum looking straight downwards. A fibrous band called the *inguinal ligament* stretches between the pubic tubercle and the anterior superior iliac spine. It can be felt in the living groin as a tense resisting cord along the floor of the curved groove that extends between those two bony points. Though called a "ligament" it is the lower edge of the aponeurosis of the external oblique muscle of the wall of the abdomen; it lies along the line where the front of the thigh joins the abdomen, and is encountered in the first steps of the dissection of the lower limb. [An *aponeurosis* is a tendon or sinew in the form of a wide sheet: ἀπό (apo) = from; νεῦρον (neuron) = *nervus* = a sinew (though now both *neuron* and *nervus* always signify *nerve*).]

The **inferior ramus** is the short compressed bar which begins at the lower part of the body of the pubis, and passes downwards, backwards, and in a lateral direction to meet and fuse with the ramus of the ischium; the position of their junction may be marked by a thickening or a ridge, but is often difficult to make out in an adult bone. The two fused rami form a bar of bone called the **conjoined rami** of ischium and pubis. The bar has two surfaces and two borders. The *inner surface* is divided lengthwise by a ridge into an upper and a lower part; the upper part looks into the pelvis; the lower part looks into the perineum and gives attachment to the crus of the penis or of the clitoris. The *outer surface* is directed towards the thigh and gives attachment to thigh muscles. The *upper border* is the lower boundary of the obturator foramen. The *lower border* can be felt in the boundary between the medial side of the thigh and the anterior part of the perineum. The conjoined rami of the right and left hip bones constitute the sides of an arch called the **pubic arch.**

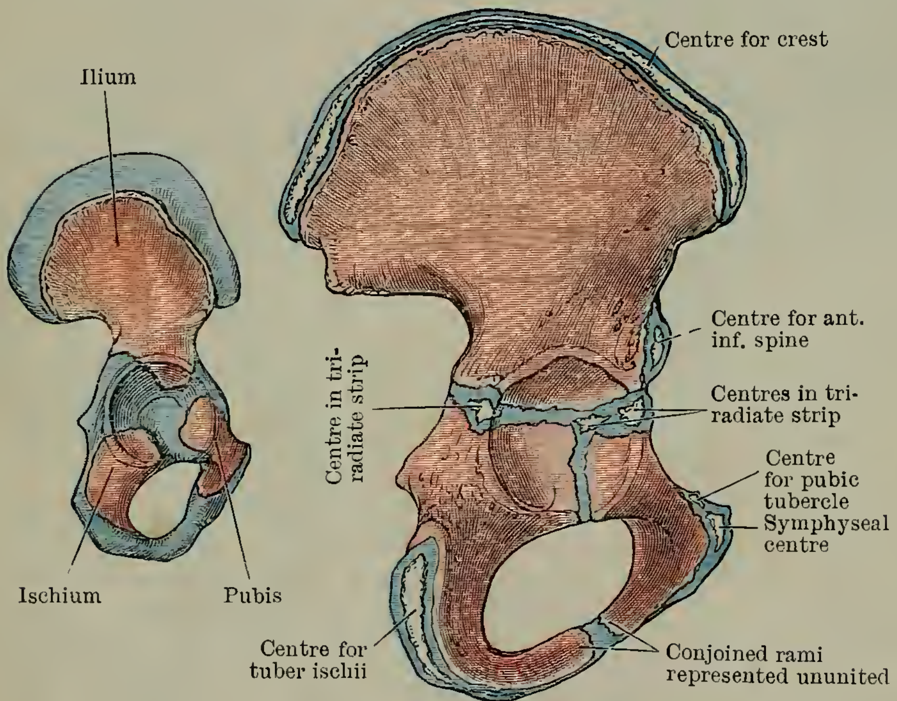
The **superior ramus**, though named merely a "ramus," is the true pubic bone. It has two ends, three borders, and three surfaces.

The **ends** are medial and lateral. The **medial end** is wide and compressed, and is described above as the "body" of the pubis. The **lateral end** is expanded to form part of the acetabulum and fuses there with the ilium and the ischium. The *ilio-pectineal eminence*, in front of the acetabulum, marks the position of its union with the ilium.

The **borders** are superior, anterior, and posterior. The **superior border** begins at or near the pubic tubercle and extends to the upper part of the ilio-pectineal eminence; it is usually a sharp edge, and is called the **pectineal line** [*pecten* = a crest or comb]. At the ilio-pectineal eminence it is continuous with the lower smooth part of the medial border of the ilium; the two together are called the **ilio-pectineal line**, which forms a great part of the brim of the pelvis minor. The **anterior border** or *obturator crest* is the blunt ridge that begins near the pubic tubercle and ends at the anterior margin of the acetabulum; it overhangs the obturator foramen. The **posterior border** is seen best from behind, *i.e.*, on the pelvic surface; it forms the anterior or upper boundary of the obturator foramen as seen from that point of view.

The **surfaces** of the superior ramus are named pectineal, pelvic, and obturator. The **pectineal surface** is the triangular area between the pectineal line and the obturator crest; the pectineus muscle arises from it; the femoral artery crosses its lateral end, but is separated from the bone by a muscle called psoas major. The **pelvic surface** is continuous with the pelvic surface of the body. The **obturator surface** is a broad oblique groove in the upper or anterior boundary of the obturator foramen; through that groove the obturator vessels and nerve pass out of the pelvis into the thigh.

Acetabulum.—The **acetabulum** is the large cup-shaped cavity on the lateral aspect of the hip bone [*acetabulum* = a vinegar cup]. It looks not only in a lateral direction, but also forwards and downwards. It articulates with the head of the femur to form the *hip joint.* The lower part of its wall is deficient, and the gap is called the **acetabular notch**; a fibrous band, called the *transverse ligament,* bridges across the notch and completes the rim. The floor of the acetabulum above the notch shows a large rough depression called the **acetabular fossa.** The rest of the inside of the cup is smooth and articular. The pubis forms about one-fifth of the acetabulum, the ischium rather more than two-fifths, and the ilium rather less than two-fifths.


Ilium
Ischium
Pubis
Centre for crest
Centre for ant. inf. spine
Centre in triradiate strip
Centres in triradiate strip
Centre for pubic tubercle
Symphyseal centre
Centre for tuber ischii
Conjoined rami represented ununited

At Birth. About 12 or 13 years.

Fig. 216.—Ossification of the Hip Bone.

Foramen Obturatum.—The **obturator foramen** is bounded by the ischium and the pubis and their rami. It is almost completely closed up with a thin, strong membrane called the *obturator membrane,* from which the foramen gets its name [*obturare* = to close up]. The outer and inner surfaces of the membrane are directed, respectively, towards the thigh and towards the cavity of the pelvis.

The **nutrient foramina** are scattered here and there on the surface of the hip bone.

Ossification.—From *three* **primary** centres and several secondary centres.

Primary Centre appears for	**Ilium,** above greater sciatic notch, early in 3rd month.	**Ischium,** below acetabulum, in 4th month.	**Pubis,** in superior ramus, in 5th month.

At birth the larger part of each bone is ossified, including a portion of its acetabular end, but a great deal is still gristle, viz.: upper part of ilium, greater part of acetabulum, lower end of ischium, medial part of body of pubis, and the conjoined rami. By the tenth year most of the cartilage is ossified, that between the three bones at the *acetabulum* being reduced to a triradiate strip; and the *conjoined rami* are completely ossified and fused together. Secondary centres appear in the acetabulum at twelve, and in the other parts at puberty.

Secondary Centre.	Appears at	Epiphysis unites at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
Two or three for triradiate strip	12th year	17	Inside laterally, outside medially.
One or two for iliac crest including superior spines	Puberty	20-25	None.
For anterior inferior spine	Puberty	20-25	Outside.
For ischial tuberosity	Puberty	20-25	None.
For symphyseal part of pubis	Puberty	20-25	No joint cavity.

Occasionally small epiphyses, which appear and fuse at the same times as those in the list above, are present for the pubic tubercle, pubic angle, and ischial spine. The portions ossified from the centres in the acetabulum fuse with the nearest bone; *os acetabuli* is the name given to the part that joins the pubic bone.

Structure and Variations.—The hip bone is composed of spongy substance enclosed in compact substance, except in the centre of the iliac fossa and the floor of the acetabulum, where spongy bone is absent; occasionally the compact bone also is absent in one or other of those two situations. The bone is thickest and strongest above the acetabulum, between it and the auricular surface, for through that part the weight of the trunk is transmitted from the sacrum to the femur. The *os acetabuli* may remain a separate bone; the acetabular notch may be absent. The groove in the upper boundary of the obturator foramen is in rare cases converted into a tunnel. A separate articular facet may be present above the auricular surface, for articulation with a small facet on the back of the sacrum lateral to the first sacral foramen (Derry). The ischial and pubic rami sometimes fail to unite.

Pelvis.

The **pelvis** is the lower subdivision of the abdomen [*pelvis* = a basin], and the large crate that constitutes its bony framework is also called the pelvis. The bony pelvis is made up of the two hip bones and the portions of the backbone or vertebral column which are called the sacrum and the coccyx. The two hip bones form the sides of the pelvis and its ventral wall, the right and left pubic bones being joined together by the symphysis at the median plane in front; the sacrum and coccyx form its dorsal wall, the sacrum being wedged in between the hip bones and held in place by strong ligaments, while the coccyx lies below the sacrum between the hip bones and also is attached to them by ligaments.

The pelvis provides a large surface for the attachment of muscles, especially those which move the lower limb; it contains and protects the urinary bladder, some of the organs of reproduction, and part of the alimentary canal; but the chief use of the bony pelvis is to serve as a firm unyielding base for the trunk resting on the thighs. The curved or ring-like construction of the pelvic framework prevents its collapse under the weight of the body, which is borne at only two points on the framework—where the thigh bones articulate with the pelvis.

Inclinatio Pelvis.—The pelvis does not occupy the position in the body which is suggested by its stance when it is set on a table. Its upper part is tilted forwards, so that when the body is in the erect posture the pubic tubercles and the anterior superior iliac spines are all in one vertical plane, and the tip of the coccyx is on a level with the upper margin of the symphysis pubis; the *anterior* or ventral wall is therefore largely *inferior*, and the *posterior* or dorsal wall is largely *superior*. The tilt of the pelvis is called the *inclination of the pelvis.*

Foramina Ischiadica.—A wide interval separates the lower part of the hip bone from the coccyx and the lower part of the sacrum. The interval is crossed by two fibrous bands named the *sacro-tuberous* and *sacro-spinous ligaments*. They are such important parts of the pelvis that in many prepared skeletons they are preserved. The **sacro-tuberous ligament** is a long, strong band which stretches from the sacrum and coccyx to the ischial tuberosity. The **sacro-spinous ligament** is a shorter, flatter band that stretches across the pelvic surface of the sacro-tuberous ligament from the sacrum and coccyx to the ischial spine. Those two ligaments convert the sciatic notches of the hip bone into foramina, named the **greater sciatic foramen** and the **lesser sciatic foramen**, through which muscles, nerves, and vessels pass between the pelvis and buttock. The dissector of the lower limb encounters both the ligaments and the foramina during the dissection of the gluteal region. (See Figs. 286, 287, p. 338.)

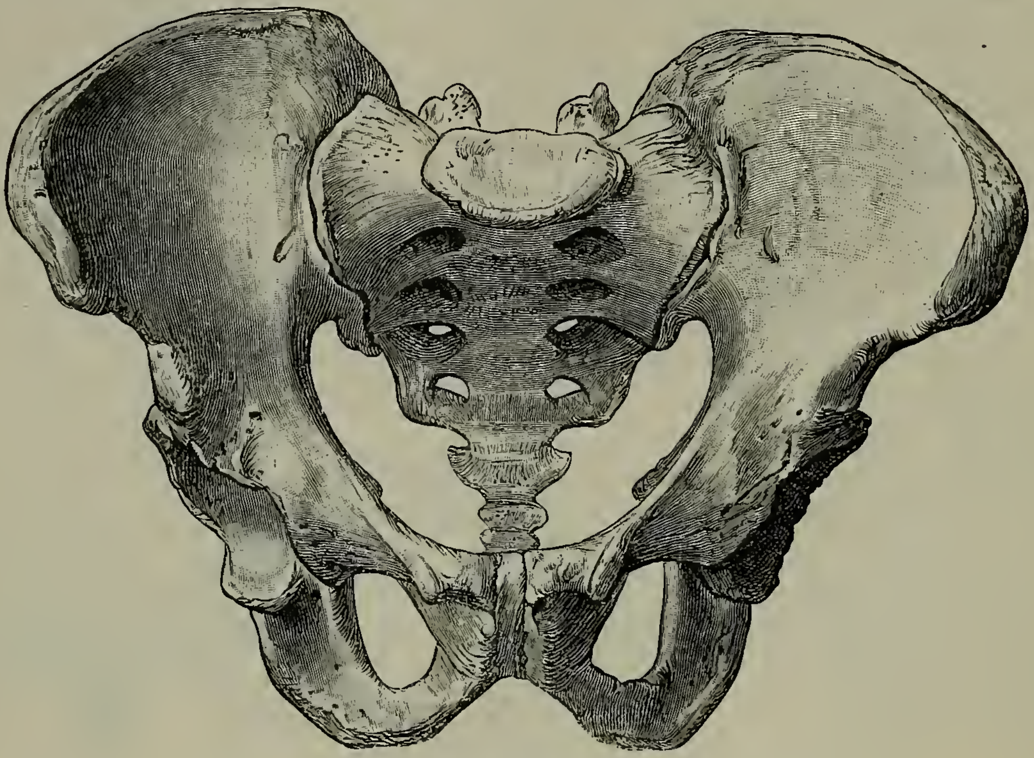


Fig. 217.—The Male Pelvis seen from the front.

Arcus Pubis.—The **pubic arch** is the arch formed by the conjoined rami of ischium and pubis of the two sides. The apex of the arch is the lower margin of the symphysis pubis and is rounded off by a fibrous band called the *arcuate ligament,* the fibres of which curve from one side to the other just below the symphysis. The archway is to a large extent filled in by a sheet of muscle called the *urogenital diaphragm,* which is covered on both upper and lower surfaces with fibrous

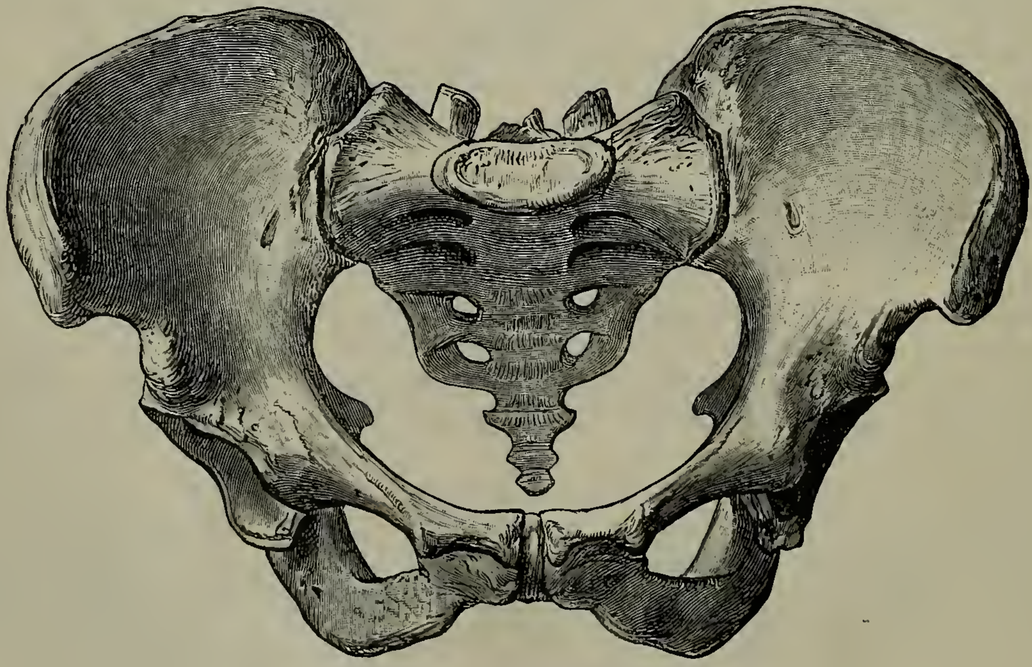


Fig. 218.—The Female Pelvis seen from the front.

membrane or fascia; the inferior fascia is a strong membrane comparable to the obturator membrane.

Pelvis Major.—The pelvis is divided into the pelvis major and the pelvis minor. The **pelvis major** is the part above the level of the sacrum and the ilio-pectineal lines; it forms part of the walls of the abdomen proper.

Pelvis Minor.—The **pelvis minor** is the true pelvis. When reference is made to "the pelvis" in the description of muscles, viscera, etc., it is usually the pelvis minor only that is meant. The bones which form it are the sacrum and coccyx, the pubis, the ischium, and the lower part of the sacro-pelvic surface of the ilium.

The **cavity** of the pelvis minor is a short, wide canal or tunnel which is curved in general conformity with the curve of the sacrum and coccyx; in length it measures five or six inches along the sacrum and coccyx, but only one and a half or two inches along the symphysis pubis. The cavity is continuous with that of the abdomen proper at the *inlet* or **superior aperture** of the pelvis, the boundaries of which constitute the **brim** of the pelvis. The aperture is directed forwards rather than upwards, and its *boundaries* are: (1) the promontory of the sacrum in the median plane *behind*; (2) the upper margin of the symphysis pubis in the median plane *in front*; and, *on each side* from behind forwards, (3) the anterior margin of the ala of the sacrum, (4) the ilio-pectineal line, and (5) the crest of the pubis. The *outlet* or **inferior aperture** of the pelvis is *bounded* by: (1) the coccyx in the median plane *behind*; (2) the lower margin of the symphysis pubis in the median plane *in front*; and, *on each side* from behind forwards, (3) the sacro-tuberous ligament, (4) the lower end of the ischium, and (5) the side of the pubic arch. These are also the boundaries of the region called the *perineum*, which is shut off from the cavity of the pelvis by the urogenital diaphragm and two pairs of thin muscles called the levatores ani and the coccygei.

Planes and Axes of the Pelvis.—The **plane of the superior aperture** is the plane in which the sacral promontory and the upper margin of the symphysis pubis lie; owing to the inclination of the pelvis it forms an angle of about 60° with the horizontal. The **plane of the inferior aperture** is that in which the tip of the coccyx and the lower margin of the symphysis lie; it forms an angle of only 10° to 15° with the horizontal, because the symphysis is much shorter than the sacrum and coccyx. The **planes of the cavity** are a plane that passes through the middle of the third sacral vertebra and the middle of the symphysis pubis, and any number of planes set in intermediate positions between that plane and those of the apertures. The **axis of the superior aperture** is a line drawn at right angles to the centre of its plane; the line, if continued, would pass through the umbilicus and through the tip of the coccyx. The **axis of the inferior aperture** is a line drawn at right angles to the centre of its plane; if continued upwards the line would strike the sacral promontory. The **axis of the pelvis** is a line drawn through the centres of the planes of the cavity and the apertures; it is therefore curved and parallel to the curve of the sacrum and coccyx.

Diameters of the Pelvis.—The **intercristal diameter** is the distance from the outer lip of one iliac crest to that of the other where they are furthest apart. The **interspinous diameter** is the distance between the two anterior superior iliac spines. The **external antero-posterior diameter** is the distance between the tip of the spine of the first sacral vertebra and the upper margin of the symphysis pubis.

The **diameters of the pelvis minor** are of more importance.

Diameters of Superior Aperture.—*Antero-posterior* or conjugate: from the middle of the sacral promontory to the upper margin of the symphysis pubis. *Transverse*: across the aperture where it is widest. *Oblique*: from one sacro-iliac joint to the ilio-pectineal eminence of the other side.

Diameters of Cavity.—*Antero-posterior*: from the centre of the pelvic surface of the middle piece of the sacrum to the middle of the pelvic surface of the symphysis pubis. *Transverse*: across the cavity where it is widest. *Oblique*: from the posterior end of one sacro-iliac joint to the centre of the obturator membrane of the other side.

Diameters of Inferior Aperture.—*Antero-posterior*: from the tip of the coccyx to the lower margin of the symphysis pubis; it varies in the same pelvis, especially in the female, owing to the mobility of the coccyx. *Transverse*: across the aperture where it is widest. *Oblique*: from the point where the sacro-tuberous and sacro-spinous ligaments of one side cross each other to the junction of the pubic and ischial rami of the other side.

The first three diameters are slightly longer in a man's pelvis; but all the diameters of the pelvis minor are longer in a woman's pelvis than in a man's. Measurements vary in individuals of the same sex. In the following table the smaller figures are average measurements in inches and correspond to those given in Quain's *Anatomy*, 10th Edition; the large figures are millimetres, not the exact equivalents of the inches, but the nearest to them in round numbers (25 mm. is very slightly less than 1 inch).

	Female.			Male.		
Intercristal . . .	11 ; 275			11¼ ; 280+		
Interspinous . . .	9¼ ; 230+			9½ ; 235+		
External antero-posterior	7 ; 175			7¼ ; 180+		
Pelvis Minor.	Superior Aperture.	Cavity.	Inferior Aperture.	Superior Aperture.	Cavity.	Inferior Aperture.
Antero-posterior . .	4½ 110+	5 125	4-5 100-125	4 100	4¼ 105+	3¼ 80+
Transverse . . .	5¼ 130+	5 125	4¾ 120 –	5 125	4¾ 120 –	3½ 85+
Oblique	5 125	5¼ 130+	4½ 110+	4¾ 120 –	4½ 110+	4 100

Sexual Differences.—The pelvis of a woman differs from that of a man in many particulars, because the female pelvis is modified for the function of child-bearing. Distinctive sex characters are present in the fœtal pelvis, appearing as early as the third or fourth month of fœtal life; they are less marked in childhood; they become fully developed after puberty. The essential differences between male and female pelves are in the pelvis minor. The female pelvis minor is absolutely wider in all the diameters, especially in those of the inferior aperture, so that the cavity is less funnel-shaped; but the cavity is shorter. Nearly all the differences in detail are due to the fact that the cavity of the **pelvis minor** in the **female** is *roomier, less funnel-shaped,* and *shorter.* Most of the differences cannot be appreciated by a beginner unless he has at hand both a male and a female pelvis which he can compare; but the following difference will enable him to decide whether the specimen of pelvis or of hip bone which he is using for study is male or female: the **pubic arch** in the **female** is *wide* and its *apex is rounded*; it is usually wide enough to accommodate a right angle; in the male it is less than a right angle, and the apex is rather pointed.

The differences in detail are very numerous. The chief of them are that **in the female**—The bones are lighter and thinner, and muscular markings are less evident. The *ilium* is less everted and the *iliac fossa* is shallower. The **superior aperture** is larger, and is kidney-shaped rather than heart-shaped; its *plane* forms a wider angle with the horizontal, for the tilt of the pelvis is greater, so that the anterior superior iliac spines are even further forward than the pubic tubercles; the *sacral promontory* projects less, and the *pubic tubercles* are wider apart. The **cavity** is less funnel-shaped, is shorter, but is much roomier. The *sacrum* is shorter and wider, and its curve is said to be less uniform, being flatter above and more sharply turned forwards below. The **inferior aperture** is much larger. The *pubic arch* is wider and more rounded. The *coccyx* is more movable. The *sciatic notches* are wider and shallower; the *ischial spine* is less inturned. The *obturator foramen* is smaller and may be triangular in outline rather than oval. The *acetabula* are further apart and are smaller, especially relatively, for the head of the femur is smaller in a woman while the hip bone is larger. A pre-auricular sulcus is present just in front of the convex margin of the auricular surface of the ilium.

Growth of the Pelvis.—At birth, in either sex, the pelvis is relatively small; and so are the lower limbs, which are then only about a quarter of the length of the body. After birth the lower limbs grow much more rapidly than the rest of the body, especially after the first year when the child begins to learn to walk. The whole pelvis keeps pace with the lower limbs; it gives origin to a great number of the muscles that move the limbs, and grows concurrently with them to provide them with adequate attachments. At birth the pelvis minor is not big enough to hold the pelvic organs; the greater part of the urinary bladder and, in the female, the uterus and ovaries are in the abdomen proper; but by the sixth year the pelvis has grown large enough to contain them. The rate and manner of growth are similar in boys and girls till puberty, when the growth is modified to produce the distinctive sex characters of the adult pelvis.

Besides mere relative increase of size, there are other changes in the pelvis when the child, learning to walk, straightens out the lower limbs and adopts the erect attitude. The principal changes are: (1) The upper part of the pelvis is tilted forwards so that the sacro-vertebral angle, *i.e.*, the angle between the front of the sacrum and the last lumbar vertebra, becomes less obtuse. (2) The basal or upper part of the sacrum, now bearing the weight of the trunk obliquely, sinks more deeply between the two hip bones, and that further accentuates the sacro-vertebral angle. (3) The sacrum becomes more curved also, for while the weight of the trunk bends the basal part downwards, the apical part is held down and prevented from tilting up by the sacro-tuberous and sacro-spinous ligaments. (4) At the same time the hip bone, where it bounds the pelvis minor, becomes curved outwards, and thus the pelvis minor is widened; for those parts of the two hip bones, at that time, resemble the limbs of the letter V, the apex being at the symphysis pubis; the sacrum lies between the upper ends of the limbs of the V, and the weight of the trunk is transmitted to them through the sacrum; they are fastened to the sacrum at their upper ends and to each other at the apex, *i.e.* at the symphysis pubis, and therefore, under the weight of the trunk, have to bend outwards in the middle. (5) The acetabulum becomes deeper to make the hip joint more stable. (6) The part of the ilium between the acetabulum and the auricular surface, through which the weight of the trunk is transmitted from sacrum to femur, grows stronger, and in consequence of its growth the iliac part of the ilio-pectineal line becomes better defined.

Attachments.—(A) Of Structures encountered in the Dissection of the Lower Limb.— The lateral end of the inguinal ligament is attached to the **anterior superior iliac spine.** The sartorius muscle arises from that spine and from part of the notch below; the tensor fasciæ latæ muscle from the spine and the adjoining two inches of the outer lip of the **iliac crest.** The lateral part of the fascia lata is attached to the whole length of the outer lip of the crest, its ilio-tibial tract being attached to the **tubercle of the crest**; the ilio-femoral ligament to the lower part of the **anterior inferior spine**; the straight head of the rectus femoris muscle from its upper part; the reflected head from the rough depression on the **dorsum ilii** just above the acetabulum; the gluteus minimus muscle from the area between the *inferior* and *anterior gluteal lines*; the gluteus medius from the area between the *anterior* and *posterior gluteal lines*; the gluteus maximus from the upper, rough part of the area behind the *posterior line* and from the *back* of the **sacrum** and *sacro-tuberous ligament*; the iliacus muscle from the **iliac fossa**; the piriformis muscle from the *pelvic surface* of the middle three pieces of the **sacrum,** and from the upper margin of the **greater sciatic notch** and the sacro-tuberous ligament, as the muscle emerges from the pelvis through the *greater sciatic foramen*; the obturator internus muscle from the side wall of the cavity of the pelvis, viz., the inner surface of the **obturator membrane,** the bone around the obturator foramen, especially the wide, flat area between the foramen and the greater sciatic notch, and the fibres converge on the tendon, which leaves the pelvis through the *lesser sciatic foramen*; the superior gemellus muscle from the **ischial spine** where it forms the upper boundary of the lesser sciatic foramen; the inferior gemellus from the **ischial tuberosity** where it forms the lower boundary. The sacro-spinous ligament stretches from the tip of the *ischial spine* to the side of the last piece of the *sacrum* and first piece of the *coccyx.* The sacro-tuberous ligament covers the dorsal surface of the medial and larger part of the sacro-spinous ligament; its upper end widens out to be attached to the side of the *coccyx* and *sacrum* and to the **posterior superior** and **posterior inferior iliac spine**; its lower end widens out to be attached to the medial margin and lower medial area of the **ischial tuberosity,** and sends a prolongation, called its *falciform process*, forwards along the inner surface of the *ischial ramus.* The quadratus femoris muscle arises from the *lateral margin* of the **ischial tuberosity.** The surface of the tuberosity is divided by a transverse line into an upper and a lower part, and each of those is divided into a lateral and a medial part. The tendon of the semimembranosus arises from the *upper lateral* area; the tendons of the semitendinosus and the short head of the biceps conjointly from the *upper medial* area; the adductor magnus muscle from the *lower lateral* area and from the lower part of the outer surface of the *conjoined rami*, the sacro-tuberous ligament being attached to the *lower medial* area.

The medial end of the inguinal ligament is attached to the **pubic tubercle,** and its expansion, called the lacunar ligament, to the medial inch of the **pectineal line.** The pectineus muscle arises from the *pectineal line* and *pectineal surface* of the **pubis**; the tendon of the adductor longus from the *femoral surface* of the body of the pubis, in the angle between the crest and the symphysis; the gracilis muscle from the margin of the *symphysis* and of the **inferior ramus**; the adductor brevis muscle from a broad strip lateral to the gracilis and below the adductor longus; the obturator externus muscle from the area below and in front of the obturator foramen and from the adjoining half of the **obturator membrane,** and as it winds backwards below the neck of the femur it lies in the wide groove below the acetabulum.

The fascia lata has a continuous attachment to the inguinal ligament, the lower lip of the pubic crest, the margin of the symphysis pubis, the lower margin of the conjoined rami, the medial margin of the ischial tuberosity, the medial margin of the sacro-tuberous ligament, the back of the sacrum and coccyx, and the whole length of the outer lip of the iliac crest.

The transverse ligament bridges across the *acetabular notch* and completes the rim of the acetabulum. The ligamentum teres femoris spreads out to be attached to the transverse ligament and the margins of the **acetabular notch** and **fossa.** A fibro-cartilaginous ring, called the labrum glenoidale, is attached to the *rim* and serves to deepen the cavity of the acetabulum and narrow its mouth. The fibrous capsule of the hip joint is attached to the labrum below and in front, to the bony rim above and behind, and to the rough strip above the acetabulum. The thickened parts of the capsule are attached as follows: the ilio-femoral ligament to the lower part of the *anterior inferior iliac spine*; the pubo-capsular ligament to the lateral end of the *obturator crest*; the ischio-capsular ligament to the *ischium* below the acetabulum.

(B) **Of Structures encountered in the Dissection of other Parts.**—The iliacus muscle arises from the upper and larger part of the floor of the **iliac fossa.** The fascia iliaca and part of the transversalis fascia are continuous with each other at the *inner lip* of the **iliac crest** above the iliac fossa and are loosely attached to that part of the lip. Part of the transversus abdominis arises from the anterior half of the inner lip; part of the quadratus lumborum from the inner lip immediately behind the transversus, above the posterior part of the iliac fossa; a slip of the latissimus dorsi from the corresponding part of the *outer lip.* Part of the external oblique is inserted into the anterior half of the outer lip, and part of the internal oblique arises from the anterior half of the *intermediate line.* The ilio-lumbar ligament is attached to the upper end of the **medial border** of the ilium; the anterior ligament of the sacro-iliac joint to the convex margin of the **auricular surface**; the interosseous and short posterior sacro-iliac ligaments to the lower half of the iliac **tuberosity**; the lower part of the sacro-spinalis arises from the upper half, and from the back of the *sacrum.* The long posterior sacro-iliac ligament stretches from the **posterior superior iliac spine** to the side of the back of the sacrum half-way down; the sacro-tuberous ligament stretches from both *posterior spines* and from the side of the sacrum and coccyx to the lower part of the **ischial tuberosity** and the *ischial ramus.* The sacro-spinous ligament stretches from the tip of the **ischial spine,** across the pelvic surface of the sacro-tuberous ligament, to the side of the last piece of the sacrum and the first piece of the coccyx; the coccygeus muscle lies on the front of the sacro-spinous ligament and has the same attachments, the ligament being merely the degenerated dorsal fibres of the muscle. The piriformis muscle arises from the *pelvic surface* of the second, third, and fourth pieces of the **sacrum,** from the upper margin of the *greater sciatic notch,* and from the sacro-tuberous ligament; the obturator internus from the side wall of the pelvic cavity; the posterior fibres of the levator ani from the *ischial spine,* its anterior fibres from the *pelvic surface* of the **body of the pubis** below its middle, the greater part of the muscle from the fascia covering the obturator internus. The pubo-prostatic ligaments are attached to the pubis above the levator ani.

The fibro-cartilage of the symphysis pubis is attached to the **symphyseal border** or surface; the superior, anterior, posterior, and inferior pubic ligaments to the *margins* of that surface, the inferior ligament being called the arcuate ligament because on each side it curves backwards on to the inferior pubic ramus.

Part of the fascia transversalis is attached to the posterior or upper lip of the **pubic crest** and to the medial half of the **pectineal line.** The rectus abdominus arises from the crest in front of the fascia and from the anterior pubic ligament; the pyramidalis from the crest in front of the rectus. The falx inguinalis or conjoined tendon is attached to the anterior ligament of the *symphysis* below the rectus, to the *crest* in front of the pyramidalis, and to the *pectineal line* in front of the fascia transversalis; the reflex inguinal ligament (when present) to the medial half-inch of the pectineal line in front of the falx; the lower medial part of the external oblique aponeurosis to the anterior or lower lip of the pubic crest and to the anterior ligament of the pubis, below the falx inguinalis.

The inguinal ligament stretches from the anterior superior iliac spine to the **pubic tubercle** and, by means of the lacunar ligament, to the medial inch of the *pectineal line,* in front of the reflex ligament. One end of the loops of the cremaster muscle is attached to the pubic tubercle behind the inguinal ligament. The tendon of the psoas minor is inserted partly into the **ilio-pectineal line** and **eminence.**

The fascia of Colles (*i.e.,* the deeper membranous layer of the superficial fascia of the perineum) is attached to the lower margin of the **ischial ramus.** The crus penis or crus clitoridis is attached to the lower half of the *inner surface* of the **conjoined rami,** the lower half usually being grooved lengthwise for the lodgment of the crus. The ischio-cavernosus and transversus perinei superficialis arise from the posterior end of the groove. The urogenital diaphragm and its inferior fascia are attached to the ridge between the upper and lower halves of the surface; immediately above them the pubic part of the ridge gives attachment to the arcuate ligament, and the ischial part to the falciform process of the sacro-tuberous ligament. Fibres of the obturator internus arise from the upper half of the surface, *i.e.,* the strip between the ridge and the obturator foramen; the fascia covering that muscle blends with the falciform process, and gives attachment to the superior fascia of the urogenital diaphragm.

Femur.

The **femur** or thigh-bone is the longest and strongest and heaviest bone in the skeleton, and is between a third and a fourth of the length of the body. It has a shaft or **body** and **two ends.** It is so thickly covered with muscles that, in the living body, it can be palpated only at and near the ends. The beginner should at once proceed to distinguish the proximal end from the distal end, the front of the bone from the back, and the medial side from the lateral side. The larger end of the bone is the **distal** end, and it is partially divided into two, the wide notch between the two parts being on the **posterior** aspect; the globular head at the proximal end is on the **medial** side.

The **proximal end** includes the head, the neck, the greater trochanter and the lesser trochanter.

The **head** is smooth and is almost a sphere. It fits into the acetabulum to form the *hip joint.* On its medial aspect there is a rough, shallow pit to which the apex of a triangular fibrous band, called the ligamentum teres femoris, is attached. [The name is not aptly chosen: *teres* = round.]

The **neck** is the thick bar that connects the head with the body of the bone in the region of the trochanters. It is nearly two inches long, is thinnest in the middle and widens towards each end, especially the end which joins the body, so that while the upper border is nearly horizontal the lower border is very oblique. The neck joins the body at an angle and is therefore liable to be broken; but a long neck joined to the shaft at an angle enables the femur to be moved freely and extensively, even though the head is deeply and stably articulated to the side of the pelvis.

The **greater trochanter** is the large, square prominence on the lateral aspect where the neck joins the shaft; its upper part stands up above the level of the adjacent part of the neck; its root is marked off from the shaft by a more or less horizontal ridge. It is the bone felt in front of the hollow on the side of the hip, and the body falls on it in a fall sideways; its upper border is on a level with the upper border of the symphysis pubis and with the centre of the hip joint. Many of the muscles of the gluteal region are inserted into the greater trochanter [τροχαντήρ (trochantēr) = a runner]. The rough pit on the medial side of the trochanter, where it joins the back of the neck, is called the **trochanteric fossa**.

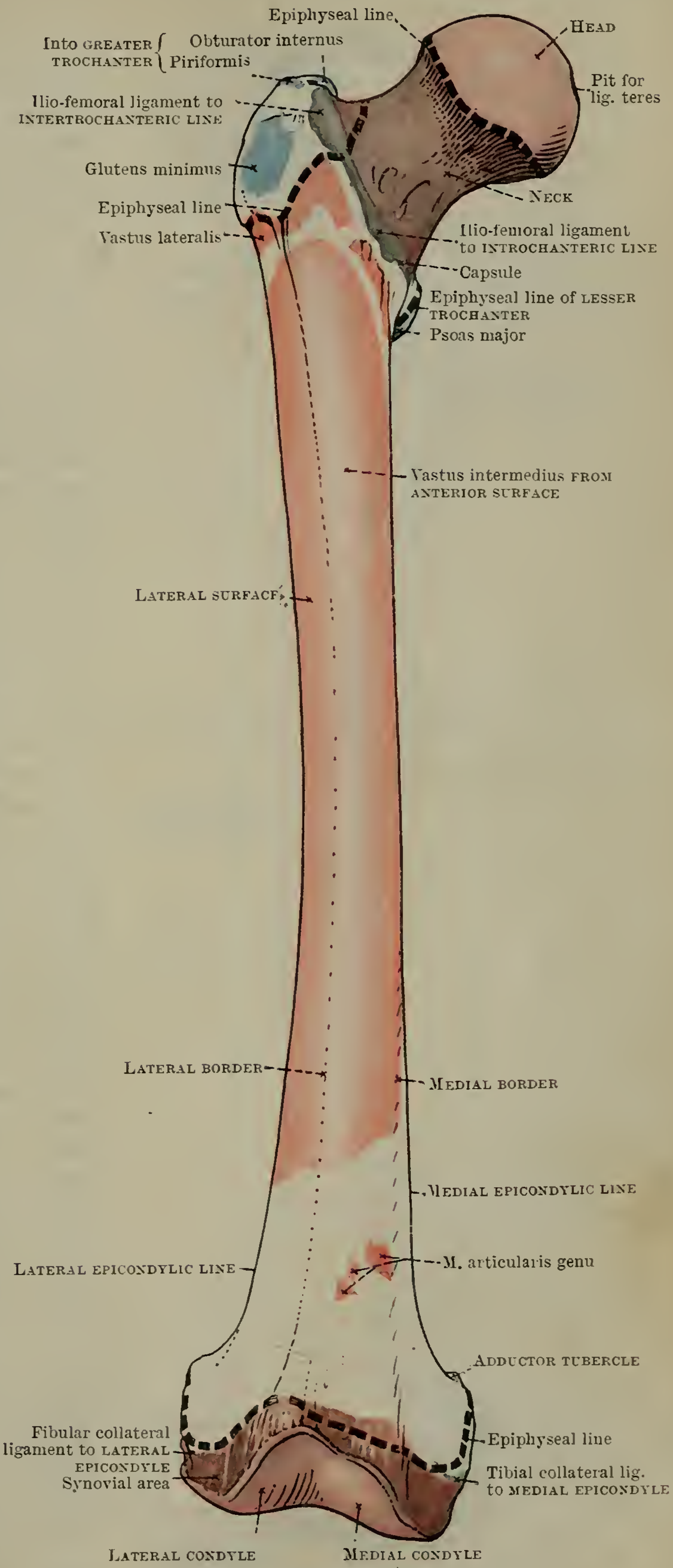


FIG. 219.—FRONT OF RIGHT FEMUR.

The **lesser trochanter** is the rounded, conical projection on the posterior and medial aspect of the bone where the lower part of the neck joins the body.

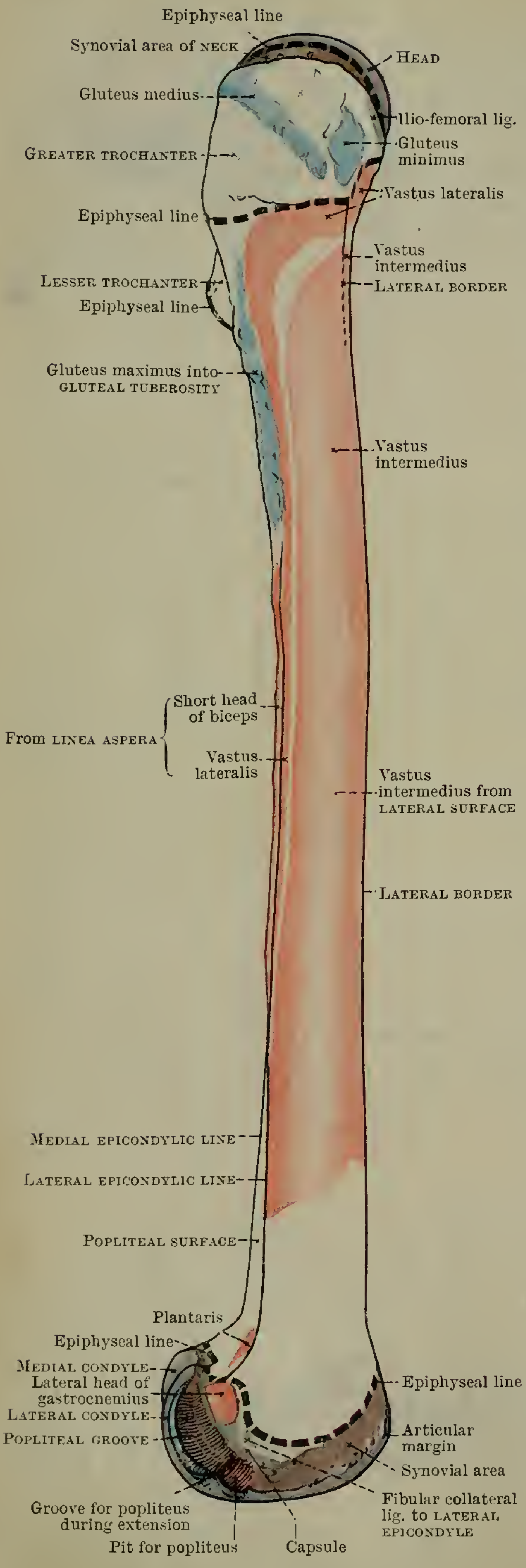


FIG. 220.—LATERAL ASPECT OF FEMUR.

The ridge connecting the lesser trochanter with the back of the greater trochanter is called the **trochanteric crest**. The low, rounded swelling on or alongside the crest, on the back of the trochanter major, is called the **quadrate tubercle** because part of the quadratus femoris muscle is inserted into it. The **intertrochanteric line** is the rough, broad line which extends from the upper part of the anterior surface of the greater trochanter towards the lesser trochanter, and marks the union of the front of the neck with the front of the body; though called "intertrochanteric" it does not reach the lesser trochanter, but becomes continuous with a faint ridge, called the *spiral line*, which winds to the back of the bone below the lesser trochanter.

The **distal end** of the femur consists of two large masses called *condyles*, which are separated posteriorly by a wide deep interval called the *intercondylar notch*.

Condyli.—Anteriorly the **condyles** are nearly in line with the front of the shaft, but they bulge backwards considerably beyond the plane of the shaft. The anterior, distal, and posterior aspects of each condyle are smooth and articular. The *anterior parts* of the two are joined together, forming a wide surface for articulation with the patella. This **patellar surface** is deeply concave from side to side; its lateral part is more prominent than the medial, and extends farther up, so that the proximal margin of the surface is sloping. The tibia articulates with the *distal surfaces* when the knee is extended, and with the *posterior surfaces* when the knee is flexed. The surfaces which form the sides of the intercondylar notch are rough for the attachment of strong fibrous bands, called the cruciate ligaments, which lie inside the knee joint and help to bind the femur and tibia together.

On the *lateral surface* of the **lateral condyle** there is a prominence, called the *lateral epicondyle*, much nearer the back of the bone than the front; above it there is a pit or impression for the origin of the lateral head of the gastrocnemius; below it there is a pit for the origin of the tendon of the popliteus; a groove, in which the tendon lies when the knee is acutely flexed, runs upwards and backwards from the pit close alongside the articular margin. The **medial condyle** stands further away from the shaft than the lateral condyle does. Its medial surface is rough and convex; its most prominent part is called the *medial epicondyle.* On the uppermost part of the condyle there is a small, sharp prominence, called the **adductor tubercle** because the tendon of the adductor magnus is inserted into it.

The condyles can be felt as large prominences at the sides of the knee; the adductor tubercle can be felt at the most proximal part of the medial condyle, and is often used as a landmark; the tendon of the adductor magnus can usually be felt as it descends to the tubercle, but it is not the only tendon that can be felt at the medial side of the knee. When the knee is flexed, the patellar surface of the femur can be felt (or, at any rate, its lateral and medial margins), for the patella is drawn off it when the leg is bent; and a portion of the distal surface of each condyle can be felt at the side of the *ligamentum patellæ,* which is the thick broad band felt between the patella and the tibia.

Corpus Femoris.—The **body** or shaft of the femur is thinnest in its middle third and widens towards each end, especially the distal end.

The **middle third** has

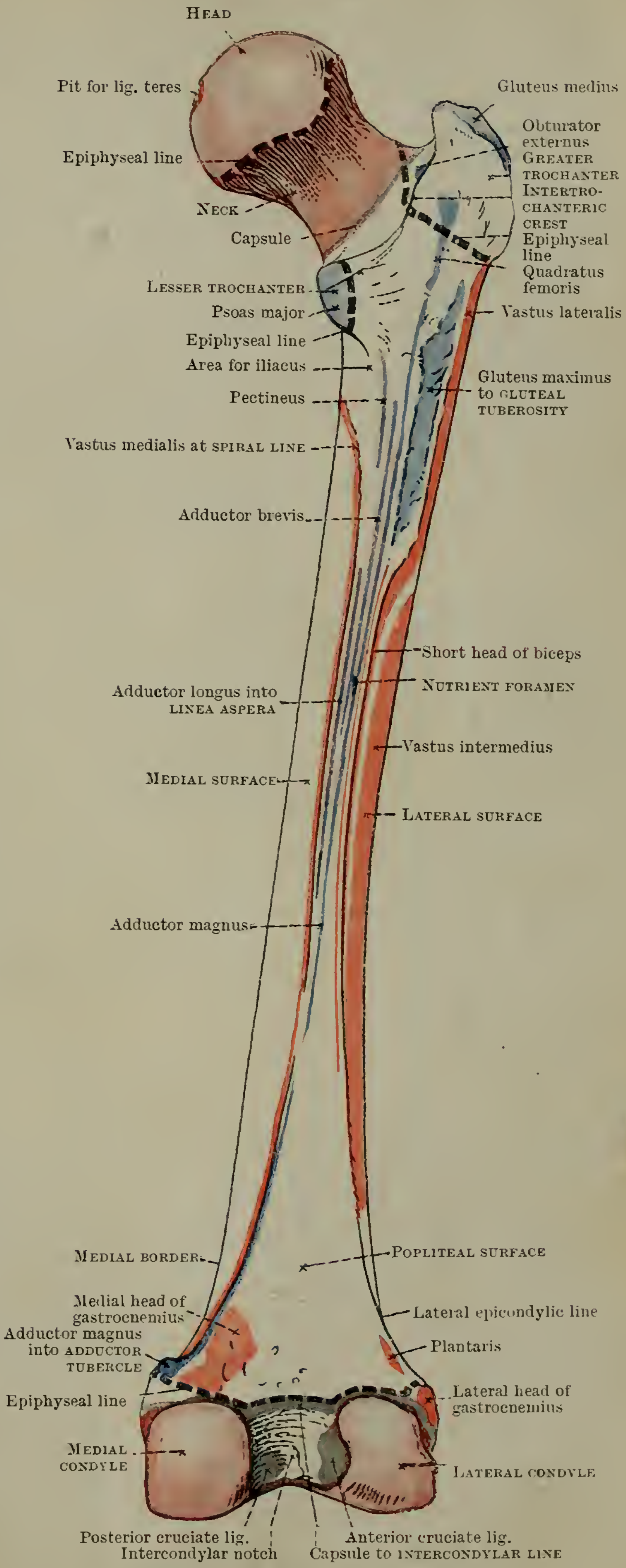


FIG. 221.—BACK OF RIGHT FEMUR.

three surfaces and three borders. The *surfaces* are anterior, medial, and lateral; the *borders* are posterior, lateral, and medial.

The *lateral* and *medial borders* are blunt and ill-defined, so that the *anterior surface* is not sharply marked off from the *lateral* and *medial surfaces*; but the *posterior border*, which separates the medial surface from the lateral surface, is well-defined and rough, and is called the linea aspera.

The **linea aspera** is the rough ridge on the back of the femur, and it is limited to the middle third of the bone. Its margins are called its *lips—lateral* and *medial*; the lateral lip is the sharper and better defined of the two. At the proximal and distal ends of the linea aspera the lips diverge from each other and become continuous with ridges, bearing different names, on the proximal and distal thirds of the femur.

At the **proximal third** the *medial* lip becomes continuous with a narrow ridge, called the **spiral line**, which winds obliquely round the medial side of the femur on to the front of the bone and becomes continuous with the intertrochanteric line. The *lateral* lip becomes continuous with a long, broad, rough mark, called the **gluteal tuberosity**, which is situated on the back of the proximal third of the femur towards the lateral side, and extends from the linea aspera to the trochanter major; it receives its name because part of the gluteus maximus muscle is inserted into it. The proximal third of the body of the femur has therefore *four* surfaces: the three surfaces continuous with those of the middle third, and an additional, fourth surface—the *posterior surface*—between the gluteal tuberosity and the spiral line.

At the **distal third** of the femur the *lateral* lip of the linea aspera becomes continuous with the **lateral epicondylic line**, which extends as a well-defined line to the lateral condyle. The *medial* lip becomes continuous with the **medial epicondylic line**, which extends to the adductor tubercle, and may serve as a guide to the tubercle if it has not been identified already. The medial epicondylic line is never so well defined as the lateral, largely because it is worn down by the femoral vessels as they pass from the medial side of the thigh into the popliteal fossa and change their name to popliteal vessels. The distal third of the body of the femur also has *four* surfaces: anterior, medial, and lateral, continuous with those of the middle third, and a *posterior surface* between the epicondylic lines. The posterior surface is usually called the **popliteal surface**, because it forms a great part of the floor or anterior wall of the popliteal fossa; on its distal part, above the medial condyle, there is a rough, raised mark, about half an inch wide each way, from which the medial head of the gastrocnemius muscle arises.

The **nutrient foramen** of the femur is situated on or near the linea aspera, and is directed towards the proximal end.

Attachments.—The ligamentum teres is attached to the *pit* on the **head.** The capsule of the hip joint is attached to the back of the **neck** a finger's-breadth from the trochanter, to the upper and lower borders of the neck near the trochanters, and to the **intertrochanteric line**; the part of the neck within the capsule is clothed with synovial membrane. The uppermost fibres of the vastus medialis muscle arise from the lower half of the intertrochanteric line; the uppermost fibres of the vastus lateralis from the upper half of the line, and from the front and lateral aspect of the root of the **greater trochanter.** The gluteus minimus is inserted into the *front* of the greater trochanter, and is partly separated from it by a *bursa*; the gluteus medius into its *lateral surface* on a broad, oblique ridge that extends downwards and forwards from the posterosuperior angle; the surface in front of the ridge is separated from the gluteus medius by a *bursa*, and another *bursa* intervenes between the gluteus maximus and the surface behind the ridge; the piriformis into the *upper border*; the obturator internus and the gemelli into the *medial surface* above the neck; the obturator externus into the **trochanteric fossa**; the quadratus femoris into the **quadrate tubercle** and into a strip leading down from the tubercle for an inch; the psoas major into the **lesser trochanter**; the iliacus into the tendon of the psoas, the lesser trochanter, and the area below and in front of the trochanter.

Part of the gluteus maximus is inserted into the **gluteal tuberosity**, and part of the vastus lateralis arises from its lateral edge; part of the vastus medialis from the **spiral line.** The surface between the spiral line and the gluteal tuberosity gives insertion to four muscles: part of the iliacus (see above); the pectineus into a strip which begins lateral to the back of the root of the lesser trochanter and runs down to the linea aspera; the upper part of the adductor brevis into the same strip, behind or lateral to the pectineus; the uppermost fibres of the adductor magnus between the attachment of the adductor brevis and the gluteal tuberosity.

The **linea aspera** gives attachment to the following structures, named from medial to lateral side: the origin of part of the vastus medialis; the medial intermuscular septum; the insertion of the adductor longus, in the whole length of the line or in the distal two-thirds only; the insertion of the lower part of the adductor brevis, in the proximal third of the line; the insertion of a part of the adductor magnus; the posterior intermuscular septum; the origin of the greater part of the short head of the biceps femoris; the lateral intermuscular septum; the origin of part of the vastus lateralis from the proximal half of the line, and of part of the vastus intermedius from the distal half.

From medial to lateral side the following structures are attached to the **epicondylic lines**: part of the vastus medialis from the proximal two-thirds of the **medial** line; the medial septum and part of the adductor magnus into the whole length, except where interrupted for the passage of the femoral vessels; the lower parts of the short head of the biceps, the lateral septum, and the vastus intermedius from the proximal two-thirds of the **lateral** line.

The greater part of the vastus intermedius arises from the proximal two-thirds or three-fourths of the **anterior** and **lateral surfaces** of the shaft; the slender bundles of the articularis genu muscle from the distal part of the anterior surface. The medial surface is covered by vastus medialis, but does not give attachment to any muscle.

The medial head of the gastrocnemius arises from the rough patch on the **popliteal surface** above the medial condyle; the plantaris from a small area above the lateral condyle; the lateral head of the gastrocnemius from an impression on the lateral surface of the **lateral condyle** and the adjoining distal end of the lateral epicondylic line; the tendon of the popliteus from the anterior end of the **popliteal groove**, and when the knee is extended it crosses the lower lip of the groove, which therefore bears a shallow notch near its anterior end. The fibular collateral ligament of the knee is attached to the *lateral epicondyle*; the anterior cruciate ligament to the posterior part of the *lateral wall* of the **intercondylar notch**; the posterior cruciate ligament to the anterior part of the *medial wall*; the tibial collateral ligament to the *medial epicondyle*. The tendon formed by the posterior part of the adductor magnus is inserted into the **adductor tubercle**.

The fascia lata blends with the periosteum of both condyles at the sides of the knee. The fibrous stratum of the capsule of the knee joint is attached to the **intercondylar line** (*i.e.* the upper or posterior margin of the intercondylar notch), to the bone immediately above the posterior parts of the condyles, to the lateral condyle between the popliteal groove and the epicondyle, and to the medial condyle just distal to the medial epicondyle. There is no definite fibrous stratum in front, and the synovial stratum is reflected off the quadriceps on to the femur about a finger's breadth above the patellar surface; but, by means of a wide communication with a large *bursa* that lies under cover of the quadriceps, the cavity of the knee joint extends upwards to a point at least three finger-breadths above the patella. The apex of the patellar synovial fold is attached to the anterior margin of the intercondylar notch.

Ossification.—The **primary** centre for body and neck appears at the seventh week of fœtal life. At birth the body is ossified, and ossification extends into the neck after birth.

Secondary Centre.	Appears at	Epiphysis fuses at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For distal end	9th month of *fœtal* life	21	Outside.
For head	1st year	20	Inside.
For greater trochanter	2nd ,,	19	Outside (inside superiorly).
For lesser trochanter	12th ,,	18	Outside.

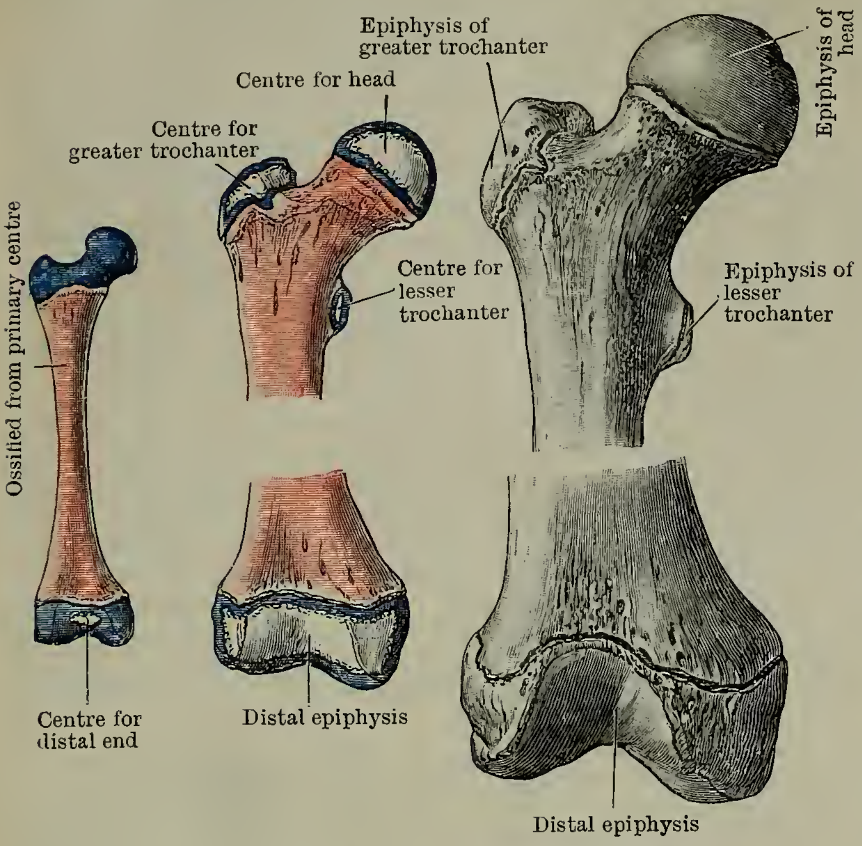
The presence of the centre in the cartilage at the distal end in a new-born child found dead is accepted as proof that the child had come to full time. The epiphyseal line at the distal end passes through the adductor tubercle, and just above the patellar surface, and along the intercondylar line. The epiphyses join at intervals of a year in the order conforming to their size.

Structure and Variations.—As in other long bones, the ends are composed of spongy substance enclosed in a shell of compact substance, and the shaft is a thick tube of compact bone enclosing a medullary cavity; the cavity begins opposite the lesser trochanter and ends about a handbreadth from the distal articular surface. A sheet of compact tissue branches off the posterior wall of the upper end of the cavity and extends upwards, through the spongy tissue under cover of the lesser trochanter, to blend with the compact tissue of the back of the neck; it is called the **calcar femorale**, from its appearance when seen in section; it strengthens the neck.

The **head** usually looks upwards and slightly forwards as well as medially. The pit is situated below and behind the centre of the head; blood-vessels from the ligamentum teres enter through it, so that the head gets a double blood supply; sometimes the pit is absent, resembling the condition in the orang.

The **neck** extends laterally, downwards and slightly backwards from the head. Its posterior surface is concave lengthwise and convex from above downwards; usually a shallow, horizontal groove can be seen on it, leading into the trochanteric fossa; the tendon of the obturator externus lies in the groove. Its anterior surface is nearly flat, and nearly in the same plane as the head and body. Near the head it often presents a smooth patch, produced by pressure against the ilio-femoral ligament. The neck is joined to the body at an angle which varies, but averages 125°.

The angle is less in the adult than in the child, and less in short-limbed people, especially in women; the proximal ends of the bodies of the two femora are separated by the width of the pelvis and by the length of the two necks, while the distal ends are in contact; therefore the body of the femur is oblique; the obliquity is more marked in short-limbed men, and still more so in women, for the pelvis is wider; and the greater the obliquity, the less is the angle. At the upper end of the **intertrochanteric line** there is often a rough prominence, called the *femoral tubercle*, for the attachment of the stronger part of the ilio-femoral ligament.


Epiphysis of greater trochanter
Centre for head
Centre for greater trochanter
Ossified from primary centre
Centre for lesser trochanter
Epiphysis of head
Epiphysis of lesser trochanter
Centre for distal end
Distal epiphysis
Distal epiphysis

At birth. About 12 years. About 16 years.

Fig. 222.—Ossification of the Femur.

Sometimes part of the **gluteal tuberosity** is so raised that it makes a prominent excrescence, easily felt in the living person, comparable to the **third trochanter** which is always present on the thigh-bone of a horse. Sometimes the tuberosity is represented by a depression called the *hypo-trochanteric fossa*.

The **body** of the femur is slightly twisted; it is curved, with the convexity forwards, and that partly accounts for the fulness of the front of the thigh; the degree of curvature varies considerably. The **linea aspera** may be a prominent keel; or it may be absent, as it is in apes. The proximal and distal parts of the body are rather compressed from before backwards; a femur showing an exaggerated degree of compression is called **platymeric**; the condition is more common in the femora of prehistoric races.

The distal surfaces of the **condyles** articulate partly with the proximal end of the tibia and partly with two crescentic pieces of fibro-cartilage, called the lateral and medial menisci [μηνίσκος (mēniscos) = a crescent], which lie within the knee joint between the femur and tibia; faint grooves, made by the anterior edges of the menisci, separate the *distal* articular surfaces from the *patellar* surface. The distal surfaces of the condyles are on the same horizontal plane when the femur is held in its proper oblique position, and therefore the medial condyle juts further downwards when the bone is held perpendicular. The medial condyle is narrower than the lateral, and is curved. The area for articulation with the patella in extreme flexion of the knee can sometimes be seen on the medial condyle where it bounds the anterior part of the inter-condylar notch.

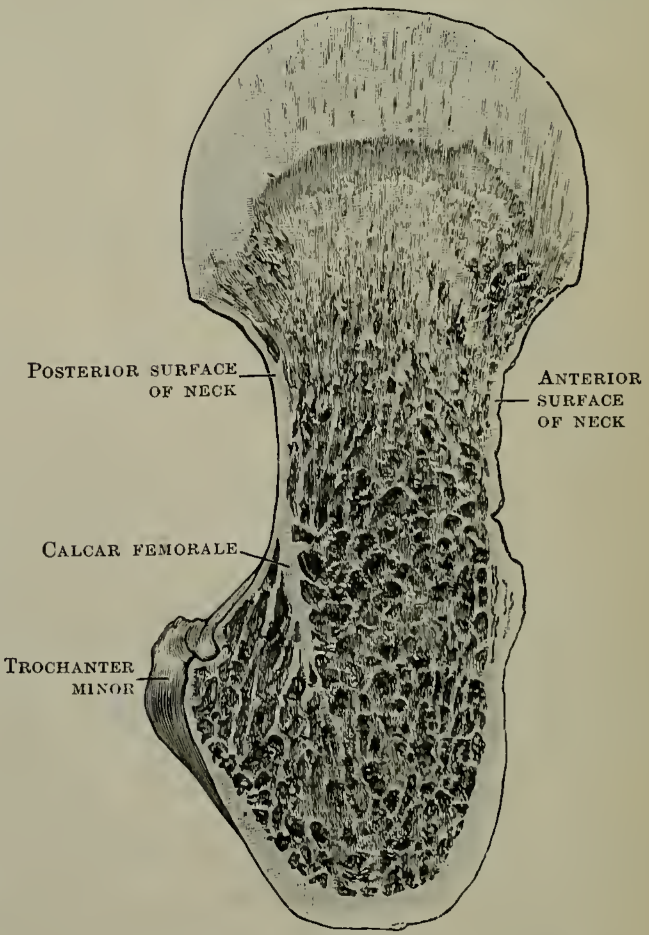


Fig. 223.—Section through Head and Neck of Femur to show Calcar Femorale.

Patella.

The **patella** or knee cap or knee pan [*patella*, diminutive of *patina* = a pan] lies in the front of the knee, and articulates with the femur. It is a small compressed bone, measuring nearly two inches each way. The **posterior surface** is largely occupied by an oval *facet* for articulation with the femur; the facet is divided by a blunt ridge into a larger lateral part, and a smaller medial part, which correspond to the sloping sides of the patellar surface of the femur. The **anterior surface** is triangular in outline; the *apex* of the triangle points towards the leg, and is on a level just above the plane of the knee joint, when the joint is extended; the base of the triangle is the anterior margin of the *base of the patella, i.e.*, its thick proximal border.

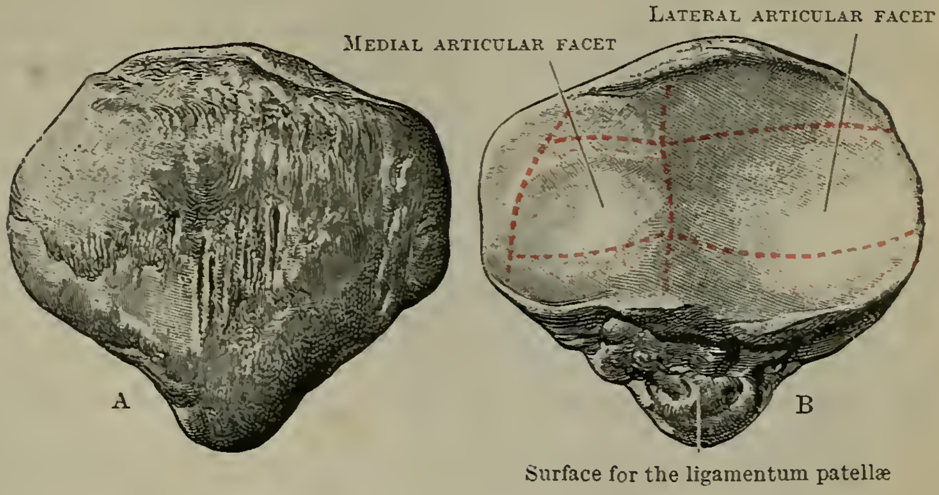


Fig. 224.—The Right Patella.

A. Anterior Surface. B. Posterior Surface.

The **patella** is the largest of the *sesamoid* bones; it lies in the tendon of the quadriceps femoris—the large four-headed muscle of the front of the thigh—and, playing against the patellar surface of the femur, it increases the leverage of the muscle when the muscle contracts to move the leg. The distal part of the quadriceps tendon is called the *ligamentum patellæ*—a strong, broad band that stretches from the patella to the tibia, and on which the body partly rests in the kneeling posture. When the knee is extended and the muscles are relaxed, the patella can be moved from side to side fairly freely, and to some extent also downwards; when the knee is flexed the quadriceps muscle, including the ligamentum patellæ, is put on the stretch, the patella is jammed hard against the femur and is immovable.

Attachments.—The three vasti and the rectus femoris are inserted into the base or proximal border; vastus lateralis and medialis, respectively, into the lateral and medial margins also. The ligamentum patellæ is attached to the apex and adjoining part of the posterior surface, but the greater part of the rough surface below the articular facet is related to fat and the synovial membrane of the knee.

Ossification.—The patella is cartilaginous at birth. Ossification, usually from a single centre, begins about the third year, and is completed about puberty.

Structure and Variations.—The patella is composed of spongy tissue enclosed in a shell of compact tissue. Cases have been noted in which the patella was absent; its absence is said to be hereditary and transmitted in the female line. A case has been recorded in which the patella was divided into a large upper part and a smaller lower part imbedded in the ligamentum patellæ; and separate epiphyseal nodules have been found in the lateral margin of the patella (Holland, *Jour. Anat.*, 1921).

Tibia.

The **tibia** or shin-bone [*tibia* = shin-bone] comes next in size after the femur, and is between a fourth and a fifth of the length of the body. It is the medial and larger of the two bones of the leg, and can be felt through the skin in all its length. It is a long bone, possessing a **body** or shaft and **two extremities.** The most outstanding border of the body is the **anterior** border; the **distal** end is the smaller end; and on the **medial** side of the distal end there is a stout blunt projection which is called the *medial malleolus.*

The **proximal end** is large and expanded to support the distal end of the femur, and is bent slightly backwards; it includes two imperfectly separated condyles and a tuberosity.

The **tuberosity** is the low elevation on the anterior aspect where the proximal end joins the anterior border of the shaft; its distal part is rough; its proximal part is smooth and rounded, and gives attachment to the ligamentum patellæ.

The two **condyles** make up nearly the whole of the proximal end of the tibia; they are separated *posteriorly* by a wide, shallow depression called the **popliteal notch**; *anteriorly,* above the tuberosity, they are united by a more or less flattened surface concealed behind the ligamentum patellæ; in the kneeling posture the body rests on the ligamentum patellæ and the anterior aspects of the two condyles. The *proximal surface* of each condyle is large, oval and smooth; it articulates with the corresponding condyle of the femur; the more central part of the surface articulates directly with the femur, but the more peripheral part is separated from the femur by a semilunar fibro-cartilage, called a *meniscus*. Between the articular surfaces of the two condyles there is a broad, rough strip, rising near its middle into a rough tubercle called the **intercondylar eminence**, and the depressions in front of and behind the eminence are called the *anterior* and *posterior* **intercondyloid fossæ**, the posterior fossa being continuous with the popliteal notch.

On the *posterior* aspect of the **medial condyle** there is a rough, horizontal groove for the insertion of part of the tendon of the semimembranosus muscle. The **lateral condyle** stands more abruptly away from the shaft than the medial does, so that it has a *distal surface* separated from the lateral surface by a curved line or ridge to which a thick band of fascia, called the *ilio-tibial tract*, is attached. On the posterior part of the distal surface there is a flat, circular **facet** for articulation with the head of the fibula; on the anterior part of the *lateral surface* there is usually quite a well-marked impression for the attachment of the anterior part of the ilio-tibial tract. Both the condyles can be felt through the skin at the sides of the knee.

The **distal end** of the tibia has five surfaces—anterior, posterior, lateral, medial, and distal.

The **anterior surface** is smooth and rounded, and can be felt indistinctly through the skin and the tendons which descend from the front of the leg to the foot.

The **medial surface** is subcutaneous, and from it there juts downwards a short, broad, thick projection, called the **medial malleolus**, which is the well-known prominence, both felt and seen, on the medial side of the ankle [*malleolus* = a small hammer]. The distal border of the malleolus is occupied by a well-marked pit for the attachment of an exceedingly strong fibrous band named, from its shape, the *deltoid ligament* [Δ = the Greek capital letter *delta*]; the lateral surface of the malleolus is smooth and articulates with the medial surface of the talus or ankle bone.

The **posterior surface** lies deeply under cover of a pad of fat and the tendo calcaneus—*i.e.*, the stout sinew felt above the heel. The surface is on the same plane as the back of the malleolus, which can be felt. Where it merges into the back of the malleolus there is a distinct vertical groove which lodges the tendons of the tibialis posterior and flexor digitorum longus; nearer the lateral side there is an indistinct groove which lodges the tendon of the flexor hallucis longus.

The **lateral surface** is occupied by a wide triangular depression, the apical part of which extends on to the body; it is called the **fibular notch** because the distal part of the fibula lies in it; the fibula is usually in actual contact with the distal smooth part, but is bound to the rough proximal part by a very short but very thick interosseous ligament.

The **distal surface** is square and smooth, concave from before backwards, slightly convex from side to side, and broader in front than behind; it articulates with and rests upon the upper surface of the talus, which is the first bone of the tarsus.

Corpus Tibiæ.—The **body** or shaft is thinnest about the junction of the middle and distal thirds; it becomes thicker towards the distal end and still more so towards the proximal end. It has three borders and three surfaces. The *borders* are anterior, medial, and lateral; the *surfaces* are posterior, lateral, and medial.

The **anterior border** or *anterior crest* is the shin of the leg. It is the most prominent of the borders; it begins at the tuberosity and extends sinuously to the anterior margin of the medial malleolus; it can be felt from end to end in the living leg. Every one is familiar with it; small notches, the result of accidental impacts, may be felt in it.

The **medial border** is a smooth, blunt margin that extends from near the back of the medial condyle to the back of the medial malleolus; it also can be felt from end to end.

The **lateral border** is a distinct, sharp line, but is not prominent. It is traced more easily from below upwards; it extends from the apex of the fibular notch to the distal aspect of the lateral condyle, some distance in front of the facet for the head of the fibula. It is usually called the **interosseous crest** because it gives attachment to the interosseous membrane—a strong, wide, fibrous sheet which stretches between the tibia and the fibula.

The **medial surface**, between the anterior crest and the medial border, is smooth and can be felt through the skin; it is continuous with the medial malleolus at the distal end; at its proximal end it is slightly roughened for the attachment of certain tendons and ligaments which overlie it.

The **lateral surface** is situated between the anterior and interosseous crests,

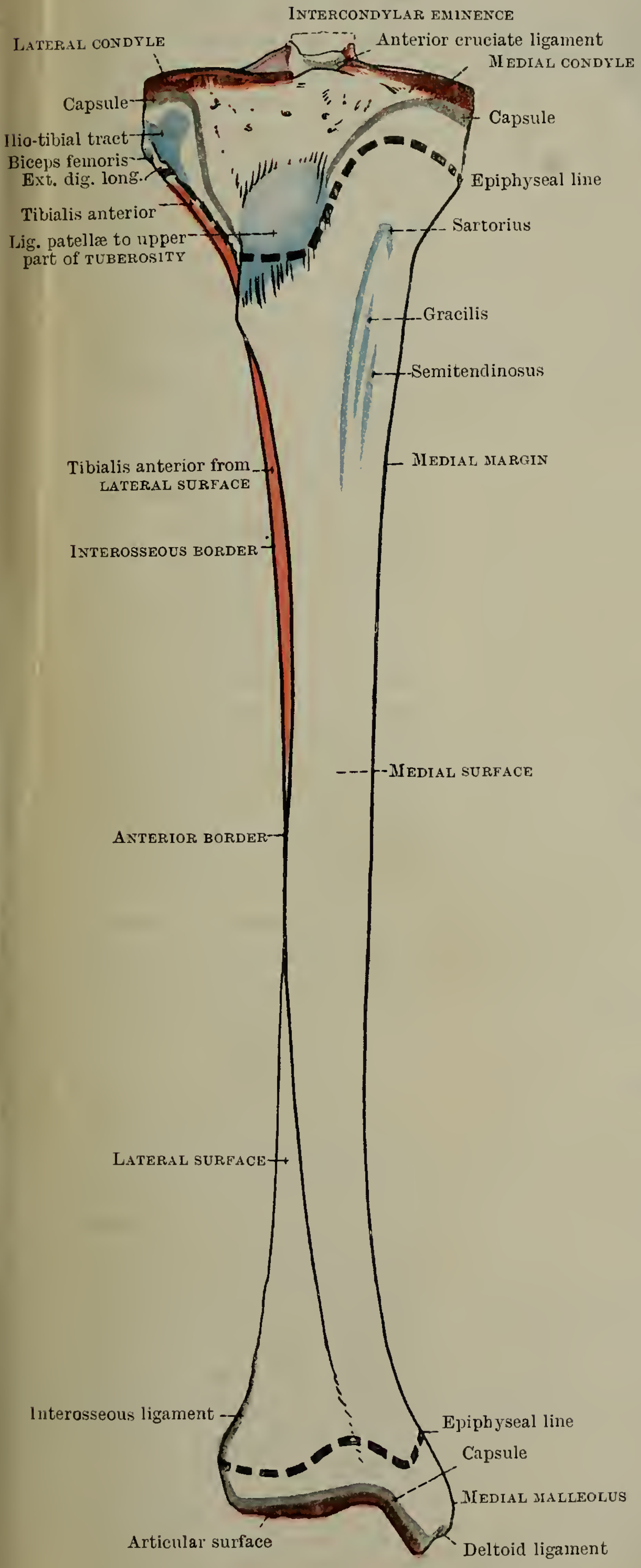


FIG. 225.—ANTERIOR ASPECT OF RIGHT TIBIA.

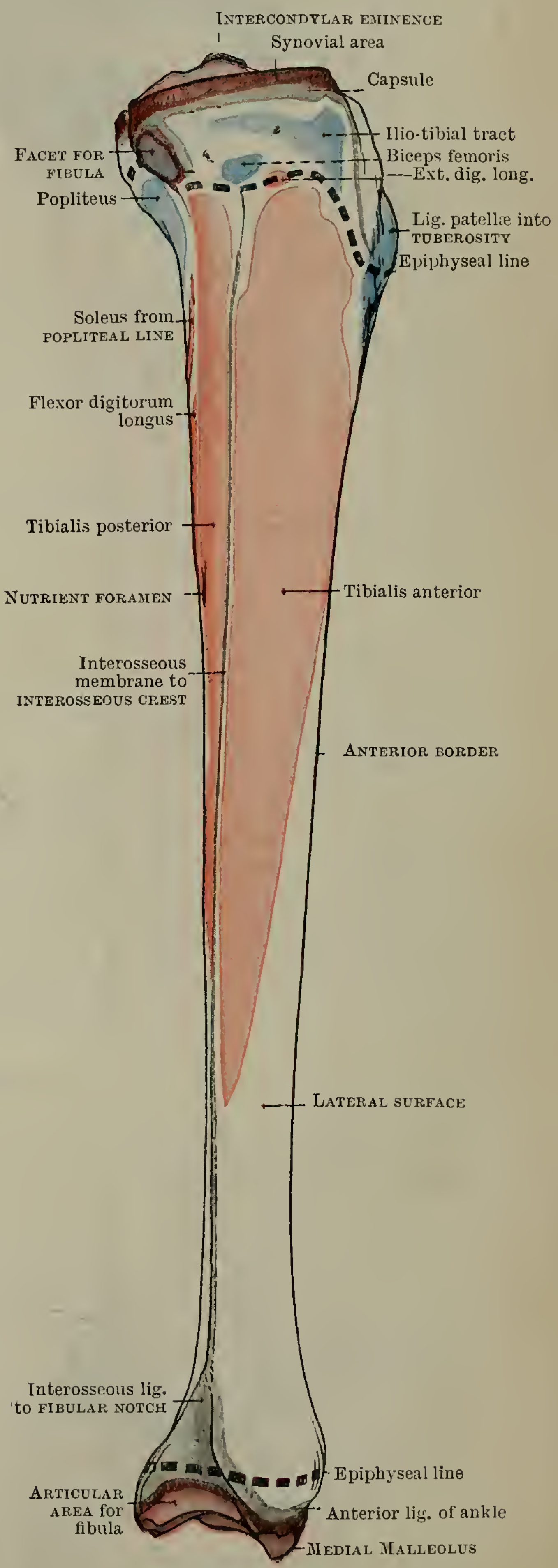


FIG. 226.—LATERAL ASPECT OF RIGHT TIBIA.

and, owing to the direction of the distal parts of those borders, it turns forwards to become continuous with the front of the distal end of the tibia.

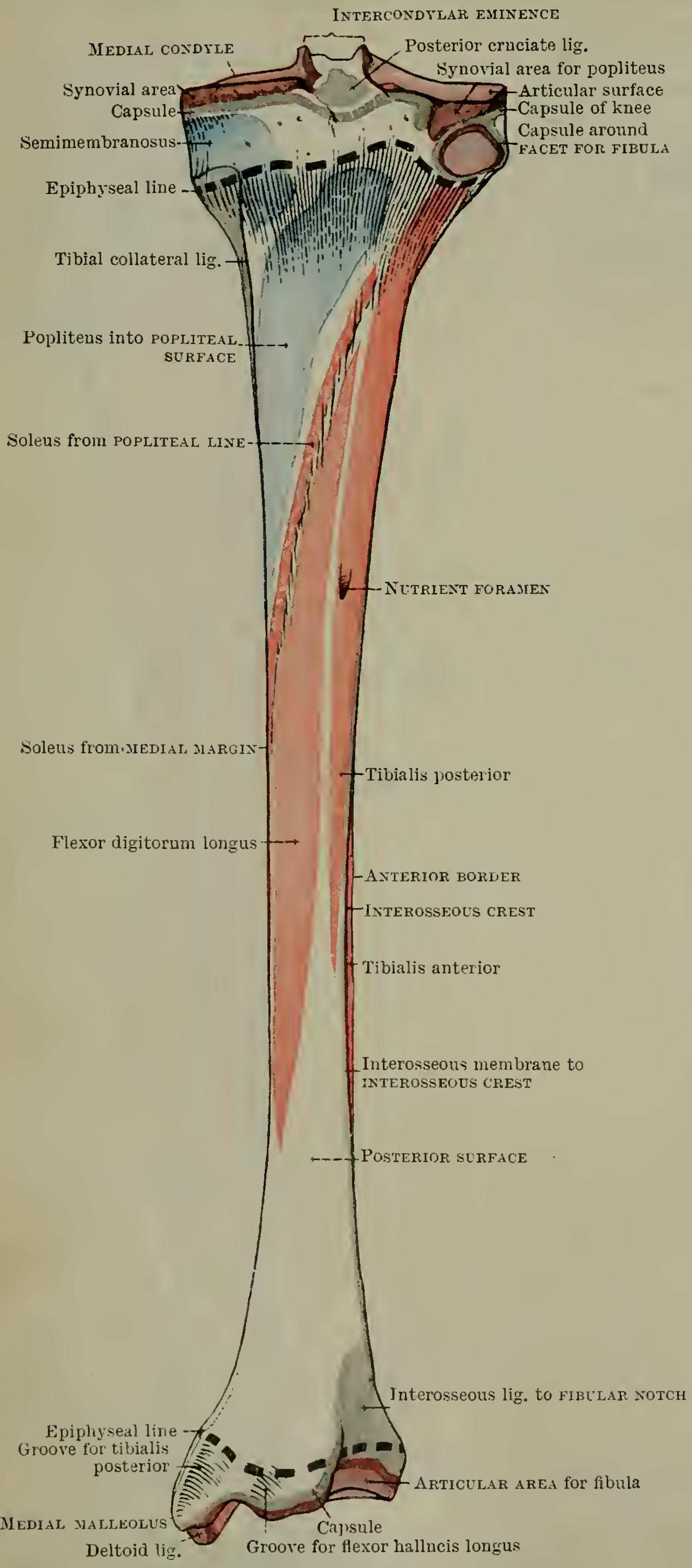


Fig. 227.—Posterior Aspect of Right Tibia.

The **posterior surface** is situated between the medial border and the interosseous crest; its proximal part encroaches on the lateral aspect of the bone owing to the position of the proximal part of the crest. The proximal third of the posterior surface is crossed by an oblique ridge, called the **popliteal line**, which begins near the facet for the head of the fibula and runs in a medial and distal direction towards the medial border. The part of the surface above the line is called the **popliteal surface** of the tibia; the popliteus muscle, which lies in the distal part of the floor of the popliteal fossa, is inserted into the popliteal surface. The part of the surface below the popliteal line is usually imperfectly subdivided into medial and lateral parts by a more or less *vertical line*, which is blunt and often ill-defined.

The **nutrient foramen** is situated near the popliteal line and is directed towards the distal end.

Attachments.—The articular capsule of the knee joint is attached to the circumference of the **condyles** just below the margins of the articular surface; the capsule of the proximal tibio-fibular joint to the circumference of the **facet for the fibula**; the cruciate ligaments and the horns of the crescentic menisci to the rough strip between the condyles, in the following order from before backwards: anterior horn of medial meniscus and anterior cruciate ligament to the *anterior intercondyloid fossa*, the horns of the lateral meniscus to the front and back of the *intercondyloid eminence*, the posterior horn of the medial meniscus to the *posterior intercondyloid fossa*, the posterior cruciate ligament to the same fossa and to the *popliteal notch*. The fascia lata to the sides of both *condyles*; its ilio-tibial tract to the ridge and impression on the *lateral condyle*. Below that ridge, on the overhanging, distal surface of the condyle, a few fibres of the biceps femoris are inserted, in front of the facet for the fibula, and a few fibres of the peroneus longus, extensor digitorum longus, and tibialis anterior muscles take origin. Part of the tendon of the semimembranosus is inserted into the medial part of the horizontal *groove* on the back of the *medial condyle* and into the rough area distal to the groove; and the ligamentum patellæ into the smooth, proximal part of the **tuberosity** of the tibia.

The tibial collateral ligament of the knee is attached to a rough patch about two inches long and half an inch wide on the *medial surface of the* **body**, just in front of the proximal part of the medial border. The tendons of the semitendinosus, gracilis, and sartorius, in that order from behind forwards, have linear insertions into the area immediately in front of that rough patch. The tendon of the popliteus, as it emerges from the knee joint, lies in a smooth, shallow groove on the back of the lateral condyle, and, becoming fleshy, it widens out to be inserted into the **popliteal surface**. Part of the soleus arises from the **popliteal line** and the middle third of the *medial border*; the flexor digitorum longus from the proximal two-thirds of the *medial area* of the **posterior surface**; part of the tibialis posterior from the *lateral area*; and the fascia covering the tibialis posterior is attached to the *vertical line*; the interosseous membrane to the *interosseous crest*; the fascia of the leg to the *medial border* and to the *anterior crest*; the transverse ligament of the leg to the distal part of the anterior crest.

The cruciate ligament of the ankle is attached to the *anterior* border of the **medial malleolus**; the deltoid ligament to the *distal* border; the ligamentum laciniatum to the *posterior* border; the posterior ligament and inferior transverse ligament of the ankle joint to the *posterior* border of the **distal end**; the anterior ligament to the *anterior* border; the interosseous tibio-fibular ligament to the rough floor of the **fibular notch**; the anterior and posterior ligaments of the lateral malleolus to the prominent anterior and posterior *margins* of the distal part of the notch.

Ossification.—The **primary** centre appears at the seventh week of fœtal life. At birth only the ends are cartilaginous.

Secondary Centre.	Appears at	Epiphysis fuses at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For proximal end	Birth	21	Outside.
For distal end	2nd year	18	Outside.

The *proximal* epiphyseal centre appears shortly after birth and sometimes shortly before birth. The *epiphyseal line* extends downwards in front to include the greater part of the tuberosity. Occasionally there are additional epiphyseal centres for the tuberosity and the medial malleolus.

Structure and Variations.—The structure is like that of the other long bones. The medullary cavity falls short of each end by two or three inches.

Tibiæ which show compression from side to side are called **platyknemic**; the condition is more common in prehistoric and savage people than among modern Europeans. Exaggerated *retroversion* of the proximal end is said to be due to the habit that some people have of walking with the knees slightly bent. The parts of the articular surface of a condyle that articulate with the meniscus and with the femur respectively may be indicated by a difference in texture or in colour. In people who habitually squat rather than sit there may be a "pressure" facet on the anterior margin of the distal end, due to contact with the neck of the talus in the squatting posture.

Fibula.

The **fibula** or splinter bone is the lateral and smaller bone of the leg. It is almost as long as the tibia but is very slender, and it has slightly expanded ends. In some animals it is pointed at one end—hence its name [*fibula* (from figibula) = a pin or skewer; the equivalent word in Greek is περόνη (peronē), hence the names *peroneus* and *peroneal* given to muscles, vessels, and nerves related to the fibula].

The fibula has a shaft or **body** and **two extremities**; it is thickly covered with muscles except at its proximal and distal ends, and is not easily palpated except at the ends. The **proximal** end is knob-like; the distal end is compressed from side to side and is triangular in outline; on the **medial** side of the distal end there is a large, nearly flat, triangular facet; the **posterior** aspect can be recognised from the fact that there is a pit *behind* the lower part of the facet.

The **proximal end** is called the *head* of the fibula. The anterior, posterior, lateral, and medial surfaces of the **head** are identified more easily after the surfaces of the body and distal end have been recognised; the medial part of the *proximal surface* bears a *facet* of considerable size for articulation with the lateral condyle of the tibia; a stunted projection, called the **apex** of the head or styloid process, stands up from the junction of the *lateral* and *posterior* surfaces. The head is felt as a hard knob well back on the lateral aspect of the leg, on a level with the tuberosity of the tibia. If the finger is passed round to its posterior surface a big nerve, called the *common peroneal nerve,* can be felt and rolled between the finger and the bone; it is felt most easily when the knee is bent to a right angle and the muscles are relaxed. The part of the shaft immediately adjoining the head is called the **neck** of the fibula and can also be felt; the nerve inclines downwards and forwards from the back of the head and ends on the lateral aspect of the neck, and is most liable to injury there.

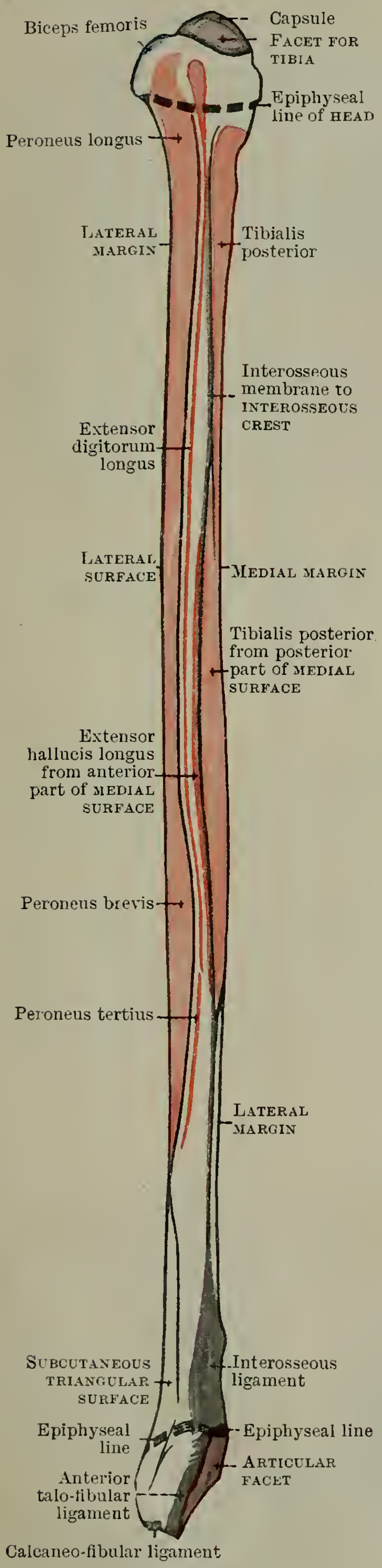

Biceps femoris
Capsule
FACET FOR TIBIA
Epiphyseal line of HEAD
Peroneus longus
LATERAL MARGIN
Tibialis posterior
Interosseous membrane to INTEROSSEOUS CREST
Extensor digitorum longus
LATERAL SURFACE
MEDIAL MARGIN
Tibialis posterior from posterior part of MEDIAL SURFACE
Extensor hallucis longus from anterior part of MEDIAL SURFACE
Peroneus brevis
Peroneus tertius
LATERAL MARGIN
SUBCUTANEOUS TRIANGULAR SURFACE
Interosseous ligament
Epiphyseal line
Epiphyseal line
ARTICULAR FACET
Anterior talo-fibular ligament
Calcaneo-fibular ligament

FIG. 228.—ANTERIOR ASPECT OF RIGHT FIBULA.

The **distal end** is called the *lateral malleolus.* It is the outstanding prominence on the lateral side of the ankle. It articulates with the lateral surface of the distal end of the tibia, but projects downwards beyond the tibia, articulating with the lateral surface of the talus; the talus is therefore gripped between the two malleoli.

The **lateral malleolus** has four surfaces—lateral medial, anterior, and posterior. The **lateral surface** is subcutaneous. The **medial surface** bears a large articular *facet*; the malleolus projects so far beyond the tibia that only the proximal edge of the facet articulates with the tibia; practically the whole of it articulates with the talus. The pit behind and distal to the facet is sometimes called the *digital fossa* because it can accommodate the tip of the little finger. The rough mark on the shaft, just above the facet, lies in the fibular notch of the tibia and is bound to its floor by an interosseous ligament. The **anterior surface** is narrow from side to side, convex from above downwards, and slightly roughened. The **posterior surface** is wider and flatter than the anterior; the tendon of the peroneus brevis lies on it and often grooves it longitudinally, and the tendon of the peroneus longus lies on that of the brevis.

The **body** or shaft of the fibula, though slender, is strongly ridged and grooved, but the ridges and grooves are not all alike in all fibulæ. Like the other long bones, the fibula is twisted, but, as it is slender and its surfaces narrow, the torsion has a greater apparent effect in altering the directions in which the surfaces look than it has in thicker bones. Therefore the identification of the surfaces and borders of the shaft of the fibula presents difficulties to the beginner and takes up time out of all proportion to its importance, for the shaft of the fibula is merely a stanchion for the attachment of muscles and fasciæ and the interosseous membrane; the fibula does not support the body, since it does not articulate with the femur, and, being closely bound to the tibia at each end, it does not serve independently as a lever in the movements of the leg.

Corpus Fibulæ.—The **body** of the fibula is described as having three borders and three surfaces. The *borders* are anterior, medial, and lateral. The *surfaces* are posterior, lateral, and medial. But an additional border, called the interosseous crest, divides the medial surface into an anterior part and a posterior part; and there is an additional, small "triangular subcutaneous surface" not included in any of the three surfaces named above.

The **triangular subcutaneous surface** should be identified first. It is a narrow triangular area, about two inches long, on the distal part of the body; its base is continuous with the lateral surface of the lateral malleolus, and both the malleolus and the triangular surface are easily identified through the skin.

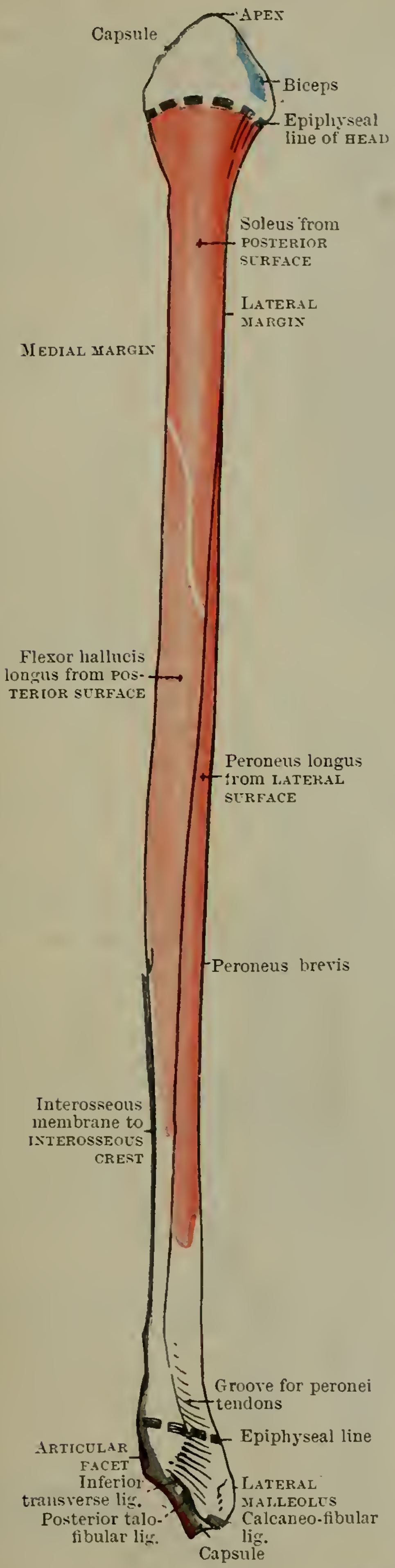

Apex
Capsule
Biceps
Epiphyseal line of head
Soleus from posterior surface
Lateral margin
Medial margin
Flexor hallucis longus from posterior surface
Peroneus longus from lateral surface
Peroneus brevis
Interosseous membrane to interosseous crest
Groove for peronei tendons
Epiphyseal line
Articular facet
Inferior transverse lig.
Posterior talo-fibular lig.
Lateral malleolus
Calcaneo-fibular lig.
Capsule

Fig. 229.—Posterior Aspect of Right Fibula.

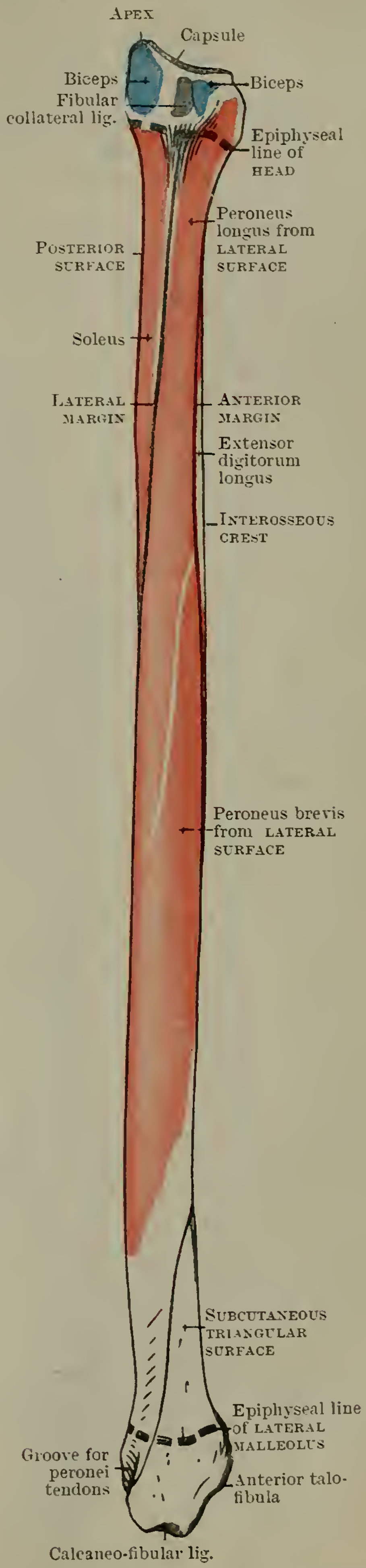

Apex
Capsule
Biceps
Fibular collateral lig.
Biceps
Epiphyseal line of head
Peroneus longus from lateral surface
Posterior surface
Soleus
Lateral margin
Anterior margin
Extensor digitorum longus
Interosseous crest
Peroneus brevis from lateral surface
Subcutaneous triangular surface
Epiphyseal line of lateral malleolus
Groove for peronei tendons
Anterior talo-fibula
Calcaneo-fibular lig.

Fig. 230.—Lateral Aspect of Right Fibula.

Crista Anterior.—The **anterior border** or **crest** is located most easily at the *apex* of the triangular subcutaneous surface, where it bifurcates to enclose that surface; from that point it passes proximally to the neck as a sharp even line.

Crista Interossea.—The **interosseous crest** should be located next. It is medial to the anterior border, and should be looked for first in the distal third of the body, where there is nearly always an interval of a quarter of an inch or so between it and the anterior border. Its distal end runs into the rough triangular patch above the medial surface of the malleolus. When traced towards the neck it is apt to be lost, for in many fibulæ it approaches the anterior border or crest so closely that the two almost merge into one, and even when the two crests remain quite distinct there is seldom more than a twelfth of an inch interval between them near the neck. The interosseous crest is never a strongly marked line though the interosseous membrane is attached to it.

Crista Medialis.—The **medial border** should be looked for next; it is medial to and behind the interosseous crest, and in some fibulæ it is the most outstanding ridge on the bone. It begins at the neck, but, instead of running the whole length of the shaft like the other borders, it joins the interosseous crest three or four inches from the distal end; it should be located there first and traced towards the neck.

Crista Lateralis.—The **lateral border** is the remaining ridge on the fibula, and is usually well defined. It begins at the neck and ends at the posterior margin of the medial surface of the malleolus.

Facies Lateralis.—The **lateral surface** is that which lies mainly between the lateral border and the anterior border, but its distal fourth or fifth lies between the lateral border and the subcutaneous triangle, and, owing to the twist of the fibula, it becomes continuous with the *posterior* surface of the malleolus.

Facies Posterior.—The **posterior surface** lies between the lateral border and the medial border in the proximal two-thirds or so of the bone; but, since the medial border does not reach the distal end, the distal part of the surface lies between the lateral border and the interosseous crest, and, owing to the twist, it becomes continuous with the medial surface of the malleolus.

Facies Medialis.—The **medial surface** is the remaining surface; it is divided by the interosseous crest into an anterior and a posterior part. The *anterior part* lies between the anterior border and the interosseous crest; towards the distal end it is about a quarter of an inch in breadth; near the neck it may be reduced to a mere line. The *posterior part* lies between the interosseous crest and the medial border, and therefore is found only in the proximal two-thirds of the bone; its proximal part is often crossed by an oblique ridge which extends from above downwards and backwards, and may be mistaken for the proximal part of the medial border.

The **nutrient foramen** of the fibula is situated usually on the posterior surface, about the junction of the proximal and middle thirds, and is directed towards the distal end; it may be situated near the distal third.

Attachments.—The greater part of the tendon of the biceps is inserted into the **head**, in front of the apex. The fibular collateral ligament of the knee is attached to the head under cover of the biceps tendon; the capsule of the proximal tibio-fibular joint to the margins of the *facet*; the ilio-tibial tract to the *lateral aspect* of the head. The muscles that arise from the proximal part of the shaft take origin also from the adjoining surfaces of the head.

The peroneus longus arises from the head and the proximal two-thirds of the *lateral surface* of the body; the peroneus brevis from the distal two-thirds, overlapping the longus anteriorly in the middle third; part of the soleus from the head and the proximal third of the *posterior surface*; the flexor hallucis longus from the distal two-thirds; part of the tibialis posterior from the head and the *posterior part of the medial surface*; the extensor digitorum longus from the head and the proximal two-thirds of the *anterior part*; the peroneus tertius from the distal third; and, medial to those two, the extensor hallucis longus from the middle three-fifths. The interosseous membrane is attached to the *interosseous crest*; the fascia covering the tibialis posterior to the *medial border*; the posterior intermuscular septum to the *lateral border*; the anterior intermuscular septum to the greater part of the *anterior border*; the deep fascia of the leg to the *margins of the subcutaneous surface*, including the lig. transversum cruris attached to its anterior margin; the interosseous ligament to the rough area above the facet at the distal end.

The anterior and posterior ligaments of the **lateral malleolus** are attached to the corresponding margins of the facet; the anterior talo-fibular ligament to the *anterior surface* of the malleolus near its tip; the calcaneo-fibular ligament to the *tip*; the posterior talo-fibular ligament and the inferior transverse ligament of the ankle joint to the **digital fossa**; the superior retinaculum of the peroneal tendons to the margins of the *posterior surface* of the malleolus.

Ossification.—The primary centre appears at the seventh week of fœtal life. Only the ends are cartilaginous at birth.

Secondary Centre.	Appears at	Epiphysis fuses at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For distal end	2nd year	18-20	Medial part inside, lateral part outside.
For proximal end	4th ,,	20-25	Outside.

Structure and Variations.—The structure is like that of other long bones. The medullary canal extends from the neck to a point about three inches from the tip of the malleolus. The fibula is occasionally absent or incompletely developed. The facet on the head may be double or may be absent.

Tarsus.

The term **Tarsus** originally included nearly the whole foot [ταρσός (tarsos) = the part of the foot between the toes and the heel], but it is now applied only to the posterior half of the foot, the skeleton of which consists of seven bones called tarsal bones.

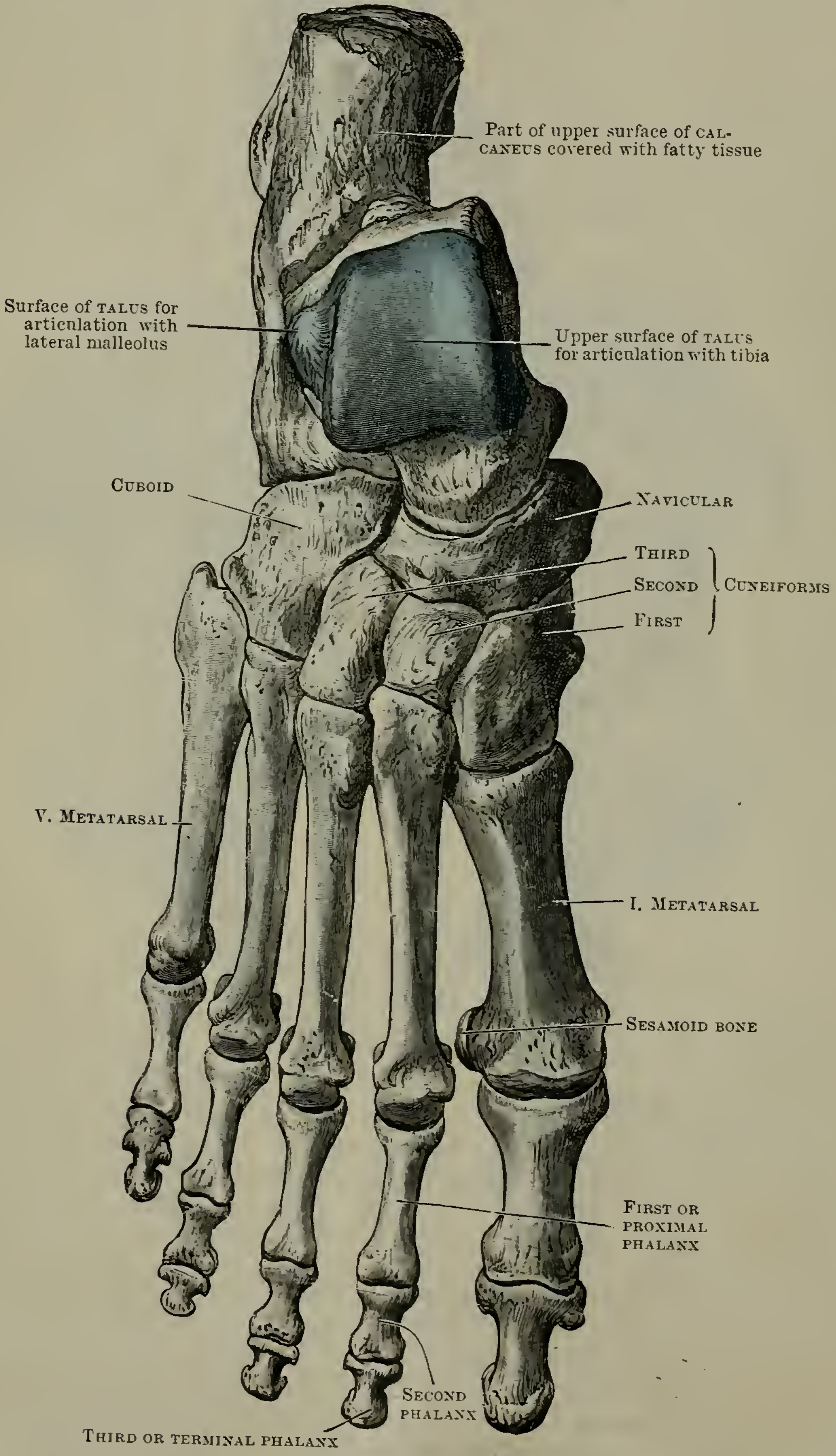

Part of upper surface of CALCANEUS covered with fatty tissue
Surface of TALUS for articulation with lateral malleolus
Upper surface of TALUS for articulation with tibia
CUBOID
NAVICULAR
THIRD
SECOND
FIRST
CUNEIFORMS
V. METATARSAL
I. METATARSAL
SESAMOID BONE
FIRST OR PROXIMAL PHALANX
SECOND PHALANX
THIRD OR TERMINAL PHALANX

FIG. 231.—UPPER OR DORSAL SURFACE OF BONES OF RIGHT FOOT.

7
5
12
7
1
1
6

The **tarsal bones** are closely bound together by ligaments. They are arranged in two rows, with an intermediate bone between the rows. There are two bones in the first row; they are the largest of the tarsal bones and are named the **talus** and the **calcaneus**; they are placed not side by side, but the talus on the top of the calcaneus. The second or distal row comprises four bones placed side by side—three **cuneiform** bones and, lateral to them, the **cuboid** bone. The intermediate bone is called the **navicular**; it is placed between the talus and the three cuneiform bones.

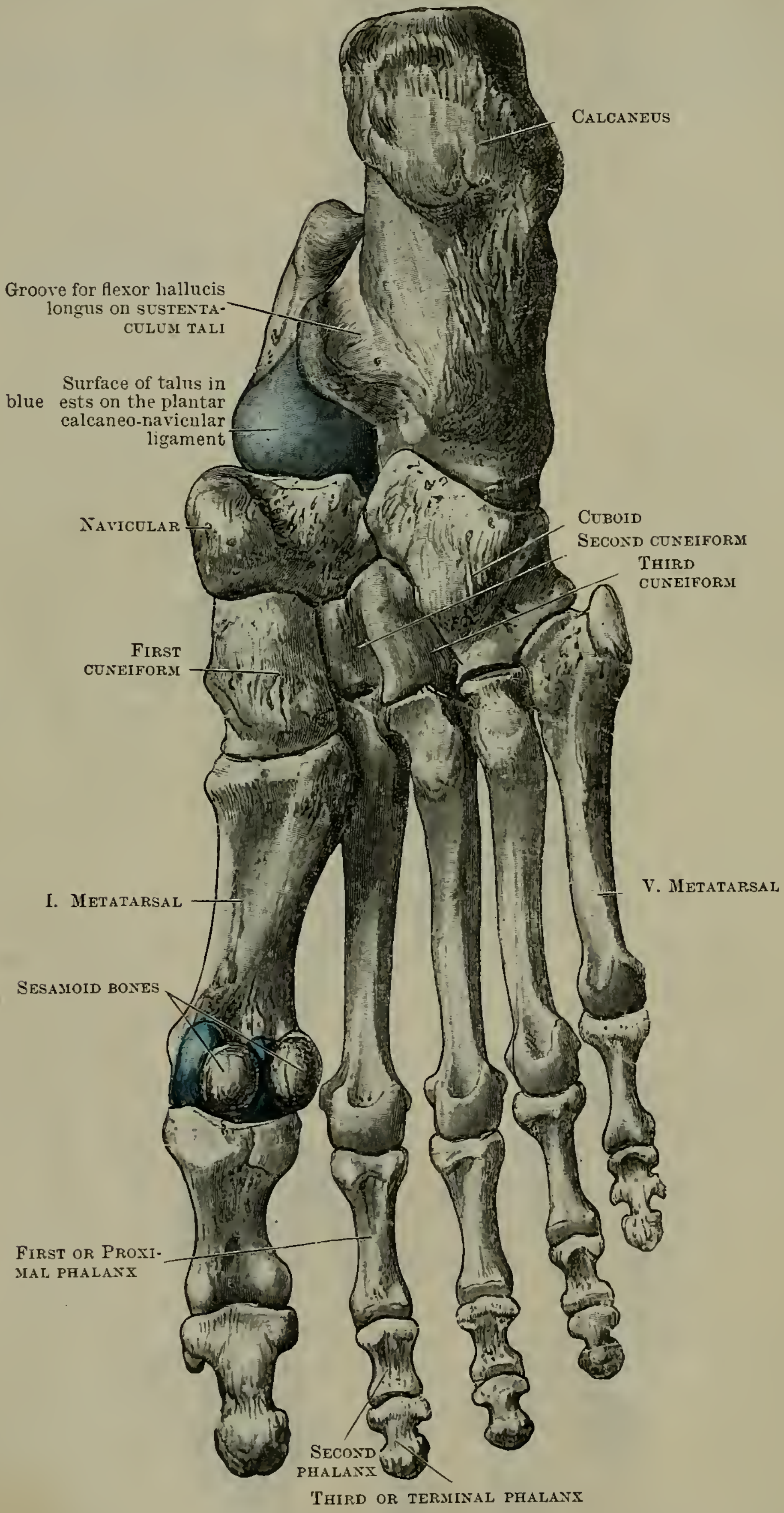

Calcaneus
Groove for flexor hallucis longus on sustentaculum tali
Surface of talus in blue rests on the plantar calcaneo-navicular ligament
Navicular
Cuboid
Second cuneiform
Third cuneiform
First cuneiform
I. Metatarsal
V. Metatarsal
Sesamoid bones
First or Proximal phalanx
Second phalanx
Third or terminal phalanx

Fig. 232.—Lower or Plantar Surface of Bones of Right Foot.

All the tarsal bones are more or less cuboidal in shape, and each is therefore described as having six surfaces—anterior, posterior, superior, inferior, lateral, and medial.

A knowledge of the characters of the individual bones is more necessary in the case of the tarsus than in the case of the carpus.

Calcaneus.

The **calcaneus** is the bone of the heel [*calcaneum* (allied to calx) = the heel]. It is the largest of the tarsal bones, being nearly three inches in length and about half of that in thickness.

The *anterior* and *posterior surfaces* are the ends of the bone. The anterior surface is smooth and concavo-convex, and articulates with the cuboid bone; the posterior surface is rough, and the tendo calcaneus is inserted into a specially roughened strip across the middle of the surface.

The *superior surface* is distinguished from the others because it has a large, oval, smooth facet about its middle; the facet is for articulation with the body of the talus. In front of the facet there is a rough groove for the attachment of a strong interosseous ligament that binds the talus and calcaneus together. In front of the lateral part of that groove there is a rough, fairly flat area, and at the anterior and medial corner of the area there is usually a small facet for articulation with the head of the talus. In front of and medial to the medial part of the groove there is a projecting shelf of bone, called the **sustentaculum tali** because part of the talus rests on it; the upper surface of the sustentaculum is smooth for articulation with the talus; its lower surface is occupied by a shallow groove in which the tendon of the flexor hallucis longus is lodged as it runs forwards into the sole of the foot; the thick, rough medial border of the sustentaculum can be felt in the living body as an ill-defined bony resistance directly below the medial malleolus.

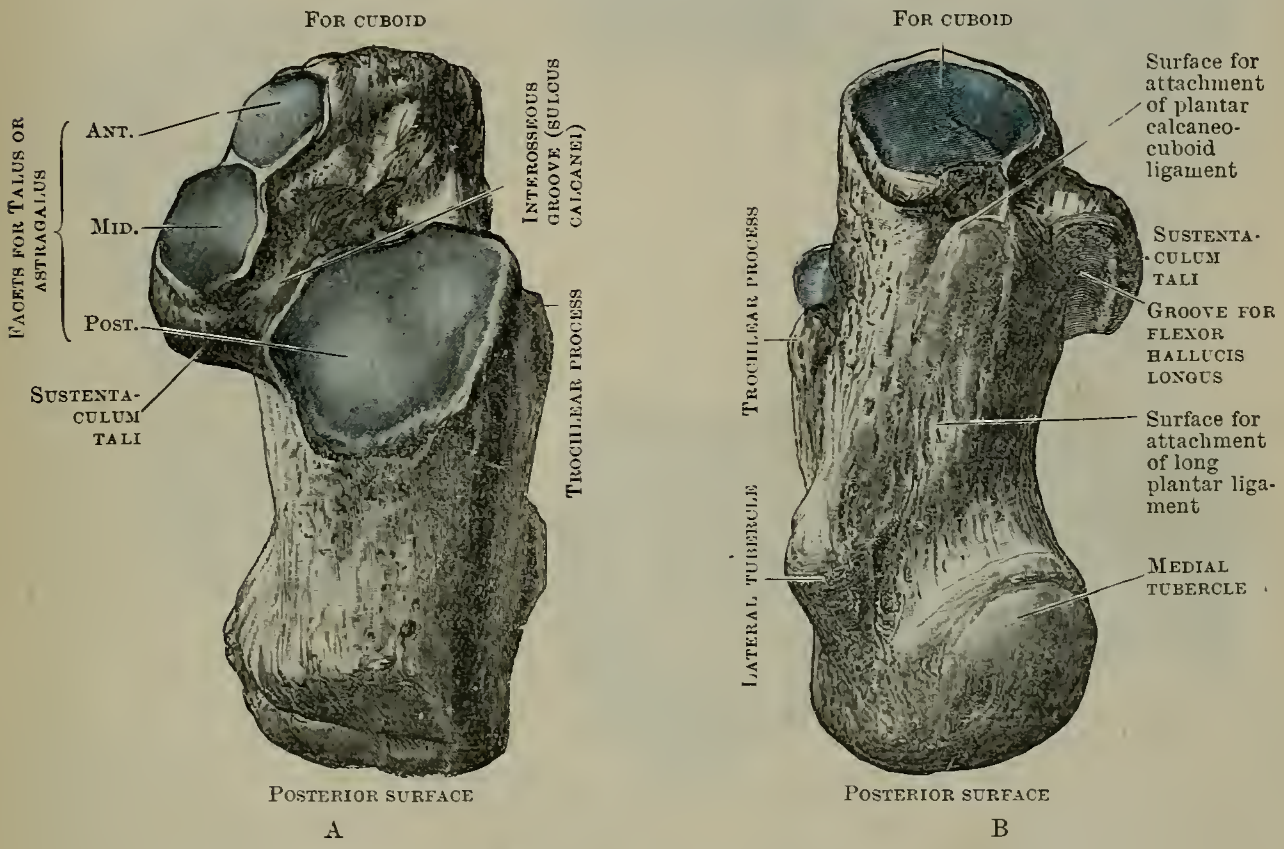

For cuboid
Facets for Talus or Astragalus
Ant.
Mid.
Post.
Sustentaculum tali
Interosseous groove (sulcus calcanei)
Trochlear process
Posterior surface
A
For cuboid
Surface for attachment of plantar calcaneo-cuboid ligament
Sustentaculum tali
Groove for flexor hallucis longus
Trochlear process
Surface for attachment of long plantar ligament
Lateral tubercle
Medial tubercle
Posterior surface
B

Fig. 233.—Right Calcaneus. A, seen from above; B, seen from below.

The *inferior surface* is rough. At its anterior part there is a low, rounded eminence called the **anterior tubercle** of the calcaneus. At its most posterior part there are two blunt, rounded prominences called the **lateral** and **medial tubercles** or processes of the calcaneus; the medial tubercle is the larger of the two. When the calcaneus is laid on the table it rests on the three tubercles; but that is not its position in the foot: when the sole is on the ground the calcaneus is placed so that it rests on the backs of the lateral and medial tubercles, *i.e.*, on the lower, sloping part of the posterior surface, and the anterior part of the bone is raised up from the ground.

The *medial surface* is markedly concave owing to the projection of the medial tubercle and the sustentaculum. The *lateral surface* is slightly convex and is rough. On the anterior half of the surface, in some specimens, there is a small but well-marked tubercle called the **trochlear process**; the tendons of the peroneus longus and brevis cross the surface obliquely, the longus below the tubercle, the brevis above it, and produce shallow grooves on the bone. Except for the strips covered by those two tendons, the whole of the lateral surface is subcutaneous and can be felt in the living foot.

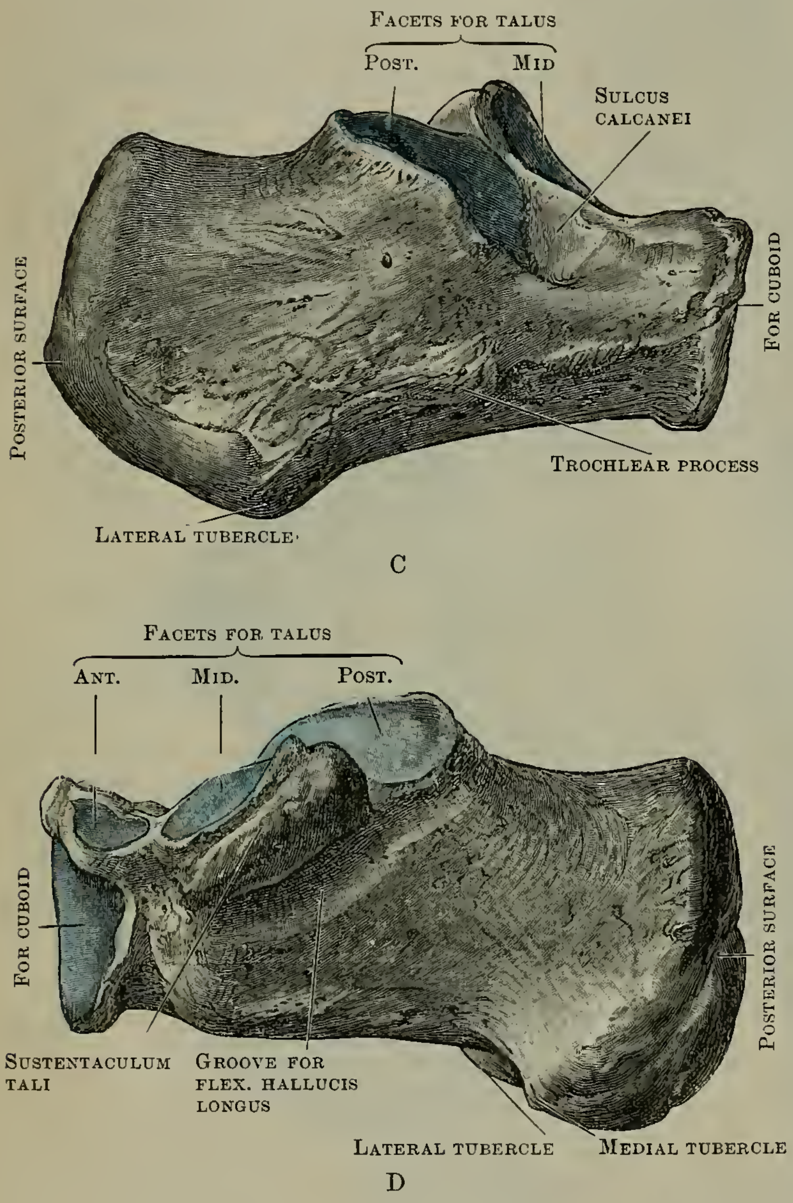


Fig. 234.—Right Calcaneus. C, Lateral side; D, Medial side.

Attachments.—The tendo calcaneus is inserted into the rough strip across the middle of the *posterior surface*, and is separated from the upper part of the surface by a *bursa*; the lower part of the surface is covered with the fatty pad on which the heel rests. The calcaneo-fibular ligament is attached to the middle of the *lateral surface*; the inferior peroneal retinaculum to the margins of the grooves which lodge the peroneal tendons. The ligamentum laciniatum and the thick, middle part of the plantar aponeurosis are attached to the **medial tubercle**, and parts of the abductor hallucis and flexor digitorum brevis arise from it; the abductor digiti quinti from both **medial and lateral tubercles**. The plantar calcaneo-cuboid ligament is attached to the **anterior tubercle**; the long plantar ligament to the wide area on the *inferior surface* behind the anterior tubercle; the lateral head of the quadratus plantæ arises from the lateral edge of that area, and the large medial head from the *medial surface*. The deltoid ligament and the plantar calcaneo-navicular ligament are attached to the medial margin of the **sustentaculum tali**, and a slip from the tendon of the tibialis posterior is inserted into it.

The following structures, after they leave the back of the leg and turn forwards into the sole of the foot, are related to the sustentaculum tali: the tendon of the tibialis posterior lies above it, between it and the medial malleolus; the tendon of the flexor hallucis longus lies on its grooved lower surface; the tendon of the flexor digitorum longus lies on its medial margin; the posterior tibial vessels and the tibial nerve lie between the tendons of the flexor digitorum and flexor hallucis.

The capsule of the talo-calcanean joint is attached to the margins of the large oval *facet* on the *upper surface*; the wide, saddle-shaped area behind the facet is covered with the fatty fibrous tissue in front of the tendo calcaneus; the groove in front of the facet gives attachment to the strong interosseous talo-calcanean ligament; the rough flat area in front of the lateral end of the groove gives attachment to the stem of the ligamentum bifurcatum, the stem of the ligamentum cruciatum cruris, and some fibres of origin of the extensor digitorum brevis; and the dorsal calcaneo-cuboid ligament is attached to the upper and lateral margins of the *anterior surface*.

Talus.

The **talus**, or witch bone, or ankle bone is next to the calcaneus in size, and has large smooth articular facets on several of its surfaces. It rests on the upper surface of the calcaneus, directly below the distal end of the tibia; it is gripped between the two malleoli, and with them and the distal end of the tibia it form the *ankle joint* [*talus* = the ankle bone].

The bulkier part of the talus is called the *body*; the smooth and rounded end is the anterior part of the bone, and is called the *head*; the rough, slightly constricted part between the head and the body is called the *neck*.

The *superior surface* of the **body** is a large face for articulation with the distal end of the tibia. It is convex from before backwards, slightly concave from side to side, and is narrower behind than in front; it is sometimes called the **trochlea**. The *inferior surface* has two facets with a deep groove between them. The posterior facet is large, concave, and oval, and articulates with the large oval facet on the upper surface of the calcaneus. The anterior facet is on body, neck, and head; it articulates with the sustentaculum tali, and with the facet on the anterior part of the upper surface of the calcaneus; the facet on the talus varies in its extent, and the part on the head may lie separate from the rest.

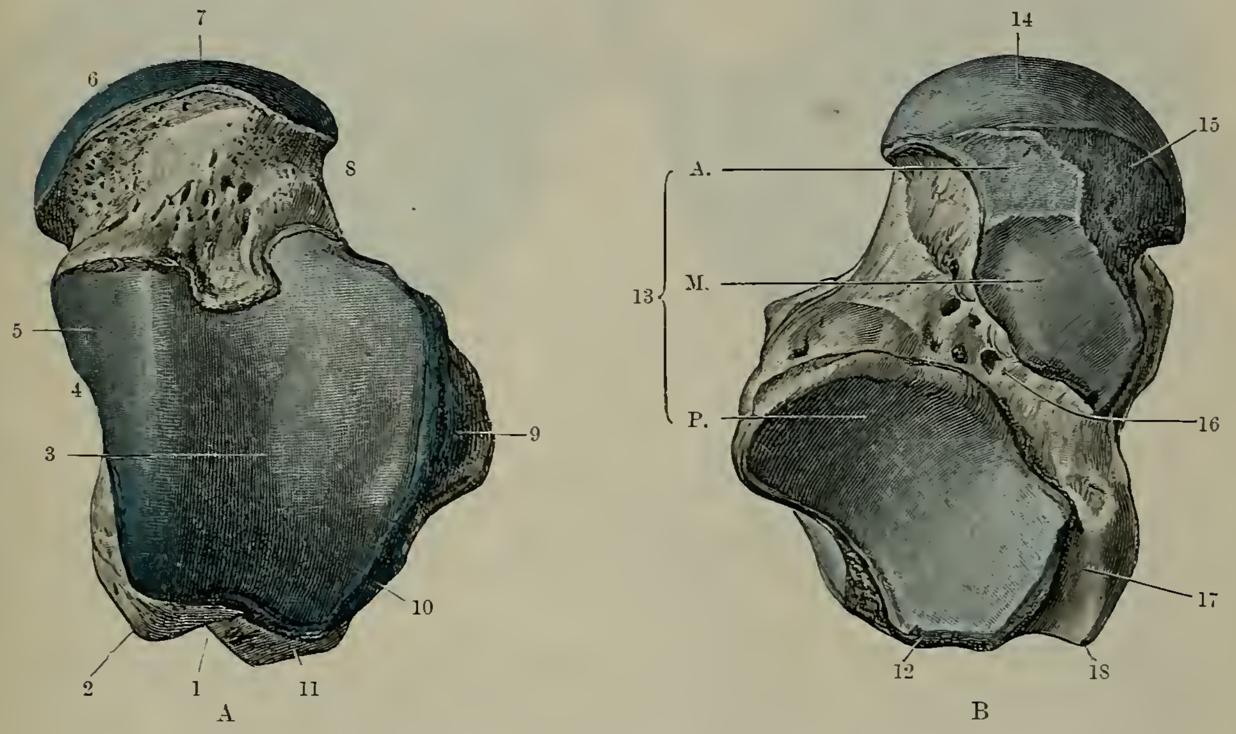


Fig. 235.—Right Talus. A, Upper surface; B, Lower surface.

1. Groove for flex. hallucis long.
2. Medial tubercle.
3. Trochlea.
4. Body.
5. For articulation with medial malleolus.
6. Head.
7. For articulation with navicular.
8. Neck.
9. For articulation with lateral malleolus.
10. Surface against which the posterior talo-fibular ligament rests.
11. Processus posterior.
12. Processus posterior.
13. Posterior, middle, and anterior facets for calcaneus.
14. For articulation with navicular.
15. Surface resting on plantar calcaneo-navicular ligament.
16. Sulcus tali.
17. Groove for flexor hallucis longus.
18. Medial tubercle.

The *medial surface* can be distinguished from the lateral surface because it is nearly all rough, and is flush with the medial side of the neck. Near the upper margin there is a comma-shaped facet for articulation with the medial malleolus.

The *lateral surface* stands away from the neck, and is nearly all occupied by a large facet for articulation with the lateral malleolus.

The *posterior surface* is very small. It is crossed by a fairly broad, oblique groove which lodges the tendon of the flexor hallucis longus. When the talus and calcaneus are placed together properly, that groove is continuous with the groove for the same tendon on the lower surface of the sustentaculum tali. The projection on the lateral side of the groove is called the **posterior tubercle** of the talus, and that on the medial side is called the **medial tubercle**.

The *anterior surface* is the convex, smooth surface of the **head**; it articulates with the navicular bone. The facet on the lower surface of the head for articulation with the anterior part of the upper surface of the calcaneus is usually continuous with the facet that articulates with the sustentaculum tali. The lower part of the medial side of the head articulates not with a bone, but with a ligament called the plantar calcaneo-navicular or "spring" ligament, which stretches between the sustentaculum tali and the plantar surface of the navicular bone; a faint ridge often marks off that area from the rest of the articular surface of the head.

When the talus and the calcaneus of the same foot are placed together properly, their anterior surfaces are almost in the same transverse vertical plane, and the anterior surface of the talus is medial to that of the calcaneus as well as above it; the anterior surfaces of the talus and the calcaneus articulate respectively with the navicular and the cuboid, and the two joints are spoken of together as the *transverse tarsal joint.* The movements of inversion and eversion of the foot take place largely at the transverse tarsal joint. **Inversion** is the movement whereby the medial border of the foot is lifted up, and the sole looks towards the median plane. **Eversion** is the movement whereby the lateral border of the foot is lifted up, and the sole looks in a lateral direction. When the foot is extended so that it is almost in line with the leg, and is inverted, the head of the talus can be both felt and seen as a distinct prominence about an inch in front of and below the ankle joint, and the body of the talus also may be felt near the lateral malleolus.

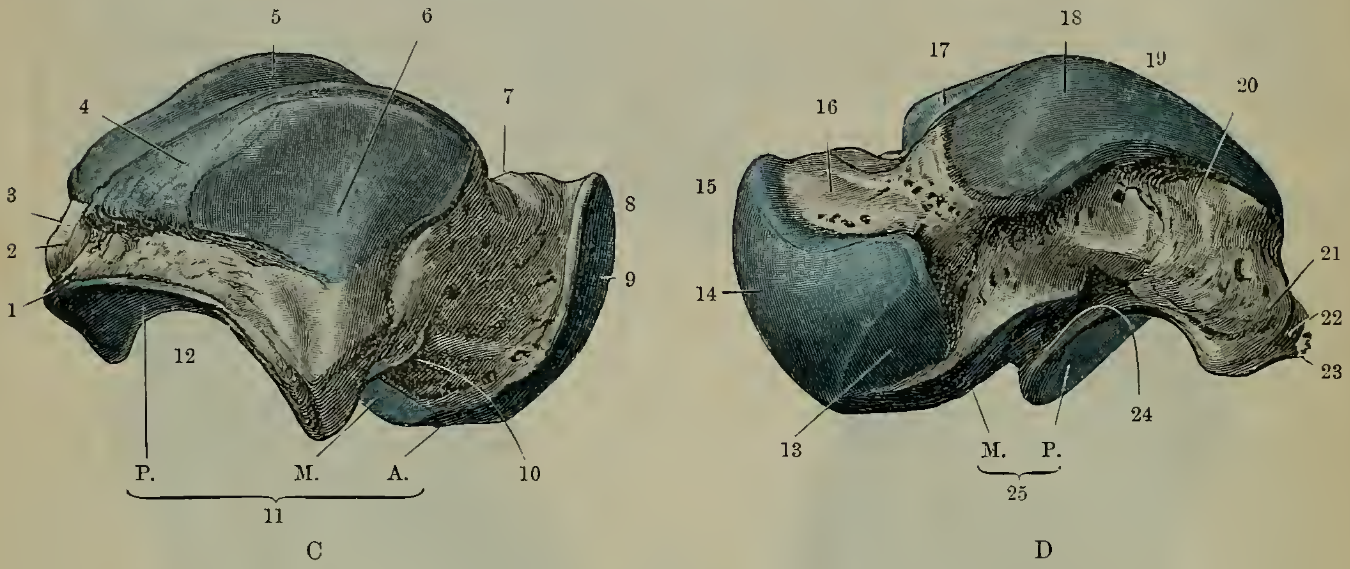


Fig. 236.—Right Talus. C, Lateral side; D, Medial side.

1. Processus posterior.
2. Groove for flexor hallucis longus.
3. Medial tubercle.
4. Surface against which the posterior talo-fibular ligament rests.
5. Trochlea for tibia.
6. Facet for lateral malleolus.
7. Neck.
8. Head.
9. For articulation with navicular.
10. Sulcus tali.
11. Anterior, middle, and posterior facets for calcaneus.
12. Body.
13. Surface resting on plantar calcaneo-navicular ligament.
14. Surface for navicular.
15. Head.
16. Neck.
17. Trochlea for tibia.
18. Facet for medial malleolus.
19. Body.
20. Impression for deltoid ligament.
21. Medial tubercle.
22. Groove for flexor hallucis longus.
23. Processus posterior.
24. Sulcus tali.
25. Posterior and middle facets for calcaneus.

Attachments.—The anterior ligament of the ankle joint and the dorsal talo-navicular ligament are attached to the *upper surface* of the **neck**; the anterior talo-fibular ligament to the *lateral surface*; a part of the deltoid ligament to the *medial surface* of both neck and **body**; the capsule of the talo-calcanean joint to the margins of the large oval facet on the *lower surface* of the body; the interosseous talo-calcanean ligament to the *groove* in front of that facet; the posterior ligament of the ankle joint to the upper part of the *posterior surface*; the posterior talo-fibular ligament to the **posterior tubercle.** The talus does not give attachment to any muscle or tendon. When the talus and calcaneus are placed together, the grooves which give attachment to the interosseous ligament form a tunnel, called the **sinus tarsi.**

Os Cuboideum.

The **cuboid** bone may be picked out from the other smaller tarsal bones because of its more cubical shape. It lies in the lateral margin of the foot in front of the calcaneus.

The *anterior* and *posterior surfaces* can be distinguished from the other surfaces because each of those two is wholly covered with an articular facet. The posterior surface is concavo-convex and sloping; it articulates with the calcaneus. The anterior surface also slopes and is nearly flat; it is subdivided by a faint vertical ridge into two parts which articulate with the bases of the fourth and fifth metatarsal bones.

The *superior* or *dorsal surface* is distinguished from the others because it is nearly flat and is rough, having no articular facet. Owing to the slope of the dorsum of the foot from medial to lateral border, the upper surface of the cuboid is flush not with the upper surface of the calcaneus but with the lateral surface, when the bones are placed together properly. The *inferior* or *plantar surface* is rough and uneven. Close to its anterior margin it is crossed by a fairly deep groove which lodges the tendon of the peroneus longus as it crosses the sole of the foot; the posterior boundary of the groove is a broad prominent ridge called the **tuberosity.**

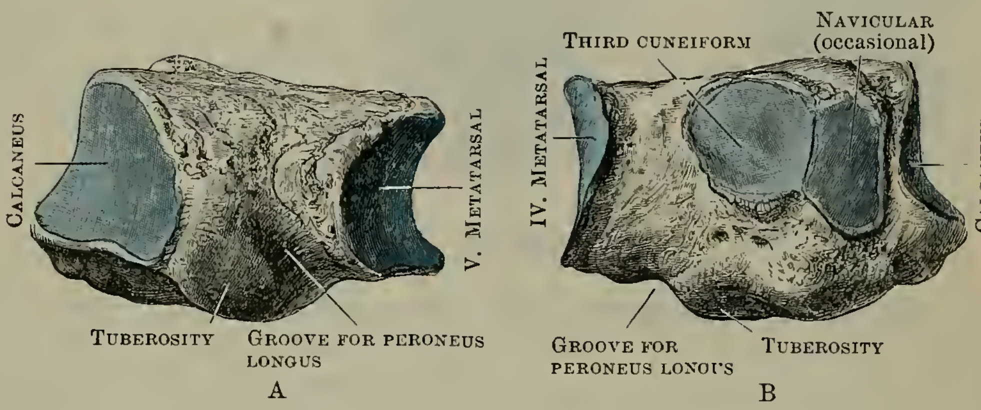


FIG. 237.—RIGHT CUBOID BONE. A, Lateral Side; B, Medial Side.

The *lateral surface* is the smallest of all the surfaces, owing to the slope of the anterior and posterior surfaces. It is formed by the lateral ends of the groove and ridge seen on the plantar surface; at the lateral end of the ridge there is often a smooth facet produced by contact with a sesamoid bone or cartilage which lies in the substance of the peroneus longus tendon as the tendon turns from the lateral surface of the cuboid on to its plantar surface. The *medial surface* is large and rather uneven; about its middle there is a facet for articulation with the third cuneiform bone; and behind that facet, and continuous with it, there may be another, smaller facet for articulation with the navicular bone.

Attachments.—Dorsal, plantar, and interosseous ligaments, binding the **cuboid** to neighbouring bones, are attached to the rough parts of its surfaces. The long plantar ligament is attached to both *lips* of the **groove** on the *plantar surface* and holds the peroneus longus tendon in place. A slip from the tendon of the tibialis posterior is inserted into the medial part of the groove; and a slip of the flexor hallucis brevis arises from the medial part of the area behind the ridge.

Os Naviculare Pedis.

The **navicular bone** is readily identified because one of its two large surfaces is markedly concave—hence its name, from a fancied resemblance to a boat. It lies in the medial side of the foot in front of the talus, and is compressed from before backwards.

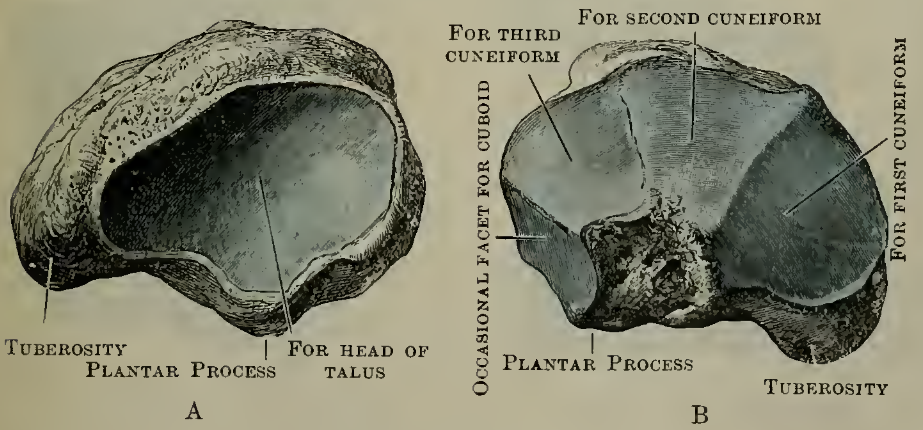


FIG. 238.—RIGHT NAVICULAR BONE.
A, Posterior aspect; B, Anterior aspect.

The *posterior surface* is the large, smooth, concave surface, and articulates with the head of the talus. The *anterior surface* also is smooth, but it is slightly convex, and it is mapped out by faint ridges into three areas for articulation with the three cuneiform bones. The *superior* or *dorsal surface* is rough and is convex in its longer measurement. The *inferior* or *plantar surface* also is rough, but it is much smaller than the dorsal surface and is very uneven; its most prominent point is sometimes called the **plantar process.**

The *medial surface* is modified into a rough projection, called the **tuberosity** of the navicular bone, which can be felt on the medial side of the foot about an inch below and in front of the medial malleolus, and is much used as a landmark; when shoes are worn the tuberosity is on a level with the upper margin of the shoe. The *lateral* surface is not marked off from the superior surface by any definite line; it is small and usually rough, but may be faceted to articulate with the cuboid bone.

Attachments.—Dorsal and plantar ligaments are attached to the rough parts and bind the **navicular** bone to adjacent bones. The most important of those is the plantar calcaneo-navicular ligament, which stretches from its *plantar surface* to the sustentaculum tali. The anterior fibres of the deltoid ligament are attached to the **tuberosity**, which receives also a great part of the tendon of the tibialis posterior.

Ossa Cuneiformia.

The three **cuneiform** bones are wedge-shaped [*cuneus*=a wedge]. They lie side by side in front of the navicular bone; they are named by number, **first**, **second**, and **third**, from medial to lateral side, and each articulates with the metatarsal bone of corresponding number. Their anterior and posterior surfaces are occupied by smooth articular facets. The first cuneiform is the largest and most important of the three; the second is the smallest and is the most definitely wedge-shaped.

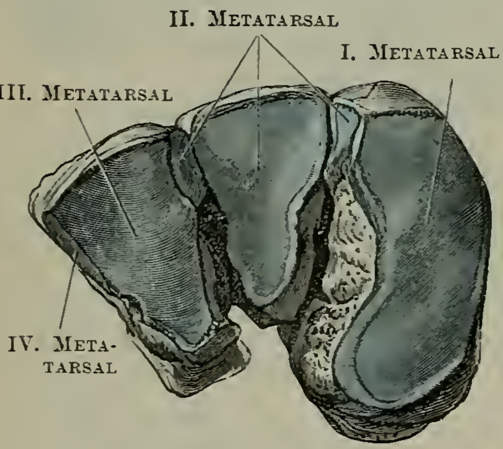


Fig. 239.—Anterior Surfaces of the three Cuneiform Bones of the Right Foot.

The **first cuneiform** lies in the medial side of the foot between the navicular bone and the first metatarsal. The *anterior surface* is kidney-shaped in outline, the concave edge being its lateral margin; it articulates with the base of the first metatarsal bone. The *posterior surface* is concave and pear-shaped, with the stalk of the pear upwards; it articulates with the navicular bone. The *lateral surface* is uneven and slightly concave; it has facets near its posterior and upper margins for articulation with the second cuneiform and with the medial side of the base of the second metatarsal bone. The *medial surface* is the largest of the surfaces and is rough. It can be felt in front of the tuberosity of the navicular, and, in conformity with the shape of the medial side of the foot, it is convex from above downwards. At the most anterior and lowest part there is a smooth impression, resembling a facet, for the insertion of the greater part of the tendon of the tibialis anterior. The *inferior* or *plantar surface* is the rough base of the wedge. The *superior* or *dorsal surface* is reduced to a border—the edge of the wedge—between the lateral and medial surfaces, and it slopes downwards and backwards, because the posterior surface is smaller than the anterior.

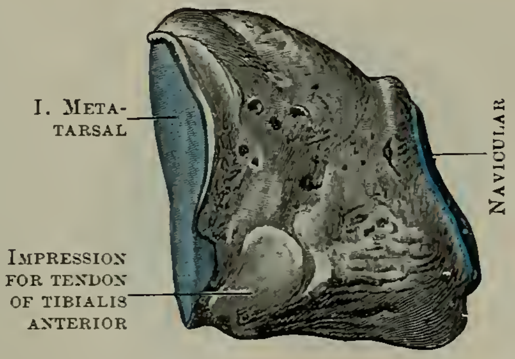


Fig. 240.—Right First Cuneiform (Medial Side).

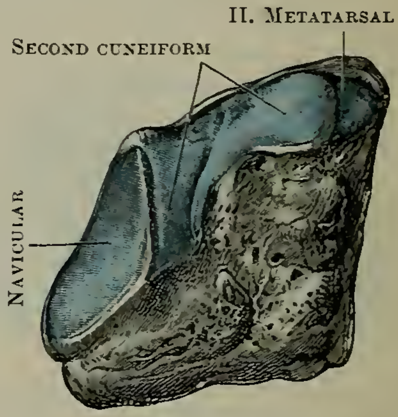


Fig. 241.—Right First Cuneiform (Lateral Side).

Second Cuneiform.—The *superior* or *dorsal surface* is square in outline, rough and nearly flat, and is the base of the wedge. The *inferior* or *plantar surface* is reduced to a rough border between the medial and lateral surfaces, and is the edge of the wedge. The *anterior* and *posterior surfaces* are triangular in outline: the anterior is slightly convex and articulates with the base of the second metatarsal bone; the posterior is slightly concave and articulates with the navicular bone. The *medial surface* has a facet along its upper border and another along its posterior border, both for articulation with the first cuneiform; the rest of the surface is rough. The *lateral surface* has a facet along its posterior border for articulation with the third cuneiform, and the rest of it is rough. The facet along the upper border distinguishes the medial surface from the lateral surface; the facets along the posterior borders enable one to distinguish the posterior surface from the anterior, if that has not been done already.

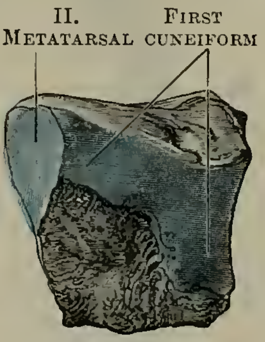


Fig. 242. — Right Second Cuneiform (Medial Side).

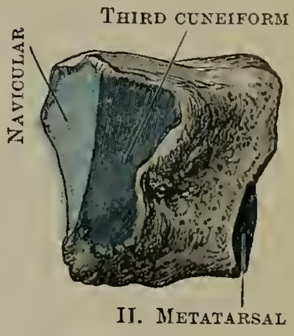


Fig. 243. — Right Second Cuneiform (Lateral Side).

The **third cuneiform** is larger than the second cuneiform, provided that both specimens come from the same skeleton. A beginner may have difficulty in distinguishing the third cuneiform of a small foot from the second of a large foot, for the two bones are not unlike in general appearance.

The *superior* or *dorsal surface* is oblong in outline, rough and nearly flat, and is the base of the wedge. The *inferior* or *plantar surface* is reduced to a rough, thick border between the medial and lateral surfaces, and is the edge of the wedge. The *anterior surface* is all covered with a facet for articulation with the base of the third metatarsal bone, and is nearly triangular in outline. The upper and larger part of the *posterior surface* is covered with a quadrangular facet for articulation with the navicular bone, and the small, lower part is rough. The *medial surface* has a narrow facet along its posterior border for articulation with the second cuneiform, and usually two small facets along its anterior border for articulation with the lateral side of the base of the second metatarsal bone; the rest of the surface is rough. The *lateral surface* is usually wider from before backwards than the medial surface; it has a small facet at its anterior border for articulation with the medial side of the base of the fourth metatarsal bone, and a large facet in its upper posterior corner. That facet distinguishes the lateral surface from the medial surface, distinguishes the third cuneiform from the second, and enables one to identify the posterior surface, for it lies close to the posterior border; it articulates with the cuboid bone. The rest of the lateral surface is rough.

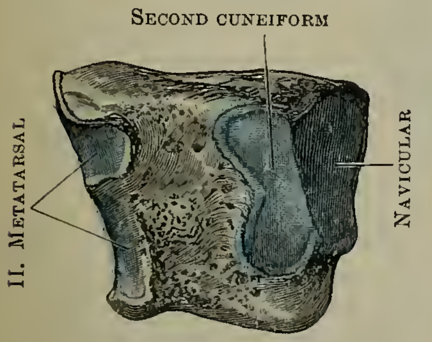


Fig. 244.—Right Third Cuneiform (Medial Side).

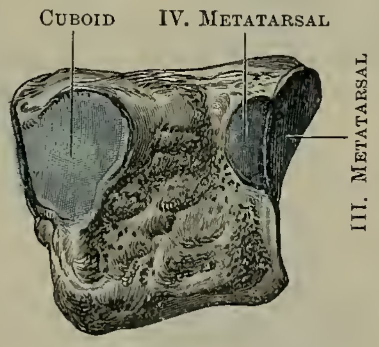


Fig. 245.—Right Third Cuneiform (Lateral Side).

When the three cuneiform bones are fitted together their posterior surfaces are nearly flush, for they all articulate with the front of the navicular bone. The second cuneiform is shorter than the other two, so that a gap is left, between the first and the third, in front of the second. The base of the second metatarsal bone fits into the gap, so that it articulates posteriorly with the second cuneiform, and at the sides with the first and the third—an arrangement which increases the stability of the foot, but adds to the difficulty of amputating the foot at the tarso-metatarsal joints. The second and third cuneiform bones are placed edge downwards and are of less depth than the first; therefore the plantar surfaces of the cuboid bone and the first cuneiform are not far apart.

Attachments.—The three **cuneiform** bones are united to each other and to adjacent bones by dorsal, plantar, and interosseous ligaments. A large part of the tendon of the tibialis posterior is inserted into the posterior part of the *plantar surface* of the **first** cuneiform, and it sends slips to the plantar surfaces of the **other two**. The greater part of the tendon of the tibialis anterior is inserted into an impression situated low down and far forward on the *medial surface* of the **first** cuneiform, and the smaller part of the peroneus longus tendon is inserted into an impression at the corresponding point on its *lateral surface*. The first cuneiform therefore receives parts of the tendons of the tibialis anterior, tibialis posterior, and peroneus longus, while the second and third cuneiform bones get only slips from the tibialis posterior.

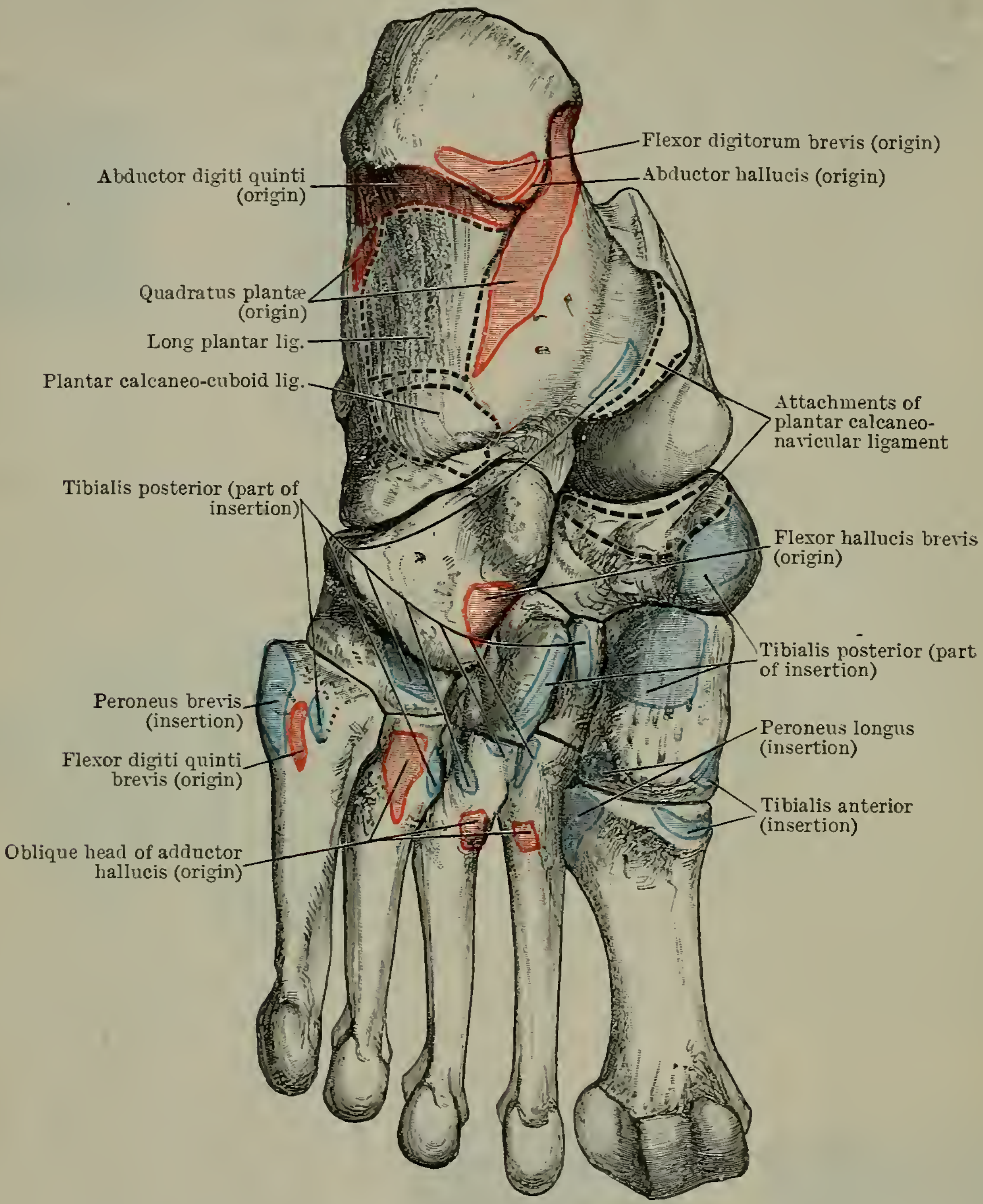

Flexor digitorum brevis (origin)
Abductor hallucis (origin)
Abductor digiti quinti (origin)
Quadratus plantæ (origin)
Long plantar lig.
Plantar calcaneo-cuboid lig.
Attachments of plantar calcaneo-navicular ligament
Tibialis posterior (part of insertion)
Flexor hallucis brevis (origin)
Tibialis posterior (part of insertion)
Peroneus brevis (insertion)
Peroneus longus (insertion)
Flexor digiti quinti brevis (origin)
Tibialis anterior (insertion)
Oblique head of adductor hallucis (origin)

Fig. 246.—Muscle-Attachments to Left Tarsus and Metatarsus (Plantar Aspect).

Metatarsus.

The **metatarsus** lies in front of the tarsus, and is the skeleton of the anterior or distal half of the foot proper [μετά (meta) = next after]. It consists of five separate **metatarsal bones**, one corresponding to each toe. They are named by number—*first, second,* etc., beginning with the one corresponding to the big toe. Each metatarsal is a miniature long bone, possessing a **body** or shaft and **two ends.** Each of them is slightly concave lengthwise on its inferior or plantar surface; the rounded end is the **anterior** or distal end, and is called the *head*; the **posterior** end is larger, and is called the *base.*

The corresponding bones of the hand are called *metacarpal bones*; they are not unlike metatarsal bones, and a beginner may mistake a metacarpal bone for a metatarsal. The metatarsal bones are more flattened from side to side than the metacarpals, and a metacarpal has on its dorsal surface a long, flat, triangular area, the base of which is at the head of the bone, while the metatarsal bones have no such area. The metatarsals are about three inches long, and are rather longer than the metacarpals, if the bones are from the same skeleton. The first metatarsal and first metacarpal are distinguished by their size: the first metatarsal is the thickest of all those bones, and the first metacarpal is the shortest.

Basis.—The **bases** of the metatarsal bones are firmly bound to the tarsus by ligaments, and their *posterior surfaces* articulate with the tarsus, forming *tarso-metatarsal joints.* The bases of the lateral four are tightly bound to each other and articulate *side by side*, forming *inter-metatarsal joints*; the base of the first sometimes articulates with that of the second.

Capitulum.—The **heads** articulate with the proximal row of phalanges, forming *metatarso-phalangeal joints.* The sides of the heads have pits and tubercles for the attachment of the collateral ligaments of those joints. The articular part extends much further on to the plantar surface than on to the dorsum, because when the toe is *flexed, i.e.,* moved towards the sole, the base of the phalanx articulates with the plantar surface of the head of the metatarsal; when the toe is *extended* it is in straight line with the metatarsal, and the base of the phalanx articulates with the distal surface of the head. *Dorsiflexion* or *hyper-extension* is the movement of bending the toe upwards out of line with the metatarsal; the degree to which it is possible varies in different people but is never great, and therefore the articular surface of the head extends very little on to the dorsum.

Os Metatarsale Primum.—The **first metatarsal bone** can be felt in all its length in the medial side of the foot. Its **base**, looked at end on, is kidney-shaped, and the notched or concave side is the *lateral* side. It articulates with the first cuneiform bone. The **head** is slightly compressed from above downwards, and has two well-marked grooves on its lower or *plantar* surface, for articulation with two small sesamoid bones. The **body** is three-sided; its surfaces are dorsal, plantar, and lateral, and can be identified by reference to the head and base.

Os Metatarsale Quintum.—The **fifth metatarsal bone** is easily distinguished from the others because it is compressed from above downwards, has a relatively small **head**, and has a large **tuberosity** on the *lateral* side of the **base**. The whole length of the bone can be felt in the lateral border of the foot, and the tuberosity makes the prominence, seen as well as felt, about midway between the heel and the little toe. The posterior surface of the base articulates with the cuboid.

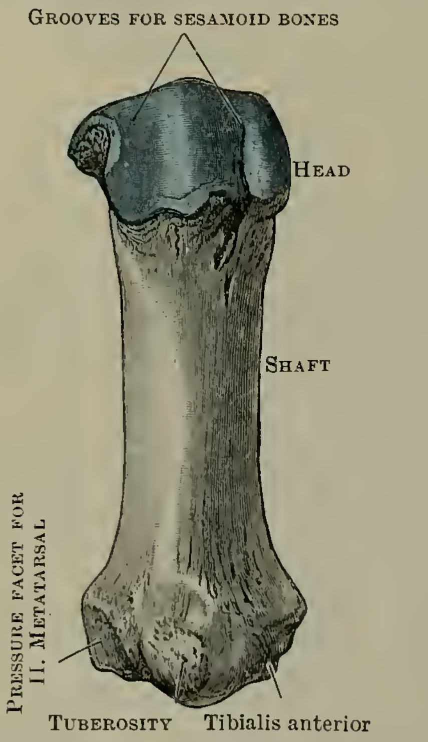


Fig. 247.—First Right Metatarsal Bone (Plantar Aspect).

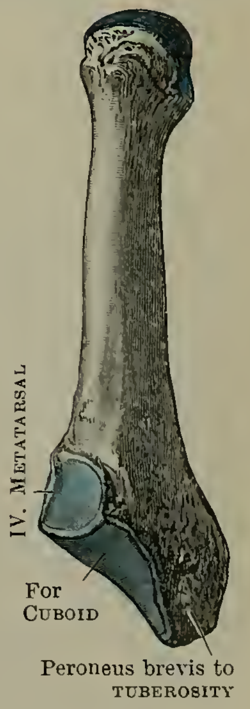
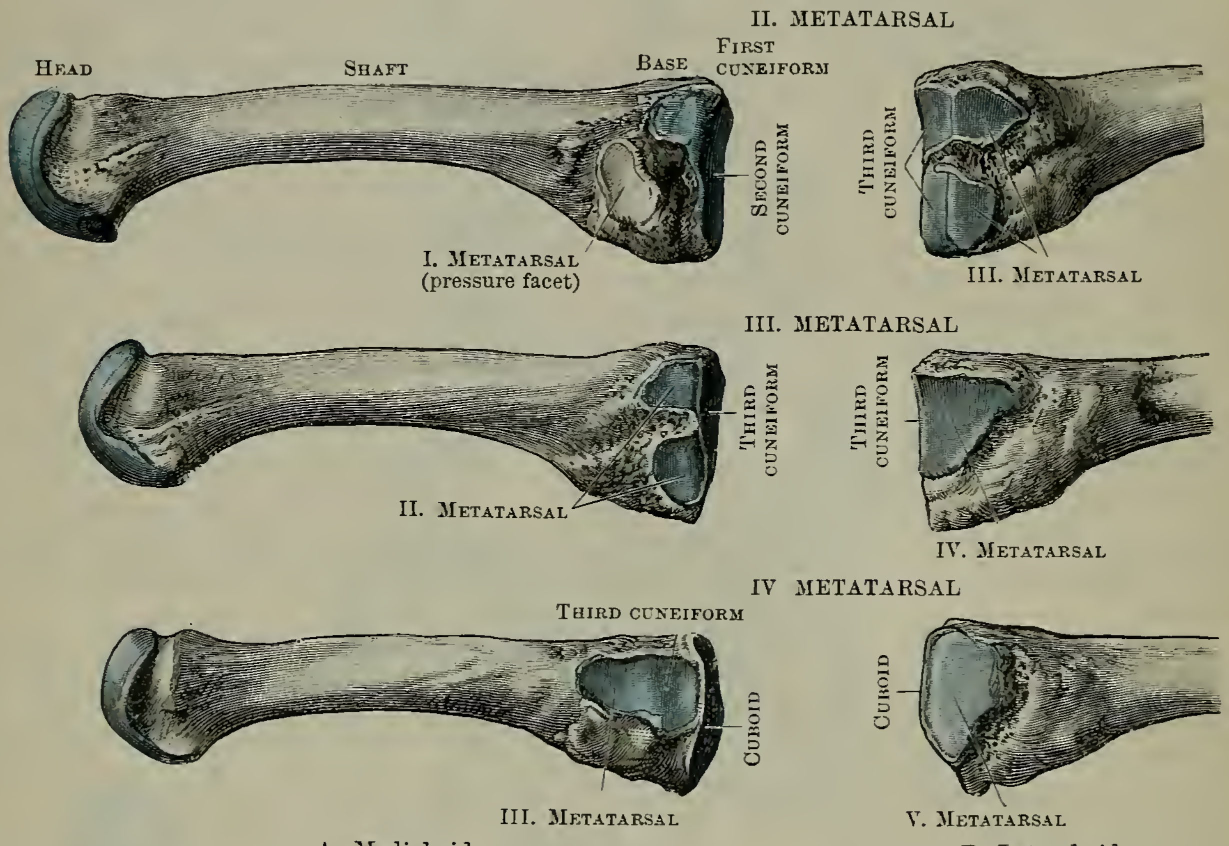


Fig. 248.—Fifth Right Metatarsal Bone (Dorsal Aspect).

A line drawn from the base of the first metatarsal to the tuberosity of the fifth slants backwards, and corresponds fairly closely to the position of the tarso-metatarsal joints. Therefore those joints and the posterior surfaces of the bases of the lateral four metatarsals slope backwards from medial to lateral side; consequently, the lateral surface of a metatarsal is longer than the medial surface and can be distinguished from it at a glance.

The **second** and **third metatarsal bones** are very much alike. They are compressed from side to side in all their length; the posterior surface of the base is nearly triangular in outline and articulates with the cuneiform bone of corresponding number. But they can be distinguished if the *lateral* surface of the base is examined: the lateral surface of the **second** has two facets, an upper and a lower, separated by a horizontal groove, and one or both of the facets are double; for the base of the second metatarsal fits in between the first and third cuneiform bones, articulating with them, and the lateral surface articulates also with the base of the third metatarsal.

The **head** and **body** of the **fourth metatarsal bone** resemble those of the second and third, but the base is more irregular, is more cuboidal in shape, and its posterior surface, which articulates with the cuboid, is more nearly square in outline. The *lateral surface* of the **base** has a large facet bounded by an oblique groove; in that respect it resembles the lateral surface of the third, but the medial surfaces are quite different: the *medial surface* of the **third** has two small facets, an upper and a lower; the *medial surface* of the **fourth** has a large facet which is usually subdivided, for it articulates not only with the base of the third metatarsal but also with the lateral surface of the third cuneiform bone.



A, Medial sides. B, Lateral sides.

FIG. 249.—VIEW OF THE BASES AND SHAFTS OF THE SECOND, THIRD, AND FOURTH METATARSAL BONES OF THE RIGHT FOOT.

Attachments.—In the case of *each metatarsal*, collateral ligaments pass from the sides of the **head** to the sides of the base of the first phalanx, and the plantar accessory ligament closes in the metatarso-phalangeal joint below, being attached loosely to the plantar surface of the metatarsal just behind the head, and firmly to the plantar surface of the base of the phalanx, while the extensor tendon takes the place of a dorsal ligament. Dorsal, plantar and interosseous ligaments bind the **bases** to each other and to the tarsus.

Slips of the long plantar ligament are attached to the plantar surfaces of the **bases** of the *second*, *third*, and *fourth* metatarsals; slips of the tibialis posterior tendon are inserted into those bases, and the oblique head of the adductor hallucis arises from them. One head of a dorsal interosseous muscle arises from each side of the **body** of each of those three bones, and the first and second plantar interosseous muscles arise respectively from the third and fourth.

The smaller part of the tendon of the tibialis anterior is inserted into an impression on the medial side of the **base** of the *first* metatarsal bone near the sole, and the greater part of the peroneus longus tendon into an impression at the corresponding point on the lateral side; one head of the first dorsal interosseous muscle arises from the lateral surface of the **body**.

The peroneus brevis tendon is inserted into the tuberosity on the **base** of the *fifth* metatarsal; the peroneus tertius tendon into the dorsal surface of the base; part of the flexor digiti quinti brevis arises from the plantar surface. The third plantar interosseous muscle arises from the plantar surface of the **body**, and one head of the fourth dorsal interosseous from the medial surface.

Phalanges Digitorum Pedis.

Each **phalanx** is a miniature long bone, possessing a **body** or shaft and **two ends** [φάλαγξ (phalanx) = a round log or roller]; the **proximal** end is the larger end and is called the *base*; the **distal** end is called the *head.* The first phalanx of a toe is about the same length as the second phalanx of a finger, but it can be picked out from among phalanges of fingers because its base is larger, and its body is relatively more attenuated; the first phalanx of the great toe, on the contrary, is thicker than any other phalanx. The second and third phalanges of the toes are so greatly reduced in length that they cannot be mistaken either for the first phalanx of a toe or for the phalanges of fingers.

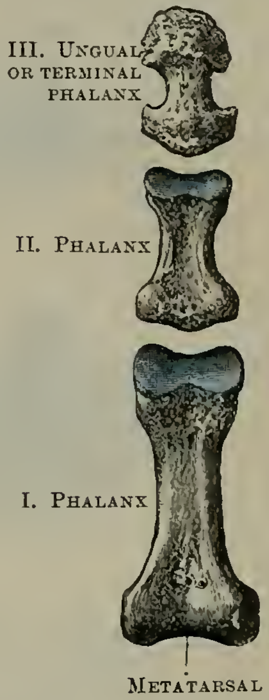


FIG. 250.—PHALANGES OF A TOE (Plantar Aspect).

The **first phalanx** of a toe is a little more than an inch in length, and is slightly concave lengthwise on its inferior or *plantar surface.* The **base** is expanded and is concave on its proximal surface for articulation with the rounded head of the metatarsal. The **body** is thin, being compressed from side to side near the base, and from above downwards near the head. The **head** is pulley-shaped and articulates with the base of the second phalanx; the articular part extends on to the plantar surface but scarcely at all on to the dorsum, for dorsiflexion is a limited movement, while flexion is free, and the middle joint of the toes in many people who have worn boots since infancy is in a permanent position of flexion.

The **second phalanx** is very short, usually less than half an inch in length, and it may be a mere nodule of bone. The **base** articulates with the head of the first phalanx and is therefore the reverse of a pulley: it has two concave smooth areas with a low vertical smooth ridge between them. The **body** is convex on its dorsal surface and either flat or concave on its plantar surface; but it may be difficult to distinguish the surfaces if the phalanx is stunted. The articular part of the **head** is a shallow pulley, and as it extends some distance on to the plantar surface it is a guide to the surfaces.

The **third phalanx** also is very small. The **base** articulates with the head of the second phalanx and is relatively expanded. The **body** is constricted, the **head** is expanded and is very rough on its plantar surface.

The **great toe** has only two phalanges. The **first** resembles the first phalanx of the other toes and **second** resembles the third; but they are much larger in every way than the phalanges of other toes. In an adult great toe the medial side of the base of a phalanx is larger than the lateral side, so that the toe inclines towards the other toes; the inclination is not an abnormality due to wearing pointed boots, but it may be exaggerated by the use of boots that do not fit.

Owing to the slant of the joints between the tarsus and metatarsus and to the fact that the toes are progressively shorter from the second to the fifth, the nail of the little toe is about the level of the root of the big toe; the root of the little toe or fifth metatarso-phalangeal joint is the yielding prominence on the lateral border of the widest part of the foot, and usually bulges out the side of the shoe a little in front of the middle, and, being so far back, is apt to be mistaken for the base of the metatarsal bone.

Attachments.—The plantar accessory and the collateral ligaments of the metatarso-phalangeal joints and interphalangeal joints are attached to the **bases** and the **heads**; the fibrous flexor sheaths that hold the flexor tendons in their place on the toes are attached to the **bodies**.

The abductor hallucis is inserted into the medial side of the **base** of the **first phalanx** of the *big toe*; the adductor hallucis into the lateral side; the flexor hallucis brevis into both sides; the medial tendon of the extensor digitorum brevis into the dorsum. The flexor brevis and abductor digiti quinti are inserted into the lateral side of the base of the first phalanx of the *little toe*; the third plantar interosseous and the fourth lumbrical into the medial side. Plantar and dorsal interossei and lumbricales are inserted into the sides of the base of the first phalanx of the *other three toes.*

The **base** of the **second phalanx** of the *great toe* receives the insertion of the tendons of the long flexor and extensor on the plantar and dorsal aspects respectively. A tendon of the flexor digitorum brevis is inserted into the sides of the **body** of the **second phalanx** of each of the *other toes,* and a slip of the extensor expansion into the dorsum of its base. The **base** of each **third phalanx** gives insertion to a tendon of the flexor digitorum longus on its plantar surface, and the rest of the extensor expansion on its dorsal surface.

Arches of the Foot.—The bones of the tarsus and metatarsus do not lie in a horizontal plane, but are arranged in the form of a half-dome, with longitudinal and transverse arches, so that the foot rests posteriorly on the lower part of the back of the calcaneus, anteriorly on the heads of the metatarsal bones, and at the lateral border slightly on the fifth metatarsal bone, while at the medial border it is raised well away from the ground.

The dome and its arches are due primarily to the shape of the bones with which the framework of the foot is built, and they are maintained by the ligaments that bind the bones together and by the muscles, tendons, and fasciæ of the foot, their chief support being the tendons of the tibialis posterior and peroneus longus, which cross the sole obliquely from opposite sides.

The advantages given by the arches of the foot are that the weight of the body is distributed over the foot (compare the use of arches above windows in the wall of a big building), the height of the body is slightly increased, springiness is given to the step, shocks received in running and jumping are broken; and a space is provided in which the soft parts of the sole of the foot may lie free from pressure.

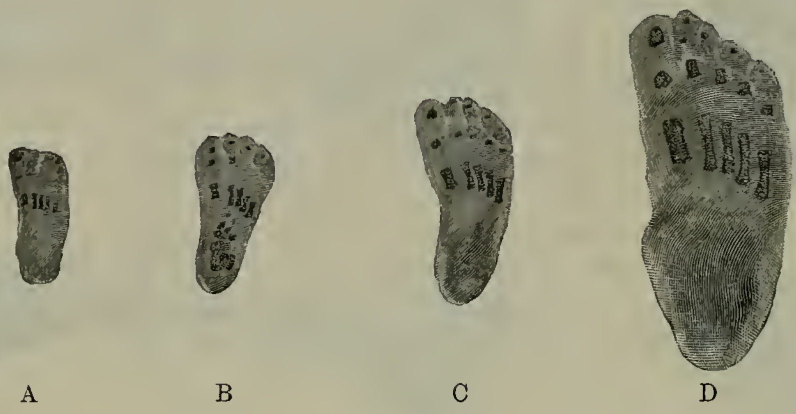


Fig. 251.

A. About the end of the third month. The primary centres of all the metatarsals are shown, as well as the centres for the phalanges of the great toe and the terminal phalanx of the third toe.

B.[1] A little later. The centres for the terminal phalanges of the medial four toes are seen, as well as the centres for the first phalanges of the great and second toe.

C. About the fourth month. The centres for all the terminal phalanges, as well as those of the first row, are well ossified.

D. About the fifth month. In this the centre for the second phalanx of the second toe has already made its appearance.

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[1] This specimen displays the occurrence of anomalous centres within the tarsus the significance of which is not apparent. The appearance is not due to any defect in the plate, but recurred in repeated radiographs.

The muscles and tendons may become inefficient owing to malnutrition; the strain of upholding the arches under the weight of the body then becomes too much for the ligaments; they stretch, and the arches sink down gradually, till a condition of flat-foot or splay-foot is established, the bones altering in shape to fit each other in their modified positions in the flattened arch.

Ossification of Bones of Foot.—Tarsus. Each tarsal bone has one *primary* centre.

	Calcaneus.	Talus.	Cuboid.	Third Cuneiform.	Second Cuneiform.	First Cuneiform.	Navicular.
Primary centre appears at	6th month of fœtal life	8th month of fœtal life	Birth	1st year	2nd year	3rd year	4th year

The calcaneus alone has a *secondary* centre. It appears in the eighth year for the part of the bone that bears the medial and lateral tubercles. Ossification of all the tarsal bones is completed after puberty. The posterior process of the talus may have a separate centre, and the process may develop as an independent bone called the *os trigonum.*

Metatarsus.—A *primary* centre for each metatarsal appears in the ninth week of fœtal life. They are well ossified at birth. A *secondary* centre for each appears as follows:—

Secondary Centre.	Appears at	Epiphysis fuses at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For *base* of first	2nd year	18	Outside.
For *head* of others	2nd-4th year	18	Outside.

Phalanges.—Each has a *primary* centre for body and head; the base of each is ossified from a secondary centre. (See next page.)

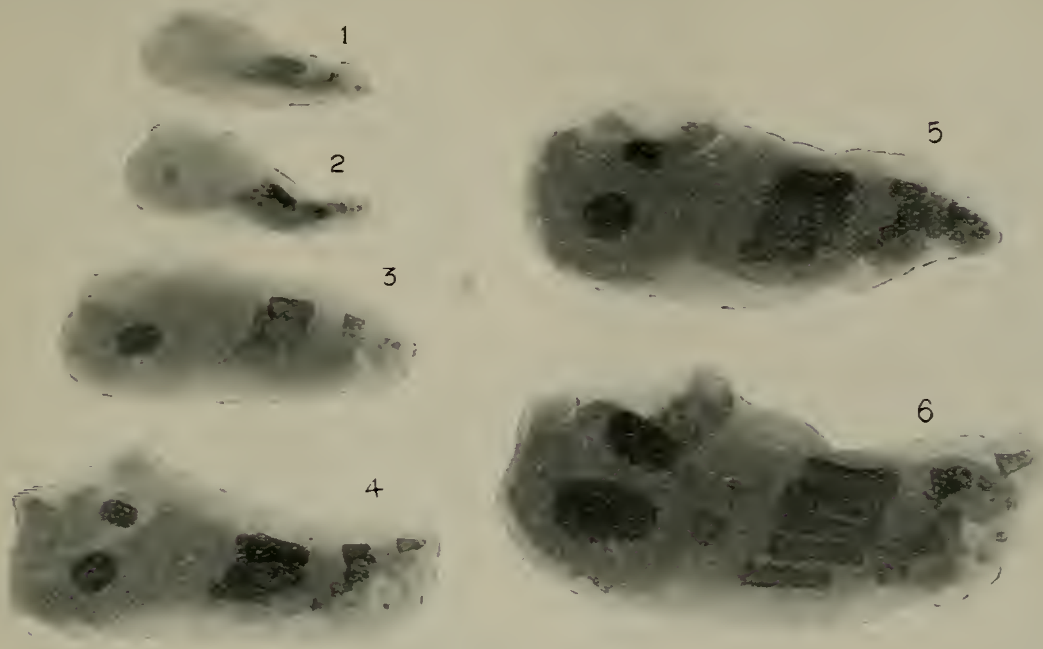

Fig. 252.—Radiographs of the Fœtal Foot.

1. About fifth month. No ossification in the tarsus visible.
2. About sixth month. Appearance of a nucleus for the calcaneus.
3. About seventh month. Nucleus for calcaneus well developed.

4 and 5. About eighth month. Centre for talus, as well as for calcaneus, is now seen.

6. About birth. Centres for the talus and calcaneus are well developed; there is also a considerable centre for the cuboid, and the centre for the third cuneiform has appeared.

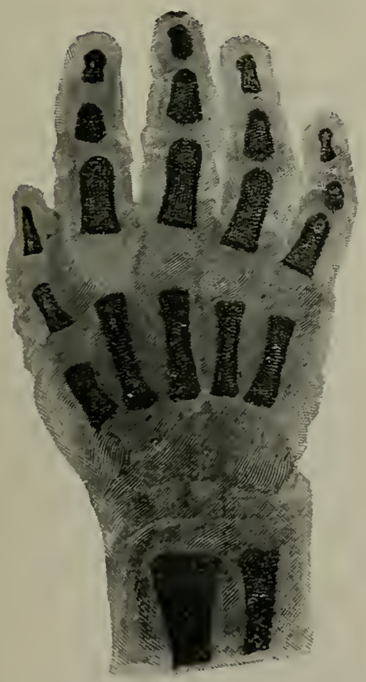

Fig. 253.—Radiograph of the Hand at Birth.

It will be noticed that whilst the primary centres for the metacarpus and phalanges are well ossified, the carpus is still entirely cartilaginous.

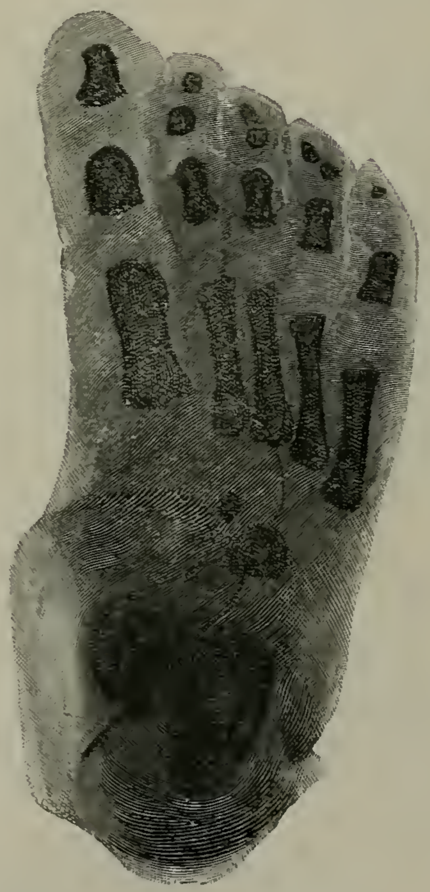

Fig. 254.—Radiograph of the Foot at Birth.

The centres for the calcaneus and talus are well developed, the centre for the cuboid is quite distinct, and in this instance the third cuneiform is already commencing to ossify.

Primary Centre for	Ungual Phalanx.	First Phalanx.	Second Phalanx.
Appears	At end of 3rd month	At end of 4th month	6th month—birth

Secondary Centre.	Appears at	Epiphysis fuses at	Relation of Epiphyseal Line to Capsule of Neighbouring Joint.
For base	4th year	16-18	Outside.

Structure and Variations.—The *tarsal* bones are composed of spongy tissue enclosed in compact tissue. The *metatarsal* bones and the *phalanges* have the structure of long bones. The bones are arranged in two columns. The lateral column is formed by the calcaneus, the cuboid, the fourth and fifth metatarsal bones, and the phalanges of corresponding digits; the medial column consists of the talus, the navicular, the three cuneiform bones, the medial three metatarsal bones, and the phalanges of corresponding digits.

The **calcaneus** occasionally articulates with the navicular. The sustentaculum tali may be a separate bone, and so may be the trochlear process. The articular surface for the medial malleolus on the **talus** extends on to the neck in an infant. Occcasionally in an adult talus there is a small facet for the tibia on the medial part of the upper surface of the neck, probably due to the ankle joint being often in a state of extreme flexion. The *os trigonum*, when present, may be quite separate, or joined to the body of the talus by cartilage. An ossicle may be present between the talus and dorsal surface of navicular, and another on the dorsum between the talus, calcaneus, navicular, and cuboid. The tuberosity of the **navicular** is sometimes a separate bone. The **first cuneiform bone** may be divided into a dorsal and a plantar part. In rare cases a little separate ossicle is found between the posterior parts of the dorsal surfaces of the first and second cuneiform bones. Division of the **cuboid** has been recorded. The tuberosity of the base of the **fifth metatarsal** may be separate; as also the part of the base of the **first** into which the peroneus longus is inserted. A separate ossicle may be found between the bases of the first and second metatarsals. Fusion of **phalanges** is not uncommon, especially in the little toe.

Ossa Sesamoidea.

Sesamoid bones are imbedded in tendons, but there is usually one surface free and smooth for articulation. The largest sesamoid bone is the **patella.** The *flexor hallucis brevis* has two little sesamoid bones in its tendons of insertion. They are about the size of half of a marrowfat pea; they should not be mistaken for the pisiform bone of the hand, for they are compressed and oval. They play against the grooves on the plantar surface of the head of the first metatarsal bone, and they add to the size and firm consistence of the parts below the first metatarso-phalangeal joint—that is, the medial part of the ball of the foot; the medial sesamoid may be divided transversely, and sometimes there is a minute nodule between the two. Occasionally there are minute sesamoid bones at the *other metatarso-phalangeal joints* and at the *interphalangeal joint* of the big toe and other interphalangeal joints. A sesamoid bone or cartilage is usually present in the tendon of the *peroneus longus* as it crosses the lateral aspect of the cuboid bone to enter the sole. The tendon of the *tibialis posterior* is thickened at the point where it glides over the spring ligament and enters the sole; the thickening has sometimes the character of a sesamoid cartilage. More seldom, a sesamoid bone is present in the *tibialis anterior* close to its insertion, in the *psoas major* as it passes over the pubic bone, in the lateral head of the *gastrocnemius* as it crosses the lateral condyle of the femur, and in the *gluteus maximus* as it overlies the greater trochanter.

DEVELOPMENT AND MORPHOLOGY OF THE LIMBS.[1]

The limbs appear in the Human embryo about the third week as small buds on the sides of the body near the cephalic and caudal ends of the trunk. Each of them is derived from several trunk segments; for the upper limb contains branches from spinal nerves, from the fourth cervical to the second thoracic inclusive; and the lower limb contains branches from the last thoracic nerve, the five lumbar nerves, and the upper four sacral nerves. The buds arise from the ventro-lateral part of the trunk, and the nerves of a limb are derived from the anterior rami of the spinal nerves.

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[1] It is not possible to do more than touch upon the subject in a general text-book.

Each bud has two surfaces and two borders. At first the surfaces look ventrally and dorsally; the ventral aspect corresponds to the flexor surface of the adult limb, and the dorsal aspect to the extensor surface; the borders of each bud look headward and tailward, and are named **pre-axial** and **post-axial**, respectively. (Figs. 103-108, pp. 80, 81).

During the second month slight constrictions appear in the elongating buds at positions which correspond to the elbow and the wrist, the knee and the ankle; and grooves appear on the dorsal surfaces of the extremities of the buds, indicating the subdivision into digits. At the same time, the central or axial mesoderm of the bud passes through a pro-cartilage stage, and chondrifies to form the cartilage models of the limb bones. Chondrification begins in the roots of the limbs and spreads towards the digits, leaving unchondrified intervals where joints are to be formed. The cartilage developed along the pre-axial border of the forearm becomes the radius, and the pre-axial digit becomes the thumb; in the leg and foot the pre-axial cartilage and digit become the tibia and the great toe; similarly, the ulna and little finger, the fibula and little toe are developed at the post-axial borders of the respective limbs. Therefore, the thumb, the radius, and the lateral epicondyle of the humerus are serially homologous with the great toe, the tibia, and the medial epicondyle of the femur, if it is granted that the pre-axial borders of the two limbs are serially homologous.

During the third month the embryo—now called the *fœtus*—begins to assume the "fœtal position," which is one of flexion at all the joints, notably those of the limbs; the wrist and the elbow are flexed and the upper arm is bent tailwards along the side of the thorax; the ankle is flexed and the foot is turned medially, the knee is flexed and the thigh is inclined headwards along the abdomen. At the same time the upper and lower limbs are rotated around their long axes. The *lower limb* is rotated through an angle of 90°, so that the pre-axial border, which originally looked headwards, looks towards the median plane; but the rotation is not completed till after birth. The *upper limb* is rotated in the opposite direction, so that the pre-axial border is turned away from the median plane; therefore the flexor surface is the anterior aspect of the upper limb while it is the posterior aspect of the lower limb. The movement is not so complete in the upper limb as in the lower; for only in the supine position, which is an unnatural position, is the flexor surface of the upper limb directed straight forwards. The rotation takes place partly at the shoulder joint and the hip joint, and partly in the shafts of the bones; some assert and others deny that the rotation involves also the dorsal part of the limb girdles.

The homology between the limb bones of Man and those of other animals, and the serial homology or homo-dynamy between the bones of the two limbs in Man are fairly clear except in the case of the limb girdles.

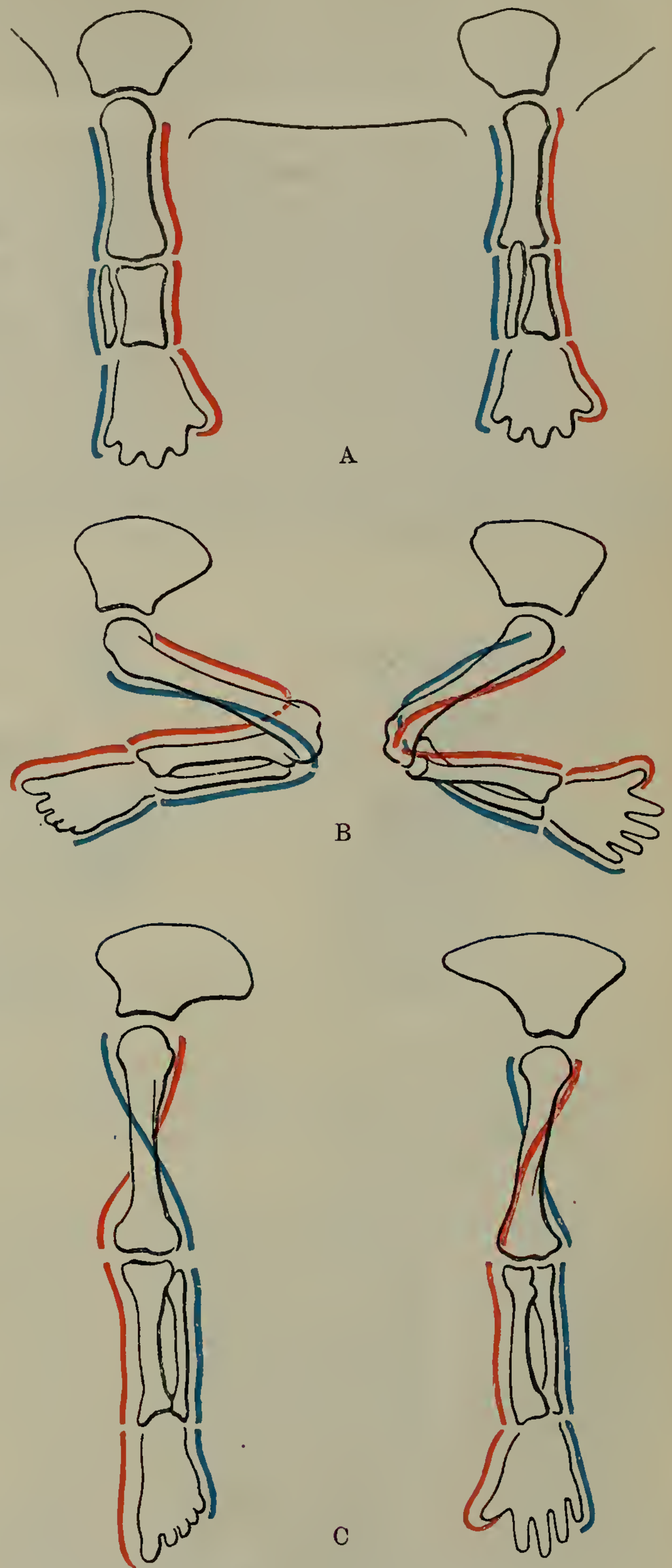

Fig. 255.—Diagram to illustrate the Homologies of the Bones of the Limbs.

The two limb buds of an embryo prior to flexion and rotation. The anterior or pre-axial border is coloured red; the posterior or post-axial border, blue. B. After the assumption of the fœtal position. Flexion and rotation have now taken place. The red and blue lines indicate the altered position of the pre-axial and post-axial borders. C. The fully developed limbs with the flexor aspects directed towards the reader. The coloured lines indicate the effect of the torsion of the upper segment of the limb through quarters of a circle.

Limb Girdles.—The homologies of the parts of the girdles have become obscured owing to the structural alterations that have occurred in order to adapt the two limbs to their different functions. Even in quadrupedal animals the functions of the fore and the hind limbs are not quite the same, though both are used for support and locomotion ; the fore limb is at the same time adapted for *pull* and the hind limb for *push* (Rabl) ; therefore the pelvic girdle is more consolidated than the shoulder girdle. The modifications from the primitive type are more varied and more profound in the case of the shoulder girdle, and began so long ago in phylogenetic development that in Man there is no evidence in ontogenetic development of how they came about.

The primitive, fundamental limb girdle is a curved bar of cartilage imbedded in the muscular substance of the side of the trunk at right angles to the long axis of the trunk. The cartilage is divisible into a dorsal part and a ventral part by means of an articulation of the middle of its lateral surface with the cartilage of the free portion of the limb.

In higher vertebrates the *ventral part* of the developing cartilage of the **pelvic girdle** is divided into two bars, a cephalic and a caudal ; the cephalic bar corresponds to the pubis, the caudal bar to the ischium. The *dorsal part* is undivided and corresponds to the ilium.

The **shoulder girdle** does not show such a uniform arrangement. The *dorsal part*, however, does not undergo grave modification ; it corresponds to the blade of the scapula and may be regarded as homologous with the ilium.

The *ventral part* is subdivided to a varying extent in different vertebrates, and the names given to subdivisions have been "coracoid," "epicoracoid," "metacoracoid," "precoracoid," and "subcoracoid," different names having sometimes been given by different writers to the same subdivision. In **amphibians** the developing ventral part is divided into two portions, a caudal portion named the **coracoid**, and a cephalic portion named the **precoracoid**, which, as development proceeds, is overlaid by a clavicle of dermal or membranous origin. In man the clavicle was at one time (Gegenbauer) regarded as a bone ossified from a primordial cartilage, possibly homologous with the precoracoid ; and the ventral part of the primitive shoulder girdle was considered to be represented by the clavicle and the coracoid process, those two parts being equivalent to the pubis and the ischium respectively. The view that the clavicle was precoracoid in origin was abandoned, but has been recently revived only to be refuted a second time ; and at the present state of knowledge it is as well not to attempt to establish homodynamy of parts of the shoulder girdle with the ischium and pubis.

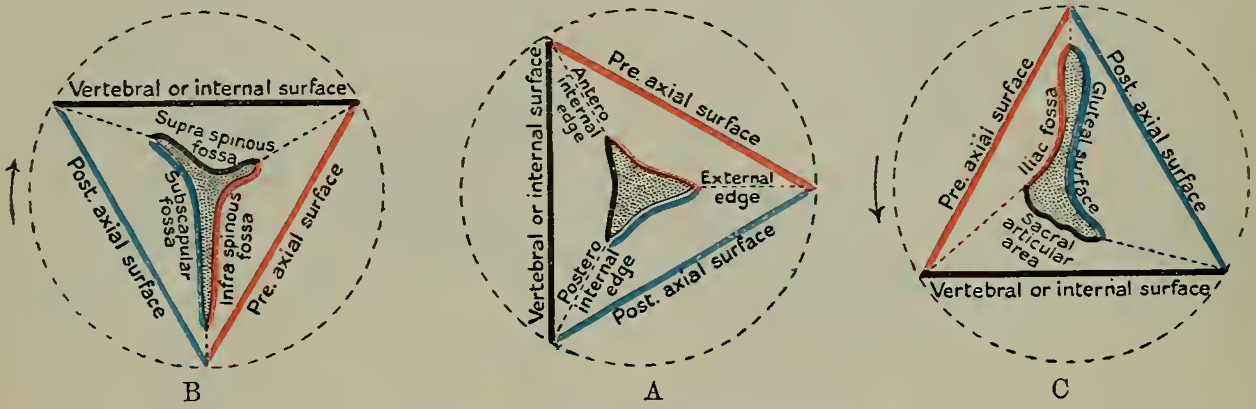

FIG. 256.—DIAGRAM TO ILLUSTRATE THE HOMOLOGOUS PARTS OF THE SCAPULA AND ILIUM, ACCORDING TO FLOWER.

A, Ideal type ; three-sided rod. B, Scapula rotated forward through a quarter of a circle (90°), so that the primitive medial or vertebral surface is now directed forwards. C, Ilium rotated backwards through a quarter of a circle so that the primitive medial surface is now directed backwards. In the diagram the primitive medial or vertebral surface of each figure is coloured black, the pre-axial surfaces red, and the post-axial surfaces blue.

The theories and facts regarding the problem have been reviewed recently by Hanson (*Anat. Record*, 1919, 1920), who has clarified the nomenclature that has arisen around the subject. The type adopted as a standard for comparison is not the amphibians but the **Permian reptiles**, which were relatives of the ancestors of the Mammals ; in them there were three elements in the ventral part of the girdle, which Hanson names **metacoracoid**, **precoracoid**, and **epicoracoid**. His summary of the evidence goes to prove that : (1) The coracoid process of Man and the coracoid of other mammals represents part of the precoracoid of Permian reptiles, and corresponds, therefore, with the coracoid of living reptiles. (2) The part of the scapula ossified from the "subcoracoid" centre is not derived from the ventral part of the girdle, as has been asserted by some, but is merely an epiphyseal ossification. (3) The clavicle is not derived, even in part, from the precoracoid cartilage, but is of membranous origin, and the cartilage which develops after the clavicle has begun to ossify is of a secondary or accessory character and not part of the primordial cartilage of the girdle.

The clavicle is peculiar among limb bones in its mode of ossification (see Fawcett, *Jour. Anat.*, 1913). It is ossified from two primary centres which appear in two portions of mesodermal tissue which are at the pro-cartilaginous stage. When the tissue intervening between those two portions also becomes pro-cartilage the two centres fuse together to form one centre, from which the ossifying process spreads into the cartilage that appears at the ends of the bone rudiment.

Attempts have been made to demonstrate homologies between the several parts of the scapula and ilium. Flower's scheme, which is the most generally accepted, assumed a primitive or ideal type bone with dorsal and ventral *ends*, pre-axial, post-axial, and vertebral or medial *surfaces*, postero-medial, antero-medial, and lateral *borders*, and postulated that the rotation of the limbs involved the scapular and iliac parts of the limb girdles in the directions indicated by the arrows in the diagram. The dorsal end is, in the case of the scapula, the vertebral border, and in the ilium it is the iliac crest; the ventral end is respectively the glenoid cavity of the scapula and the acetabular end of the ilium. The diagram sufficiently indicates the homologies of the surfaces and borders under Flower's scheme.

Humphry assumed that the girdles were not involved in the rotation of the limbs, and the second diagram expresses the homologies he ascribed to scapula and ilium. It may be noted in that diagram that the anterior border of ilium (between gluteal surface and iliac fossa), which gives origin to the rectus femoris, corresponds to the crest of the scapular spine (between the supraspinous and infraspinous fossæ) and not to the axillary border of the scapula (between the subscapular and infraspinous fossæ), which gives origin to the homologous muscle—the long head of the triceps. But Humphry explained that those muscles arose from the lateral surface of the bone (an attachment partly retained by the human rectus femoris) and in the rotation of the free part of the limb, the rectus femoris attachment was turned forward on to the anterior border, while the triceps was turned on to the posterior border (the axillary border in Man is the posterior or caudal border in quadrupeds).

Humerus and Femur.—Owing to the rotation of the limbs in opposite directions, the greater tubercle, the posterior surface of the body and the lateral epicondyle of the humerus correspond respectively to the lesser trochanter, the anterior surface, and the medial epicondyle of the femur.

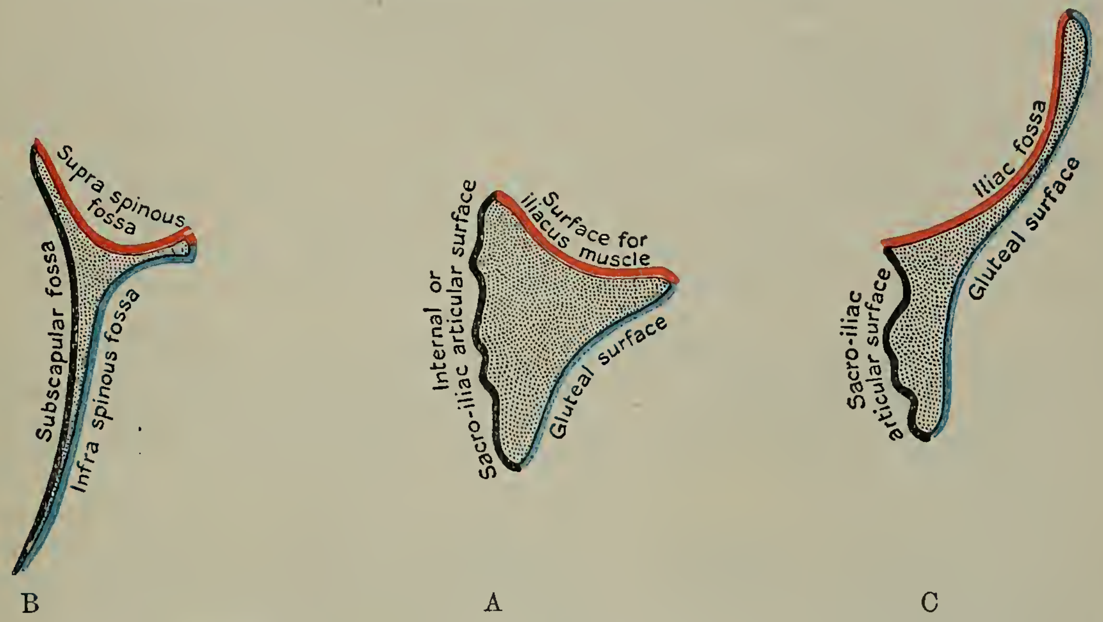

FIG. 257.—DIAGRAM TO ILLUSTRATE THE HOMOLOGOUS PARTS OF THE SCAPULA AND ILIUM, ACCORDING TO HUMPHRY.

A, Primitive rod-like ilium of kangaroo, prismatic on section. B, Scapula. C, Ilium. The corresponding surfaces are similarly coloured.

Bones of Forearm and Leg.—The radius corresponds to the tibia, and the ulna to the fibula. There is nothing in the lower limb, however, to correspond to the olecranon, and nothing in the upper limb to correspond to the patella. Those two parts are not homologous; but they are analogous, for each of them gives insertion to the extensor tendon and gives the extensor muscle more leverage for its action.

In the **hand and foot** the homology or homodynamy of metacarpus with metatarsus, thumb and fingers with toes is obvious, the radial side of the hand corresponding with the tibial side of the foot.

The homologies of the carpal and tarsal bones are not so clear; they are given in the following table, together with the more generalised type from which they are evolved:—

Type.	Hand.	Foot.
Radiale (Tibiale)	= Os naviculare (body)	= Talus.
Intermedium	= Os lunatum	= Absent, or Os trigonum (?).
Ulnare (Fibulare)	= Os triquetrum	= Calcaneus.
Centrale	= Absent, or fused with Navicular	= Navicular, less its tuberosity.
Carpale (Tarsale), i.	= Os multangulum majus	= First Cuneiform.
Carpale (Tarsale), ii.	= Os multangulum minus	= Second Cuneiform.
Carpale (Tarsale), iii.	= Os capitatum	= Third Cuneiform.
Carpale (Tarsale), iv.	= Os hamatum	= Cuboid, plus the peroneal sesamoid.
Carpale (Tarsale), v.		

The pisiform is omitted from the table, since it is now generally regarded as being a vestige of an additional digit placed post-axial to the little finger (digitus post-minimus). Its homologue in the foot is by some considered as fused with the calcaneus. The tuberosity of the navicular, formed, according to Manners Smith, of three elements, of which the sesamoid bone in the tendon of the tibialis posterior may be one, is to be regarded as the homologue of the pre-axial sesamoid in the hand, which probably fuses with the navicular to form its tuberosity. The peroneal sesamoid probably corresponds to the hamulus (sometimes an independent ossicle) of the os hamatum. Similarly, on the pre-axial border of the hand and foot, vestiges of a suppressed digit (prepollex and prehallux) may occasionally be met with. The frequent occurrence of an increase in the number of digits seems to indicate that phylogenetically the number of digits was greater than at present, and included a prepollex or prehallux, and a digitus postminimus.

In Man the lower limbs have been modified for the whole office of support and locomotion, and the upper limbs have undertaken more varied and specialised functions, including that of prehension; the lower limbs are increased in strength and length and are constructed with the view of stability, while mobility is the aim achieved in the upper limb. The elements of the lower limb girdle are welded into one bone which is firmly jointed to its fellow and to the backbone, and, with the adoption of the erect attitude, it assumes the special human characteristic of wide expansion of the ilia to support the abdominal viscera.

In order to be free and movable, the shoulder girdle is not built into the wall of the body cavity. The scapula is only loosely connected with the axial skeleton by muscles; the clavicle is joined to the sternum by a freely movable joint; and, further, those two constituents of the girdle are not fused but are connected by a movable joint. To obtain greater freedom and range of movement, the upper limb, including the ventral part of the scapula, becomes further removed from the trunk, and the scapula loses the support received through the union of the coracoid element with the sternum, as in birds, reptiles, and, to some extent, in lowest mammals. As a substitute for that support the clavicle is evolved as a new element; in its most specialised form, as in Man, it gives strength and stability to the girdle, keeps the upper limb removed from the trunk so that the movements are unhampered, and, being itself a movable fulcrum, it enlarges the range of movement.

The head of the humerus articulates with the shallow glenoid fossa and is connected with the scapula by a lax capsule; in the case of the femur, the presence of a long neck set at an angle to the shaft removes the limb from the trunk and enables the limb to have a wide range of movement, but the head of the femur articulates with a deep cup and is held firmly in place by a strong capsule.

The power of supination and pronation gives a varied mobility to the upper limb which the lower limb does not possess, though that is in some degree compensated for by the fact that, at the knee-joint, movements of rotation, as well as flexion and extension, can take place, while the elbow-joint is a simple hinge. But at the wrist-joint, movement can take place around two axes, while the ankle joint is a very stable articulation at which only hinge movements can take place, except when it is extended.

The hand, as a prehensile organ, has its phalanges increased in length and the carpus reduced; the opposability of the thumb metacarpal enables the hand to grasp cylindrical objects firmly, and the opposable fifth metacarpal enables it to grasp spherical objects. In the foot, strength and stability are required; the tarsal bones are large, and, having to sustain the weight of the body, the tarsus and metatarsus are built in the form of an arch; the foot does not have the prehensile function which it discharges in Apes, and therefore the digits are short and none of them is opposable.

MEASUREMENTS AND INDICES EMPLOYED IN PHYSICAL ANTHROPOLOGY.

(1) Craniometry.

The various groups of Mankind display in their physical attributes certain features which are more or less characteristic of the stock to which they belong. Craniology deals with the differences among them so far as they affect the skull. The method whereby the differences are recorded involves the accurate measurement of the skull in most of its details. Such procedure is included under the term *craniometry*. Here only the outlines of the subject are briefly referred to; fuller information on the subject may be obtained from the works of Broca, Topinard, Flower, and Turner.

The races of Man display great variations in regard to the size of the skull. Apart altogether from individual differences and the proportion of head-size to body-height, it may be generally assumed that the size of the skull in the more highly civilised races is much in excess of that of lower types. The size of the head is intimately correlated with the development of the brain. By measuring the capacity of the cranial cavity we can form some estimate of the size of the brain. The **cranial capacity** is determined by filling the cranial cavity with some suitable material and then taking the cubage of its contents. Various methods are employed, each of which has its advantage. The use of liquids, which of course would be the most accurate, is rendered impracticable, without special precautions, owing to the foramina. As a matter of practice, it is found that leaden shot, glass beads, or seeds of various sorts are the most serviceable. The results obtained by any of those methods display a considerable range of variation. For purposes of classification and comparison, skulls are grouped according to their **cranial capacity** into the following varieties:—

Microcephalic skulls are those with a capacity below 1350 c.c., and include such well-known races as Andamanese, Veddahs, Australians, Bushmen, Tasmanians, etc. [μικρός (micros) = small; κεφαλή (cephalē) = head.]

Mesocephalic skulls range from 1350 c.c. to 1450 c.c., and embrace examples of the following varieties: American Indians, Chinese, some African Negroes. [μέσος (mesos) = middle.]

Megacephalic skulls are those with a capacity over 1450 c.c., and are most commonly met with in the more highly civilised races: Mixed Europeans, Japanese, etc. [μέγας (megas) = big.]

Apart from its size, the form of the cranium has been regarded as an important factor in the classification of skulls; though whether the differences in shape have not been unduly emphasised in the past is open to question.

The relation of the breadth to the length of the skull is expressed by means of the **cephalic index**, which records the proportion of the maximum breadth to the maximum length of the skull, assuming the latter equal 100, or—

$$\frac{\text{Max. breadth} \times 100}{\text{Max. length}} = \textbf{Cephalic index.}$$

The results are classified into three groups:—

1. **Dolichocephalic**, with an index below 75: Australians, Kaffirs, Zulus, Eskimo, Fijians.
2. **Mesaticephalic**, ranging from 75 to 80: Europeans (mixed), Chinese, Polynesians (mixed).
3. **Brachycephalic**, with an index over 80: Malays, Burmese, American Indians, Andamanese. [βραχύς (brachys) = short; δολιχός (dolichos) = long.]

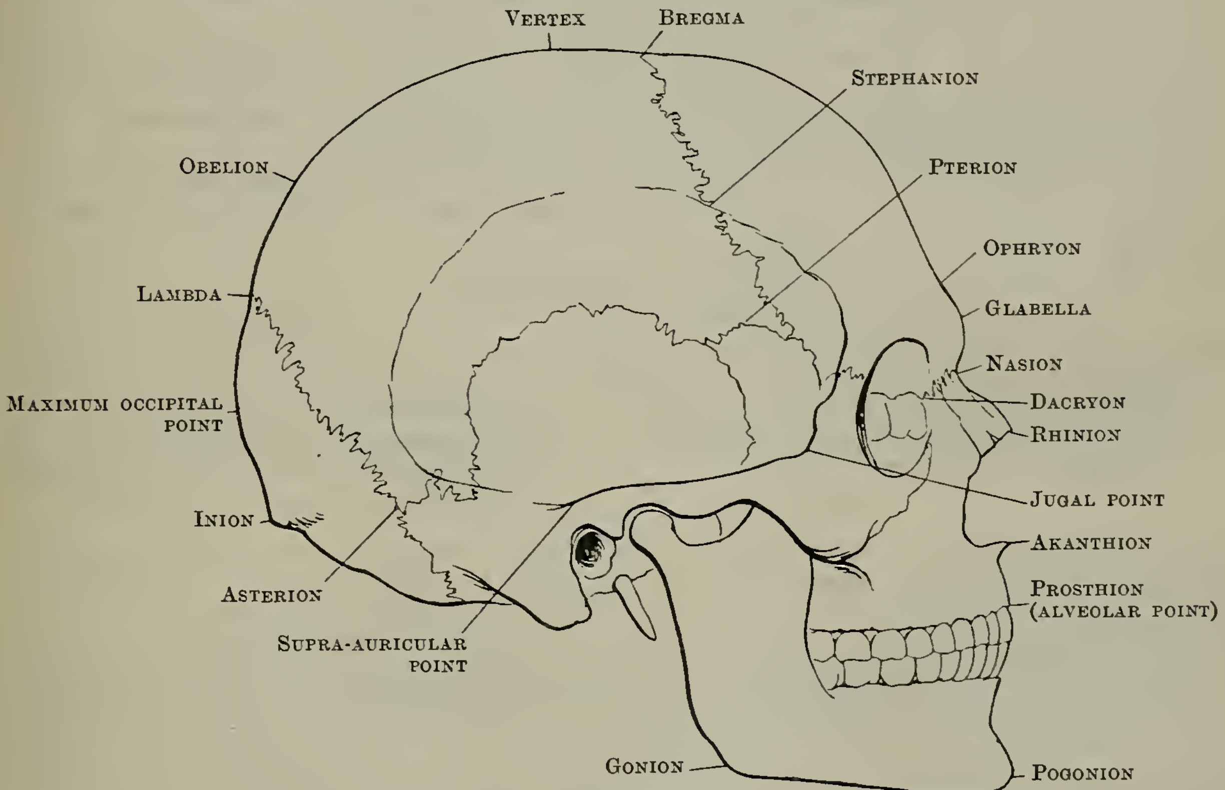

Fig. 258.

The more important of the points from which measurements are taken are included in the subjoined table:—

Nasion.—The middle of the naso-frontal suture.

Glabella.—A point midway between the two superciliary ridges.

Ophryon.—The central point of the narrowest transverse diameter of the forehead, measured from one temporal line to the other.

Inion.—The external occipital protuberance.

Maximum Occipital Point.—The point on the squamous part of the occipital in the sagittal plane most distant from the glabella.

Opisthion.—The middle of the posterior margin of the foramen magnum.

Basion.—The middle of the anterior margin of the foramen magnum.

Bregma.—The point of junction of the coronal and sagittal sutures.

Rhinion.—The most prominent point at which the nasal bones touch one another.

Alveolar Point or Prosthion.—The centre of the anterior edge of the alveolar margin of the maxilla.

Subnasal Point.—The middle of the inferior border of the piriform (anterior nasal) aperture at the root of the anterior nasal spine.

Akanthion.—The most prominent point on the nasal spine.

Vertex.—The summit of the cranial vault.

Obelion.—A point on the sagittal suture, between the parietal foramina.

Lambda.—The meeting-point of the sagittal and lambdoid sutures.

Pterion.—The region of the antero-lateral fontanelle, where the angles of the frontal, parietal, squamous part of the temporal, and great wing of sphenoid lie in relation to one another. As a rule, the sutures are arranged like the letter H, the parietal and great wing of sphenoid separating the frontal from the squamous temporal. In other cases the form of the suture is like an X; whilst in a third variety the frontal and squamous part of the temporal articulate with each other, thus separating the great wing from the parietal.

Asterion is the region of the postero-lateral fontanelle, where the lambdoid, parieto-mastoid, and occipito-mastoid sutures meet.

Stephanion.—The point where the coronal suture crosses the temporal line.

Dacryon.—The point where the vertical lacrimo-maxillary suture meets the fronto-maxillary suture at the medial angle of the orbit.

Jugal Point.—Corresponds to the angle between the frontal process and the temporal process of the zygomatic bone.

Supra-auricular Point.—A point immediately above the middle of the orifice of the external acoustic meatus close to the edge of the posterior root of the zygoma.

Gonion.—The lateral side of the angle of the mandible. [γωνία (gōnia) = a corner.]

Pogonion.—The most prominent point of the chin as represented on the mandible. [πώγων (pōgōn) = the beard.]

The measurements of the length of the skull may be taken between a variety of points—the nasion, the glabella, or the ophryon in front, and the inion or the maximum occipital point behind. Or the maximum length alone may be taken without reference to any fixed points. In all cases it is better to state precisely where the measurement is taken. The maximum breadth of the head is very variable as regards its position; it is advisable to note whether it occurs above or below the parieto-squamosal suture. The inter-relation of these measurements as expressed by the cephalic index has been already referred to. The width of the head may also be measured from one asterion to the other (**bi-asterionic width**) or by taking the **bi-stephanic diameter.**

The height of the cranium is usually ascertained by measuring the distance from the basion to the bregma. The relation of the height to the length may be expressed by the **height** or **vertical index**, thus—

$$\frac{\text{Height} \times 100}{\text{Length}} = \textbf{Vertical index.}$$

Skulls are classified in accordance with the relations of length and height as follows:—

Tapeinocephalic, index below 72.
Metriocephalic, index between 72 and 77.
Acrocephalic, index above 77 (Turner).

or

Chamæcephalic, index up to 70.
Orthocephalic, index from 70·1 to 75.
Hypsicephalic, index 75·1 and upwards (Kollmann, Ranke, and Virchow).

[ταπεινός] (tapeinos) = low; χαμαί (chamai) = on the ground. μέτριος (metrios) = moderate, middle; ὀρθός (orthos) = straight, right. ἄκρος = highest; ὕψι (hypsi) = on high.]

The **horizontal circumference** of the cranium, which ranges from 450 mm. to 550 mm., is measured around a plane cutting the glabella or the ophryon anteriorly, and the maximum occipital point posteriorly. The **longitudinal arc** is measured from the nasion in front to the opisthion behind; if the basi-nasal length and the distance between the basion and the opisthion are added to that, we have a record of the vertico-median circumference of the cranium. The frontal, parietal, and occipital portions of the superior longitudinal arc may be measured separately, and the length of each compared with the length of the arc and with each other.

The measurements of the skeleton of the face are more complex, but, on the whole, of greater value than the measurements of the cranium. In the *face* the characteristic features of race are best observed, and the osseous structure most accurately records the form and proportions of the living.

The form of the face varies, like that of the cranium, in the relative proportions of its length and breadth. Generally speaking, a dolichocephalic cranium is associated with a long face, whilst the brachycephalic type of head is correlated with a rounder and shorter face. This rule, however, is not universal, and there are many exceptions to it.

The determination of the facial index varies according to whether the measurements are made with or without the mandible in position. When the mandible is in place the length is measured from the ophryon or the nasion above to the mental tubercle below, and compared with the maximum bi-zygomatic width. This is referred to as the **total facial index**, and is obtained by the formula—

$$\frac{\text{Ophryo-mental length} \times 100}{\text{Bi-zygomatic width}} = \textbf{Total facial index.}$$

More usually, however, owing to the loss of the mandible, the proportions of the face are expressed by the **superior facial index**, which is determined by comparing the ophryo-alveolar or naso-alveolar length with the bi-zygomatic width, thus—

$$\frac{\text{Ophryo-alveolar length} \times 100}{\text{Bi-zygomatic width}} = \textbf{Superior facial index.}$$

The terms **dolichofacial** or **leptoprosope** and **brachyfacial** or **chamæprosope** have been employed to express the differences thus recorded. [λεπτός (leptos) = thin, delicate, refined; πρόσωπον (prosōpon) = the face.]

Uniformity in these measurements, however, is far from complete, since many anthropologists compare the width with the length = 100.

The proportion of the face-width to the width of the calvaria is roughly expressed by the use of the terms **cryptozygous** and **phænozygous** as applied to the skull. In cryptozygous skulls the zygomatic arches are concealed, when the skull is viewed from above, by the overhanging and projection of the sides of the cranial box; in phænozygous skulls, owing to the narrowness of the calvaria, the zygomatic arches are clearly visible. [κρυπτός (cryptos) = hidden; φαίνω (phainō) = cause to appear, *in passive* = appear.]

The projection of the face, so characteristic of certain races (Negroes for example), may be estimated on the living by measuring the angle formed by two straight lines, the one passing from the middle of the external acoustic meatus to the lower margin of the septum of the nose; the other drawn from the most prominent part of the forehead to the incisor teeth. The angle between those two lines is called the **facial angle** (Camper), and ranges from 62° to 85°. The smaller angle is characteristic of a muzzle-like projection of the lower part of the face. The larger angle is the concomitant of a more vertical profile. The degree of projection of the maxilla in the macerated cranium is most commonly expressed by employing the **gnathic** or **alveolar index** of Flower. This records the relative proportions of the basi-alveolar and basi-nasal lengths, the latter being regarded as = 100, thus—

$$\frac{\text{Basi-alveolar length} \times 100}{\text{Basi-nasal length}} = \textbf{Gnathic index.}$$

The results are conveniently grouped into three classes:—

Orthognathous, index below 98: including mixed Europeans, ancient Egyptians, etc.
Mesognathous, index from 98 to 103: Chinese, Japanese, Eskimo, Polynesians (mixed).
Prognathous, index above 103: Tasmanians, Australians, Melanesians, various African Negroes. [γνάθος (gnathos) = the jaw.]

Unfortunately, however, little reliance can be placed on the results obtained by this method, since it takes no account of the proportion of the third or facial side of the gnathic triangle. (See Thomson and MacIver, *Races of the Thebaid*, Oxford: Clarendon Press, 1905.)

The form of the piriform aperture in the macerated skull is of much value from an ethnic standpoint, as it is so intimately associated with the shape of the nose in the living. The greatest width of the aperture is compared with the nasal height (measured from the nasion to the lower border of the aperture) and the **nasal index** is thus determined:—

$$\frac{\text{Nasal width} \times 100}{\text{Nasal height}} = \textbf{Nasal index.}$$

Skulls are—

Leptorrhine, with a nasal index below 48: as in mixed Europeans, ancient Egyptians, American Indians, etc.
Mesorrhine, with an index ranging from 48 to 53: as in Chinese, Japanese, Malays, etc.
Platyrrhine, with an index above 53: as in Australians, Negroes, Kaffirs, Zulus, etc. [πλατύς (platys) = wide, flat; ῥίς (rhis) = nose.]

The form of the orbit varies considerably in different races, but is of much less value from the standpoint of classification. The **orbital index** expresses the proportion of the orbital height to the orbital width, and is obtained by the following formula:—

$$\frac{\text{Orbital height} \times 100}{\text{Orbital width}} = \textbf{Orbital index.}$$

The orbital height is the distance between the upper and lower margins of the orbit at the middle; whilst the orbital width is measured from a point where the ridge which forms the posterior boundary of the lacrimal groove meets the fronto-lacrimal suture (Flower), or from the dacryon (Broca), to the most distant point on the lateral margin of the orbital opening.

The form of the orbital aperture is referred to as—

Megaseme, if the index is over 89;
Mesoseme, if the index is between 89 and 84;
Microseme, if the index is below 84. [σῆμα (sēma) = a sign or signal.]

The variations met with in the form of the palate and dentary arcade may be expressed by the **palato-maxillary index** of Flower. The length is measured from the alveolar point to a line drawn across the posterior borders of the maxillæ, whilst the width is taken between the outer borders of the alveolar arch immediately above the middle of the second molar tooth. To obtain the index, the following formula is employed:—

$$\frac{\text{Palato-maxillary width} \times 100}{\text{Palato-maxillary length}} = \textbf{Palato-maxillary index.}$$

For purposes of classification Turner introduced the following terms:—

Dolichuranic, index below 110.
Mesuranic, index between 110 and 115.
Brachyuranic, index above 115. [οὐρανός (uranos) = the vault of heaven, any vault, the roof of the mouth.]

As is stated elsewhere, the size of the teeth has an important influence on the architecture of the skull. Considered from a racial standpoint, the relative size of the teeth to the length of the cranio-facial axis has been found by Flower to be a character of much value. The dental length is taken by measuring the distance between the anterior surface of the first premolar and the posterior surface of the third molar of the upper jaw.

To obtain the **dental index** the following formula is used:—

$$\frac{\text{Dental length} \times 100}{\text{Basi-nasal length}} = \textbf{Dental index.}$$

Following the convenient method of division adopted with other indices, the dental indices may be divided into three series, called respectively—

Microdont, index below 42: including the so-called Caucasian or white races.
Mesodont, index between 42 and 44: including the Mongolian or yellow races.
Megadont, index above 44: comprising the black races, including the Australians.

Many complicated instruments have been devised to take the various measurements required, but for all practical purposes the calipers designed by Flower or the *compas glissière* of Broca are sufficient.

As an aid to calculating the indices, the tables published in the *Osteological Catalogue of the Royal College of Surgeons of England*, Part I., Man; *Index-Tabellen zum anthropometrischen Gebrauche*, C. M. Furst, Jena, 1902; or the index calculator invented by Waterston, will be found of much service in saving time.

(2) Indices and Measurements of other Parts of the Skeleton.

In addition to the indices employed to express the proportions of the cranial measurements, there are others similarly made use of to convey an idea of the proportions of different parts of the skeleton. The following may be mentioned as those in most common use:—

Scapula.—At birth the form of the human scapula more closely resembles the mammalian type in that its breadth, measured from the glenoid cavity to the vertebral border, is greater in comparison with its length than in the adult. This proportion is expressed as follows:—

$$\frac{\text{Breadth from glenoid cavity to vertebral border} \times 100}{\text{Length from medial to inferior angle}} = \textbf{Scapular index.}$$

The index ranges from 87 in African pygmies, who therefore have proportionately broader scapulæ, to 61 in Eskimos. The average European index is about 65.

Hip Bone.—The relation of the breadth of this bone to its height is computed as follows:—

$$\frac{\text{Iliac breadth} \times 100}{\text{Ischio-iliac height}} = \textbf{Innominate index.}$$

Man, as compared with the apes, is distinguished by possessing proportionately broader and shorter hip bones. The index in man ranges from 74 to 90.

Pelvis.—The form of the human pelvis is characterised by an increased proportionate width and a reduced proportionate height or length. The relation of these diameters is expressed by the formula:—

$$\frac{\text{Ischio-iliac height} \times 100}{\text{Greatest breadth between the outer lips of the iliac crests}} = \textbf{Pelvic breadth-height index.}$$

The average index for white races is 73.

Pelvic Cavity.—The measurements usually taken are those of the superior aperture. In man there is a proportionate increase in the transverse diameter as compared with lower forms:—

$$\frac{\begin{array}{c}\text{Antero-posterior diameter (conjugate) from mid-point of sacral promontory}\\ \text{to the upper margin of pubic symphysis} \times 100\end{array}}{\text{Greatest transverse width between ilio-pectineal lines}} = \textbf{Pelvic or brim index.}$$

Turner has classified the indices into three groups:—

Dolichopellic, index above 95: Australians, Bushmen, Kaffirs.
Mesatipellic, index between 90 and 95: Negroes, Tasmanians, New Caledonians.
Platypellic, index below 90: Europeans and Mongolians generally. [πέλλα (pella) = a bowl or pail.]

Vertebral Column.—A characteristic feature of man's vertebral column is the pronounced lumbar curve associated with the erect posture in the living. Apart from the consideration of the interposition of the intervertebral fibro-cartilages between the segments, the bodies of the lumbar vertebræ influence and react on the curve by exhibiting differences in their anterior and posterior vertical diameters. Advantage has been taken of this to endeavour to reconstruct the lumbar curve from the dried and macerated bones, but it must be borne in mind that habitual posture or increased range of movements may yield results which are possibly misleading. Thus, there is reason for believing that the squatting position, when habitually adopted, may give rise to a compression of the anterior parts of the bodies of the vertebræ, suggesting an absence of or flattening of the lumbar curve, which in fact did not exist during life.

The quality of the curve is estimated from the macerated bones by an index which is computed as follows:—

$$\frac{\text{Sum of posterior vertical diameters of the bodies of the five lumbar vertebræ} \times 100}{\text{Sum of anterior vertical diameters of the bodies of the five lumbar vertebræ}} = \textbf{General lumbar index.}$$

The results are classified as follows:—

Kyrtorrhachic, index below 98, displaying a forward convexity: includes Europeans generally, and Chinese. [κυρτός (kyrtos) = curved, convex; ῥάχις (rhachis) = the lower part of the back.]

Orthorrhachic, index between 98 and 102, column practically straight: includes examples of Eskimo and Maori.

Koilorrhachic, index above 102, displaying a forward concavity: includes Australians, Negroes, Bushmen, and Andamanese. [κοῖλος (koilos) = hollow, concave.]

Sacrum.—Man's sacrum is characterised by its great breadth in proportion to its length, Those relations are expressed as follows:—

$$\frac{\text{Greatest breadth of base of sacrum} \times 100}{\text{Length from middle of promontory to middle of anterior inferior border of fifth sacral vertebræ}} = \textbf{Sacral index.}$$

The diverse forms are grouped as follows:—

Dolichohieric, index below 100, sacra longer than broad: includes Australians, Tasmanians, Bushmen, Hottentots, Kaffirs, and Andamanese.

Platyhieric, index above 100, sacra broader than long: includes Europeans, Negroes, Hindoos, North and South American Indians. The average European index is 112·4 for males, 116·8 for females. [ἱερός (hieros) = sacred.]

Thorax.—The diameters are taken at the level of the xiphisternal joint.

$$\frac{\text{Transverse diameter} \times 100}{\text{Antero-posterior diameter}} = \textbf{Thoracic index.}$$

The index is usually lower in the female, the form of the thorax being more rounded.

Limb Bones.—The proportionate length of the limb bones to each other and to the body height is of practical interest. It is a matter of common knowledge that the forearms of Negroes are proportionately longer than those of Europeans. Great differences, too, are met with in the absolute and proportionate length of the lower limbs, nor must the relation of these to body height be overlooked. An enumeration of the more important of these indices, and the manner of their computation, will suffice. The proportion of the length of the radius to the length of the humerus is expressed as follows:—

$$\frac{\text{Length of radius} \times 100}{\text{Length of humerus}} = \textbf{Radio-humeral index.}$$

Subdivided into three groups:—

Brachykerkic, index less than 75: includes Europeans, Lapps, Eskimo. [κερκίς = κνήμη—see below; but also meant *radius*.]

Mesatikerkic, index between 75 and 80: Chinese, Australians, Polynesians, Negroes.

Dolichokerkic, index above 80: Andamanese, Negritoes and Fuegians, Simiidæ in general.

The proportion of the length of the tibia to the femur is computed by the formula—

$$\frac{\text{Length of tibia from surface of condyle to articular surface for talus} \times 100}{\text{Oblique length of femur}} = \textbf{Tibio-femoral index.}$$

Subdivided into two groups:—

Brachyknemic, index 82 and under: includes Europeans and Mongolians generally.

Dolichoknemic, index 83 and over: includes Australians, Negroes, Negritoes, American Indians. [κνήμη (knēmē) = the leg.]

The proportion of the length of the upper limb to that of the lower limb is obtained thus:—

$$\frac{\text{Lengths of humerus} + \text{radius} \times 100}{\text{Lengths of femur} + \text{tibia}} = \textbf{Intermembral index.}$$

A comparison between the relative lengths of the upper segments of the limbs is obtained by the following formula :—

$$\frac{\text{Length of humerus} \times 100}{\text{Length of femur}} = \textbf{Humero-femoral index.}$$

Platymeria (see p. 266) [μηρός (mēros) = thigh].—The amount of compression of the femur is estimated as follows :—

$$\frac{\text{Sagittal diameter of shaft immediately distal to lesser trochanter} \times 100}{\text{Transverse diameter of shaft immediately distal to lesser trochanter}} = \textbf{Platymeric index.}$$

Platyknemia (see p. 271).—The degree of compression of the tibia is estimated by the formula—

$$\frac{\text{Transverse diameter of shaft at level of nutrient foramen} \times 100}{\text{Antero-posterior diameter of shaft at level of nutrient foramen}} = \textbf{Platyknemic index.}$$

The index ranges from 60 in a Maori tibia to 80 to 108 in modern French tibiæ.

For further information relating to the measurements and indices used by physical anthropologists, the reader is referred to Topinard's *Éléments d'anthropologie* ; Sir W. Turner's *Challenger Memoirs*, Part 47, vol. xvi. ; and Duckworth's *Morphology and Anthropology.*

THE ARTICULATIONS OR JOINTS.

SYNDESMOLOGY.

By David Hepburn.

Syndesmology is that branch of human anatomy which treats of the articulations or joints.

A junctura ossium (articulation or joint) constitutes a mode of union or connexion subsisting between any two separate segments or parts of the skeleton, whether osseous or cartilaginous. It has for its primary object either the preservation of a more or less rigid continuity of the parts joined together, or else the permission of a variable degree of mobility, subject to the restraints of the uniting media.

Classification of Joints.—In attempting to frame a classification of the numerous joints in the body, several considerations must be taken into account, viz., the manner and sequence of their appearance in the embryo; the nature of the uniting media in the adult, and also the degree and kind of movement permitted in those joints where movement is possible.

In this way we obtain two main subdivisions of joints:—

(1) Those in which the uniting medium is co-extensive with the opposed surfaces of the bones entering into the articulation, and in which a direct union of these surfaces is thereby effected.

(2) Those in which the uniting medium has undergone more or less of interruption in its structural continuity, and in which a cavity of greater or less extent is thus formed in the interior of the joint.

To the first group belong all the immovable joints, many of which are only of temporary duration; to the second group belong all joints which possess, as their outstanding features, mobility and permanence.

SYNARTHROSES.

The general characteristics of this group are partly positive and partly negative. Thus, there is uninterrupted union between the opposed surfaces of the bones joined together at the plane of the articulation, *i.e.* there is no trace of a joint cavity, and further, there is an entire absence of movement. Developmentally, these joints result from the approximation of ossific processes which have commenced from separate centres of ossification, and therefore the nature of the uniting medium varies according as the bones thus joined together have originally ossified in membrane or in cartilage. In the former case union is effected by an interposed fibrous membrane continuous with, and corresponding to, the periosteum. To such articulations the term **sutura** (Fig. 259) is applied. In the latter case the uniting medium is a plate of hyaline cartilage. Such articulations are called **synchondroses** (Fig. 260). In all the synchondroses, and in many of the sutures, the uniting medium tends to disappear in the progress of

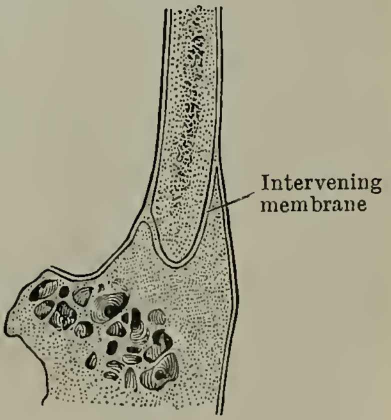

Fig. 259.—Vertical Section through a Suture.

ossification, and thus the plane of articulation becomes obliterated, so that direct structural continuity between the osseous segments takes place. The primary features common to all synarthroses are—(*a*) continuous and direct union of the opposing surfaces; (*b*) no joint cavity; (*c*) no movement.

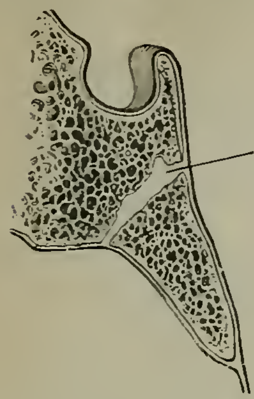

Fig. 260.—Section through the Occipito-sphenoid Synchondrosis.

Sutura.—This form of synarthrosis is found only in connexion with the bones of the skull. In a large number of cases the bones which articulate by suture present irregular interlocking margins, between which there is the interposed fibrous membrane to which reference has already been made. When these interlocking margins present well-defined projections they are said to form a **sutura vera (true suture)**; on the other hand, when the opposed surfaces present ill-defined projections, or even flat areas, they are described as **sutura notha (false suture)**. In each of these subdivisions the particular characters of the articulating margins are utilised in framing additional descriptive terms. Thus true sutures may possess interlocking margins whose projections are tooth-like (**sutura dentata**), *e.g.* in the interparietal suture; saw-like (**sutura serrata**) (Fig. 261), *e.g.* in the interfrontal suture; ridge-like, or comparable to the parallel ridges on the welt of a boot (**sutura limbosa**). Similarly false sutures may articulate by margins which are scale-like (**sutura squamosa**), *e.g.* in the squamoso-parietal suture; or by rough opposed surfaces, **sutura harmonia**, *e.g.* in the suture between the palatine processes of the maxillary bones. There is one variety of synarthrosis which, in the adult, can scarcely be called a suture, although the differences are of minor importance, viz., **schindylesis**, which is an articulation between the edge of a plate-like bone, such as the rostrum of the sphenoid, and the cleft in another, such as the vomer.

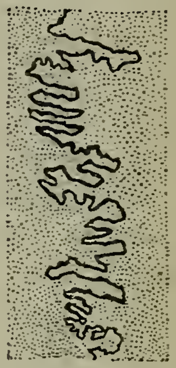

Fig. 261.—Sutura Serrata.

Synchondrosis.—Illustrations of this group can be found only in the young growing individual, because as age advances and growth ceases, the process of ossification affects the hyaline cartilage which constitutes the uniting medium, and the plane of articulation disappears. Under this heading we may include the planes of junction between all epiphyses and the diaphyses to which they severally belong. The occipito-sphenoid (Fig. 260) and the petro-jugular articulations in the base of the skull provide other well-marked examples.

AMPHIARTHROSES—DIARTHROSES (MOVABLE JOINTS).

The leading features of this group are capability of **movement** and **permanence.** In very few instances do such joints ever become obliterated under normal conditions. Determining their permanence, and regulating the amount of possible movement, there is always more or less of interruption in the continuity of the structures which bind the osseous elements together. That is, there is always some evidence of a **cavum articulare** (joint cavity), although as a matter of course such interruption can never be so extensive as entirely to disassociate the articulating elements. Therefore in all movable joints a new class of structures is found, viz., **ligamenta** (the ligaments), by means of which continuity is maintained even when all the other uniting media have given place to an articular cavity. The further subdivision of this group is founded upon the amount of movement permissible, and the extent to which the articular cavity takes the place of the original continuous uniting medium. Thus we obtain the **amphiarthroses**, or partly movable, and the **diarthroses**, or freely movable.

An **amphiarthrosis** (Fig. 264) presents the following characteristics: (*a*) partial movement; (*b*) union by ligaments and by an interposed plate or disc of fibro-cartilage, in the interior of which there is (*c*) an incomplete or partial joint cavity, which may be lined by a rudimentary **stratum synoviale** (synovial membrane) whose function it is to provide a lubricating fluid, the **synovia** or joint-oil; (*d*) a plate of hyaline cartilage coating each of the opposing surfaces of the bones concerned. All the joints belonging to this group occur in the median plane of the body. It includes the symphysis pubis, the joints between the bodies of the vertebræ, and the joint between the manubrium sterni and the body of the sternum.

A **diarthrosis** (Fig. 262) is the most elaborate as well as the most complete form of articulation. It is characterised by (*a*) capability of movement which is more or less free in its range; (*b*) a reduction of the uniting structures to a series of retaining ligaments; (*c*) an articular cavity which is limited only by the surrounding ligaments; (*d*) the constant presence of **synovial membrane**; (*e*) cartilago articularis (hyaline encrusting cartilage) which clothes the opposed surfaces of the articulating bones. The majority of the joints in the adult belongs to this group. This series of joints has been subdivided into a number of minor sections, in order to emphasise the occurrence of certain well-marked structural features, or because of the particular nature of the movement by which they are characterised. Although in all diarthroses there is a certain amount of *gliding* movement between the opposed surfaces of the bones which enter into their formation, yet, when this gliding movement becomes their prominent feature, as in most of the joints of the carpus and tarsus, they are termed **arthrodia.** But bones may be articulated together so as to permit of movement in one, two, or more fixed axes of movement, or in modifications of these axes. Thus in **uniaxial joints** the axis of movement may lie in the longitudinal axis of the joint, in which case the **trochoid rotatory form** of joint results, as in the proximal and distal radio-ulnar articulations; or it may correspond with the transverse axis of the articulation, as in the elbow-joint and knee-joint, when the **ginglymus** or **hinge variety** results. If movement takes place about two principal axes situated at right angles to each other, as in the radio-carpal joint, the terms **ellipsoid (biaxial** or **condyloid)** are applied. Movements occurring about three principal axes placed at right angles to each other, or in modifications of these positions, constitute **multiaxial joints,** in which the associated structural peculiarities suggest the alternative terms of **enarthroses** or **ball-and-socket joints.**

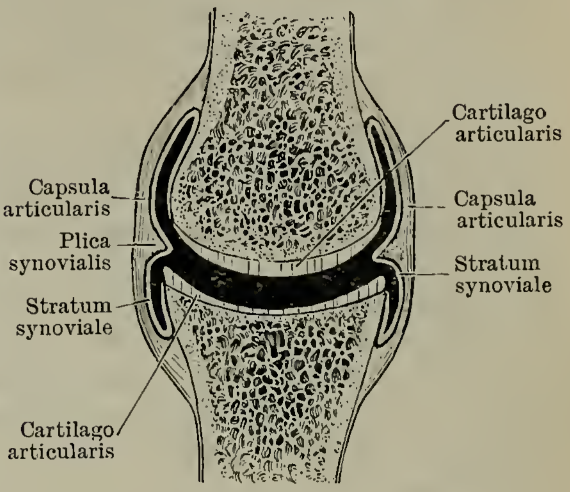

FIG. 262.—DIAGRAM OF A DIARTHRODIAL JOINT.

STRUCTURES WHICH ENTER INTO THE FORMATION OF JOINTS.

The structures which enter into the formation of joints vary with the nature of the articulation. In every instance there are two or more skeletal elements, whether bones or cartilages, and in addition there are the uniting media, which are either simple or elaborate according to the provision made for rendering the joint more or less rigid, or capable of movement. We have already seen that the uniting medium in **synarthrodial joints** is a remnant of the common matrix, whether fibro-vascular membrane or hyaline cartilage, in which ossification has extended from separate centres. Among the **amphiarthroses** there is still extensive union between the opposing surfaces of the articulating bones, but the character of the uniting medium has advanced from the primitive embryonic tissue to fibrous and fibro-cartilaginous material, as well as hyaline cartilage. These, with very few exceptions, are permanent non-ossifying substances, such as may be seen between the opposing osseous surfaces of two vertebral bodies. The joint cavity, more or less rudimentary, is confined to the centre of the fibro-cartilaginous plate, and may result from the softening or imperfect cleavage of the central tissue. It may also present rudiments of a synovial membrane.

In the **diarthrodial group** the extensive cavity has produced great interruption in the continuity of the uniting structures which originally existed between the bones forming such a joint. Ligaments have therefore additional importance in this group, for not only do they constitute the uniting media which bind the articulating bones together, but, to a large extent, they form the peripheral boundary of the joint cavity, although not equally developed in all positions. Thus, every diarthrodial joint possesses a fibrous or ligamentous envelope constituting the *fibrous stratum* of the **articular capsule**, which is attached to the adjacent ends of the articulating bones. For special purposes, particular parts of the fibrous stratum may undergo enlargement and thickening, and so constitute strong ligamentous bands, although still forming continuous constituents of the envelope.

The fibrous stratum is lined by a **stratum synoviale** (O.T. **synovial membrane**), the two strata constituting the **capsula articularis.** The synovial stratum is continued from the inner surface of the fibrous stratum to the surface of the intracapsular portion of each articulating bone. The part of the bone included within the joint consists of a "non-articular" portion covered by the synovial layer and an "articular" portion covered by encrusting hyaline cartilage. The latter provides the surface which comes into apposition with the corresponding area of another bone. In its general disposition the synovial layer may be likened to a cylindrical tube open at each end. This layer is richly supplied by a close network of vessels and nerves.

Certain diarthroses present intracapsular structures which may be distinguished as interarticular ligaments and articular discs and menisci (O.T. interarticular fibro-cartilages).

Ligamenta Interarticularia.—**Interarticular ligaments** extend between, and are attached to, non-articular areas of the intracapsular portions of the articulating bones. They are usually situated in the long axis of the joint, and occasionally they widen sufficiently to form partitions which divide the joint-cavity into two compartments, *e.g.* the articulation of the heads of the ribs with the vertebral column, and certain of the costo-sternal joints.

Articular discs and menisci (O.T. **interarticular fibro-cartilages**) (Fig. 263) are more or less complete partitions situated between and separating opposing articular surfaces, and when complete they divide the joint cavity into two distinct compartments. By its periphery, a disc is rather to be associated with the articular capsule than with the articulating bones, although its attachments may extend to non-articular areas on the latter. Those found in the knee-joint are called **menisci**; those found in other joints are called **articular discs.**

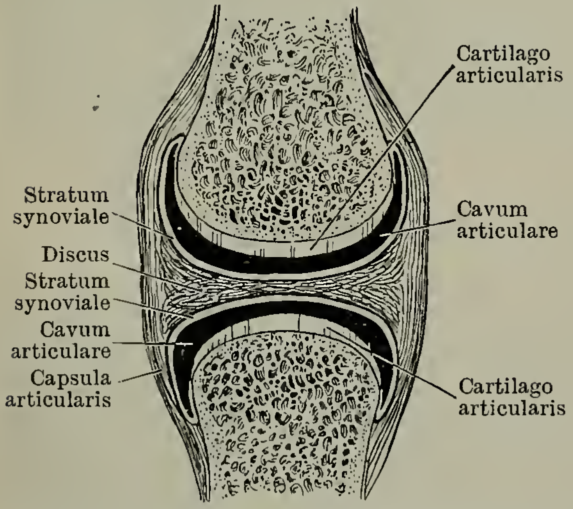

Fig. 263.—Diagram of a Diarthrodial Joint with Articular Disc dividing the Joint-Cavity into two Compartments.

Both interarticular ligaments and articular discs and menisci have their free surfaces covered by the synovial stratum.

Adipose tissue, forming pads of varying size, is usually found in certain localities within the joint, between the synovial stratum and the surfaces which it covers. These pads are soft and pliable, and act as packing material, filling up gaps or intervals in the joint. During movement they adapt themselves to the changing conditions of the articulation.

In addition to merely binding together two or more articulating bones, ligaments perform very important functions in connexion with the different movements taking place at a joint. They do not appreciably lengthen under strains, and thus ligaments may act as inhibitory structures, and by becoming tense may restrain or check movement in certain directions.

Synovial strata, in the form of closed sacs termed **mucous** or **synovial bursæ**, are frequently found in other situations besides the interior of joints. Such bursæ are developed for the purpose of reducing the friction, (*a*) between the integument and certain prominent subcutaneous bony projections, as, for instance, the point of the elbow, or the anterior surface of the patella (**subcutaneous mucous bursæ**); (*b*) between a tendon and some surface, bony or cartilaginous, over which it plays (**subtendinous mucous bursæ**); (*c*) between a tendon or a group of tendons and the walls of osteo-fascial tunnels, in which they play (**vaginæ mucosæ tendinum** or **mucous sheaths of tendons**). Subtendinous mucous bursæ are often placed in the neighbourhood of joints, and in such cases it not infrequently happens that there is a direct continuity between the bursa and the synovial stratum which lines the cavity of the joint through an aperture in the articular capsule.

THE DIFFERENT KINDS OF MOVEMENT AT JOINTS.

Reference has already been made to the existence of fixed axes of movement as a basis for the classification of certain forms of diarthrodial joints. Hence it is evident that the movements which are possible at any particular joint depend to a large extent upon the shape of its articular surfaces as well as upon the nature of its various ligaments. Therefore the technical terms descriptive of movements either indicate the directions in which they occur, or else the character of the completed movement.

In the great majority of articulations between short bones, the amount of movement is so restricted, and the displacement of the opposing articular surfaces so slight, that the term **gliding** sufficiently expresses its character.

A **gliding** movement of an extensive kind, for example that of the patella upon the femur, in which the movement largely resembles that of the tyre of a wheel revolving in contact with the ground so that different parts are successively adapted to each other, is called **co-aptation**.

Articulations between long bones, on the other hand, are usually associated with a much freer range of movement, with a corresponding variety in its character. **Rotation** is a movement around an axis which is longitudinal. Sometimes it is the only form of movement which a joint possesses; at other times it is merely one of a series of movements capable of execution at the same joint. **Flexion** or bending is a movement in which the formation of an angle between two parts of the body is an essential feature. As it is possible to perform this movement in relation to two axes, viz., a transverse and an antero-posterior axis, it is necessary to introduce qualifying terms. Thus, when two anterior or ventral surfaces are approximated, as at the hip-, elbow-, or wrist-joints, the movement is called **ventral**, **anterior**, or **palmar flexion**; but if posterior or dorsal surfaces are approximated by the process of bending, then the flexion becomes **posterior** or **dorsi-flexion**, as at the knee- or wrist-joints. Further, at the wrist-joint, the formation of an angle between the ulnar border of the hand and the corresponding aspect of the forearm, produces **ulnar flexion**, and similarly the bending of the hand towards the radial border of the forearm is **radial flexion**.

Extension or straightening consists in obliterating the angle which resulted from flexion. In the case of certain joints, therefore, such as the elbow, wrist, and knee, the segments of the limb occupy a straight line as regards each other when extended.

At the ankle-joint the natural attitude of the foot to the leg is flexion at a right angle. The diminution of this angle by approximating the dorsum of the foot towards the anterior aspect of the leg constitutes *flexion*; while any effort at placing the foot and leg in a straight line, *i.e.* obliteration of the angle, as in pointing the toes towards the ground and raising the heel, constitutes *extension*.

Abduction is a term which either expresses movement of an entire limb in a direction away from the median plane of the body, or of a digit away from the plane of the middle finger in the hand, or the plane of the second toe in the case of the foot.

Adduction is the reverse of abduction, and signifies movement towards the median plane of the body, or towards the planes indicated for the digits of the hand and foot.

Circumduction is a movement peculiarly characteristic of multiaxial or ball-

and-socket joints. It consists in combining such angular movements as flexion, extension, abduction, and adduction, so as to continue the one into the other, whereby the joint forms the apex of a cone of movement, and the free end of the limb travels through a circle which describes the base of this cone.

THE DEVELOPMENT OF JOINTS.

Just as the question of structure determines to a large extent the presence or absence of movement in joints, so in tracing their development it will be found that the manner of their appearance forecasts their ultimate destination as immovable or movable articulations.

All joints arise in mesodermic tissue which has undergone more or less differentiation.

When this differentiation has produced a continuous membranous layer, in which ossific centres representing separate skeletal segments make their appearance, we get the primitive form of suture. The plane of the articulation merely indicates the limit of the ossific process extending from different directions. If, again, the differentiation of the mesoderm has resulted in the formation of a continuous cartilaginous layer, in which ossification commences at separate centres, the plane of the articulation is marked out by the unossified cartilage—in other words, the articulation is a synchondrosis. Ultimately this disappears through the extension of the process of ossification.

To some extent sutures also disappear, although their complete obliteration is not usual even in aged people. Developmentally, therefore, synarthroses or immovable joints do not present any special structural element, and, speaking generally, they have only a temporary existence.

The development of all movable joints is in marked contrast to that of synarthroses. Not only are they permanent arrangements so far as concerns normal conditions, but they never arise merely as planes which indicate the temporary phase of an ossific process. From the outset they present distinct skeletal units, from which the special structures of the joint are derived.

The primitive movable joint is first recognised as a mass of undifferentiated mesodermic cells situated between two masses, which have differentiated into primitive cartilage.

The cell-mass which constitutes the joint-unit presents the appearance of a thick cellular disc, the proximal and distal surfaces of which are in accurate apposition with the primitive cartilages, while its circumference is defined from the surrounding mesoderm by a somewhat closer aggregation of the cells of which the disc is composed. From this cellular disc or joint-unit all the structures characteristic of amphiarthrodial and diarthrodial joints are ultimately developed.

Thus, by the transformation of the circumferential cells into fibrous tissue the investing ligaments are produced. Within the substance of the disc itself a transverse cleft, more or less well-defined and complete, makes its appearance. In this manner the disc is divided into proximal and distal segments, separated from each other by an interval which is the primitive articular cavity. This cleft, however, never extends so far as to interrupt the continuity of the circumferential part of the disc which develops into the fibrous tissue of the investing ligaments. From the proximal and distal segments of the articular disc the various structures distinctive of movable joints are developed.

Thus, in amphiarthrodial joints the cellular articular disc or primitive joint-unit gives origin to the following structures:—From its circumference, investing ligaments; from its interior, the fibro-cartilaginous plate in which an imperfect articular cavity with corresponding imperfect synovial stratum may be found.

In the case of a diarthrodial joint the changes take place on a more extended scale. The articular cavity becomes a prominent feature, in relation to which the surrounding fibrous structures form an investing capsule, lined with a synovial stratum.

When a single cleft arises, but does not extend completely across the longitudinal axis of the articular disc, the undivided portion develops into fibrous interarticular ligaments. On the other hand, when two transverse clefts are formed, that portion of the cellular disc which remains between them becomes transformed into a fibro-cartilaginous disc (or in the case of the knee-joint, menisci), which in its turn may either be complete or incomplete, and thus we may obtain two distinct synovial joint cavities belonging to one articulation.[1]

In considering the development of the synovial layer, and the surfaces on which it is found in the interior of a joint, it is necessary to keep clearly in mind that a synovial layer is a special structure, whose function it is to produce a lubricating fluid or synovia, and that, therefore, its position is determined by the essential necessity of proximity to a direct blood-supply. In other words, this condition is provided by all parts of the interior of an articular cavity except the articular encrusting cartilage. Consequently the synovial stratum is absent only from the free surface of articular cartilage, although it forms a thicker layer upon the inner surface of the articular capsule than upon the free surfaces of interarticular ligaments, discs, and menisci.

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[1] From a series of observations upon the development of diarthrodial joints, the writer considers that there is evidence to show that the "cellular articular disc" is directly responsible for the production of the epiphyses which adjoin the completed articular cavity, and that, among such amphiarthroses as exist between the bodies of vertebræ, not only the intervertebral fibro-cartilage, but the proximal and distal epiphyses which ultimately unite with the vertebral bodies have a common origin in the joint-unit.

It is not necessary to suppose that the synovial stratum has disappeared from these articular cartilages as the result of friction, because, notwithstanding constant friction, such parts as the interior of articular capsules or the menisci of the knee-joint have not been denuded of their synovial covering.

As the epiphyses adjoining articular cavities are produced in the joint-units, the attachments of the capsule should be found upon, and restricted to, the non-articular surfaces of the articular epiphyses. While this is the case in their earliest stages, yet, as development advances, considerable variations arise, until, in the adult condition, the capsule of the larger articulations, more particularly of the extremities, is not always restricted to the epiphyses for its attachments. The student will readily perceive and appreciate these variations by comparing the accounts and illustrations of the epiphyses with those of the articulations, and he should note that in some cases the epiphyseal line is *extra-capsular*, *i.e.* the capsular attachment is restricted to the epiphysis; in some the line is *intra-capsular*; and in some the epiphyseal line is partly intra-capsular and partly extra-capsular.

MORPHOLOGY OF LIGAMENTS.

From what has been said in connexion with the development of joints, it will be evident that ligaments are essentially products derived from the cellular articular disc.

Nevertheless, in relation to the fully formed joint, many structures are described as ligaments which do not take origin in the manner just indicated. Some of these ligamentous structures remain fairly distinct from the articular capsules with which they are immediately associated; others become thoroughly incorporated with the articular capsules and cannot be separated therefrom, while yet others may be found situated within the capsule of a joint, and thus play the part of interarticular ligaments.

Instances of each of these forms of adventitious ligaments may be readily given. For example, we may instance the expansion of the tendon of the semimembranosus muscle to the oblique ligament of the knee-joint, and the offshoots from the tendon of the tibialis posterior muscle to the plantar aspects of various tarsal bones, as illustrations of structures which play an important part as ligaments, but are not indelibly incorporated with the joint capsule.

Of structures which have become indelibly incorporated with the primitive capsule, we may instance the broad tendinous expansions of the quadriceps extensor muscle around the knee-joint.

The tibial collateral ligament of the same joint is regarded as a detached portion of the tendon belonging to that part of the adductor magnus muscle which takes origin from the ischium, while the fibular collateral ligament of the knee is considered by some to be the primitive femoral origin of the peronæus longus muscle. Another illustration of the same condition is found in the coraco-humeral ligament, which is regarded by some as representing a detached portion of the pectoralis minor muscle.

Two illustrations may be given of structures playing the part of ligaments within the capsule of a joint, although in the first instance they are not developed as ligaments. It is questionable if the ligamentum teres of the hip-joint is an interarticular ligament in the true sense of the term; it has been regarded as the isolated and displaced tendon of the *ambiens* muscle found in birds. In the shoulder-joint, many observers look upon the superior gleno-humeral ligament as representative of the ligamentum teres.

Such structures as the stylo-hyoid ligament and the spheno-mandibular ligament, although described as ligaments, are in reality skeletal parts which have not attained their complete ossific development.

Again, certain portions of the deep or muscular fascia of the body which become specialised into restraining and supporting bands (*e.g.* the ilio-tibial tract of the fascia lata; the stylo-mandibular ligament; the transverse carpal and dorsal carpal ligaments of the wrist-joint; the transverse crural ligament, and lig. laciniatum of the ankle-joint), although called ligaments, have no direct developmental association with articular ligaments.

Lastly, the inguinal ligament of Poupart and the lacunar ligament of Gimbernat, being special developments in connexion with an expanded tendon or aponeurosis, are still further removed from association with an articulation.

LIGAMENTA COLUMNÆ VERTEBRALIS ET CRANII.

Ligaments of the Vertebral Column and Skull.—All vertebræ, with the exception of those which deviate from the common vertebral type, present two sets of articulations whose various parts are arranged upon a uniform pattern. Thus, every pair of typical vertebræ presents an articulation between the bodies, and a pair of articulations between the vertebral arches. With the latter there are associated various important accessory ligaments which bind together laminæ, spinous processes, and transverse processes.

Articulations between Bodies of Vertebræ.—These are amphiarthrodial joints. Singly, they present only a slight degree of mobility, but when this amount of movement is added to that of the whole series, the range of movement of the vertebral column becomes considerable. The articular surfaces are the flattened surfaces of adjacent vertebral bodies. They are bound together by the following structures:—

Fibrocartilagines Intervertebrales (Fig. 264).—Each **intervertebral fibro-cartilage** accommodates itself to the space it occupies between the two vertebral bodies, to both of which it is firmly adherent. The fibro-cartilages from different parts of the vertebral column vary in vertical thickness, being thinnest from the third to the seventh thoracic vertebra, and thickest in the lumbar region. In the cervical and lumbar regions each fibro-cartilage is thicker anteriorly than posteriorly, thereby assisting in the production of the anterior convexity which characterises the vertebral column in these two regions. In the thoracic region the fibro-cartilages are thinnest on their anterior aspects in correspondence with the anterior concavity of this section of the vertebral column.

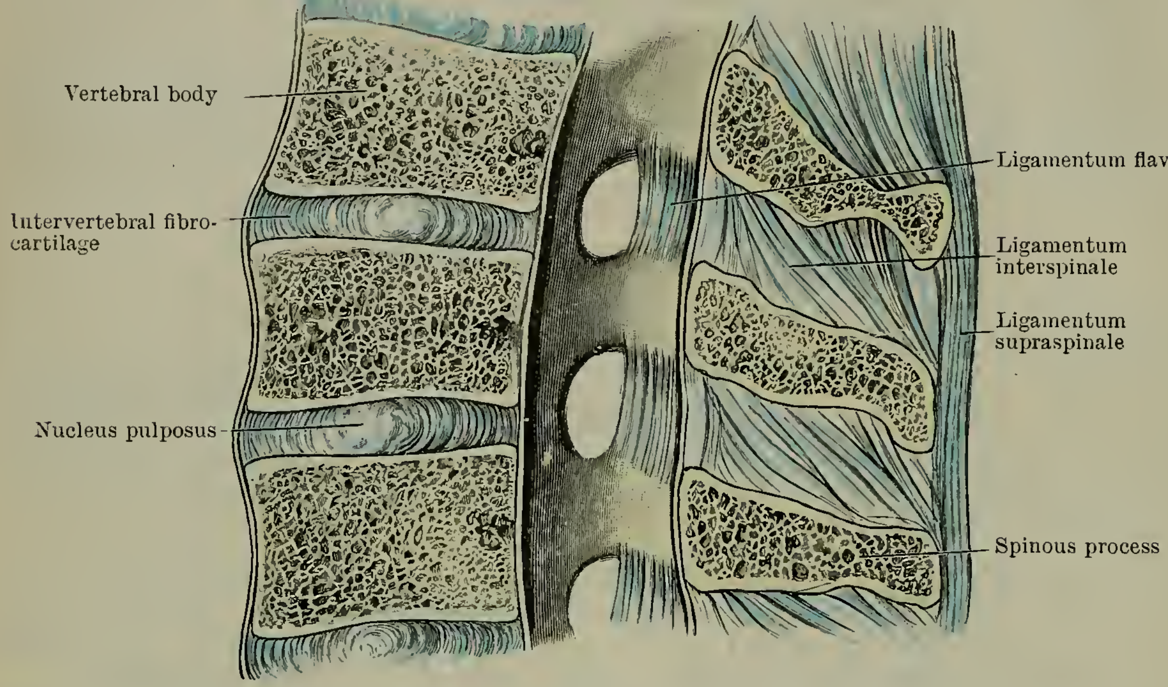

Fig. 264.—Median Section through a Portion of the Lumbar Part of the Vertebral Column.

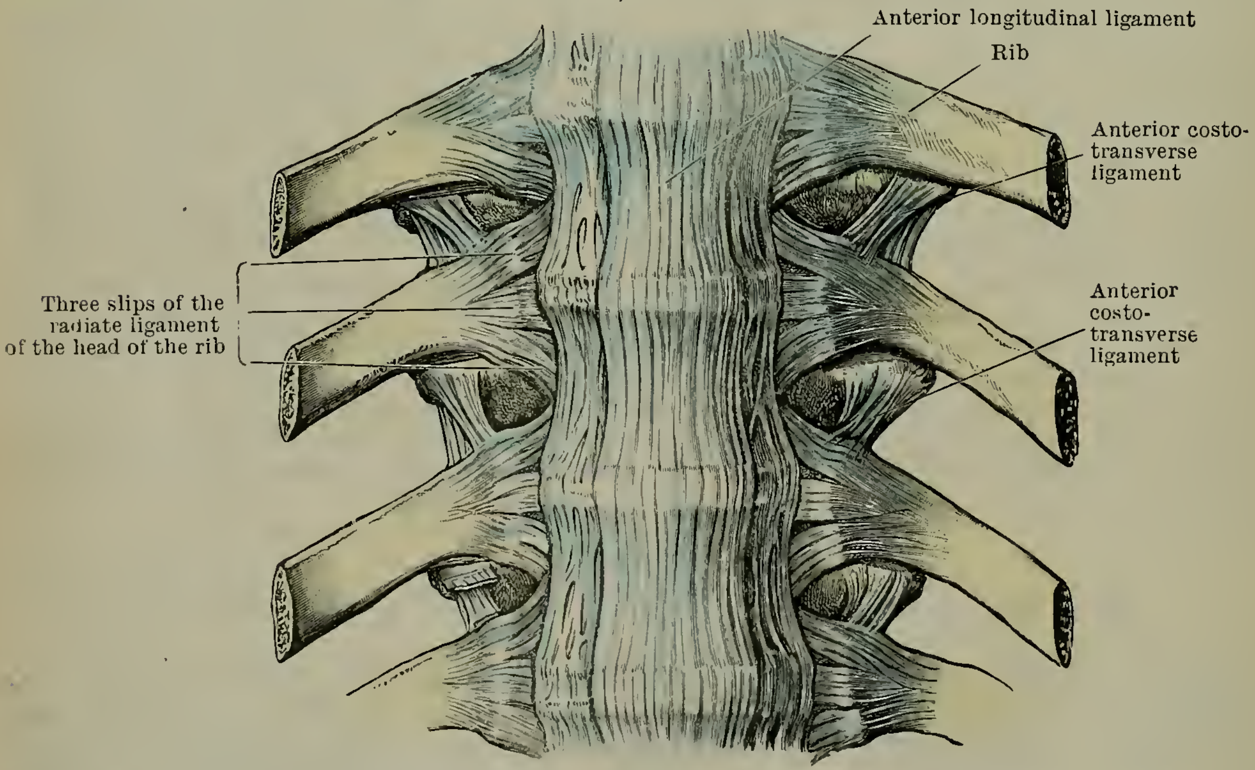
Anterior longitudinal ligament
Rib
Anterior costo-transverse ligament
Three slips of the radiate ligament of the head of the rib
Anterior costo-transverse ligament

Fig. 265.—Anterior Longitudinal Ligament of the Vertebral Column, and the Costo-vertebral Joints as seen from the front.

Each fibro-cartilage consists of a circumferential portion, annulus fibrosus, formed for the most part of oblique parallel fibres running from one vertebra to the other; horizontal fibres are also found. The axial or central part of the fibro-cartilage, the **nucleus pulposus**, is elastic, soft, and pulpy.

The superior and inferior surfaces of the fibro-cartilage are closely adherent to the adjoining epiphyseal plates of the vertebral bodies, and as ossification advances, the distinction between epiphyseal plates and vertebral body disappears.

As a rule the transverse diameter of the fibro-cartilage corresponds to that of the vertebral bodies which it joins together; but in the cervical region, where the inferior margin of the super-imposed vertebra is overlapped on each side by the one which bears it, the fibro-cartilage does not extend to the extreme lateral margin, and in this position a small diarthrosis may be seen at each lateral margin of the fibro-cartilage.

Lig. Longitudinale Anterius.—The **anterior longitudinal ligament** (Fig. 265) consists of a wide stratum of longitudinal fibres which extends from the front of the epistropheus vertebra to the front of the superior segment of the sacrum, and becomes gradually wider from above downwards. It lies on the anterior surfaces of the intervertebral fibro-cartilages, to which it is firmly attached as it passes from one vertebra to the other. Its fibres vary in length. Some are attached to contiguous margins of two adjoining vertebræ; others pass in front of one vertebra to be attached to the next below, and yet others find their lower attachment three or four vertebræ below the one from which they started. None of the fibres are attached to the transverse depression on the anterior surface of a vertebral body.

Lig. Longitudinale Posterius.—The **posterior longitudinal ligament** (Fig. 266) is found within the vertebral canal upon the posterior aspect of the vertebral bodies. It consists of longitudinal fibres, and it extends from the sacrum to the epistropheus vertebra, superior to which it is continued to the skull as the membrana tectoria. Opposite each intervertebral fibro-cartilage it is attached to the entire width of the adjacent margins of the two vertebral bodies, its fibres being continued over the posterior surface of the fibro-cartilage. In the lumbar and thoracic regions the width of the ligament is considerably reduced opposite the back of each vertebral body, and thus it forms a series of dentate projections along both of its margins; but in the cervical region the width of the ligament is more uniform. One or two large thin-walled veins escape from the body of each vertebra under cover of this ligament.

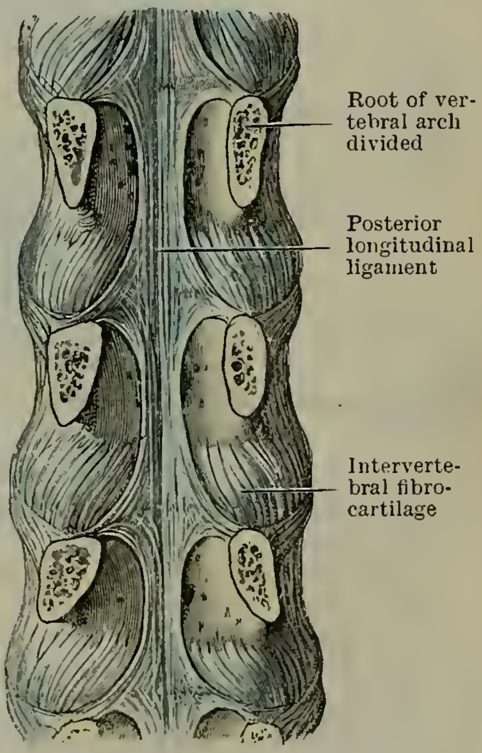
Root of vertebral arch divided
Posterior longitudinal ligament
Intervertebral fibro-cartilage

Fig. 266.—Posterior Longitudinal Ligament of the Vertebral Column.

Articulations between Vertebral Arches.—The vertebral arch of each typical vertebra carries two pairs of articular processes, by means of which it articulates with adjacent vertebral arches. The articulations between these processes are true diarthroses of the arthrodial variety.

The distinctive characters of these articular surfaces, as regards their shape and direction in the different groups of vertebræ, have been referred to in the section on osteology.

All these articulations are provided with complete but very thin-walled capsulæ articulares, which are thinnest and loosest in the cervical region, where also the movements are freest. Each capsule is lined with a stratum synoviale.

Associated with these joints between vertebral arches are certain ligaments which are accessory to the articulations, although they are quite distinct from the capsule.

The laminæ of adjoining vertebræ are bound together by the **ligamenta flava**

(Fig. 267), which consist of yellow elastic fibres. The ligamenta flava close the vertebral canal in the intervals between the laminæ. Each ligament is attached superiorly to the anterior aspect of the upper lamina at a short distance above its inferior border, and inferiorly it is attached to the posterior aspect of the lamina below.

In the thoracic region, where the imbrication of adjoining laminæ is a prominent feature, these ligaments are not so distinctly visible from behind as they are in the regions where imbrication of the laminæ is not so marked.

Laterally they extend as far as the articular capsules, while medially the margins of the ligaments of opposite sides meet under cover of the root of the spinous process.

Contiguous spinous processes are also attached to each other by **ligamenta interspinalia (interspinous ligaments)** (Fig. 264). These are strongest in the lumbar, and weakest in the thoracic region. Each consists of layers of obliquely interlacing fibres which spring from near the tips of the two adjacent spinous processes and radiate to their opposing margins. In the antero-posterior direction they extend from the base to the tip of the spinous process.

The **ligamenta supraspinalia (supra-spinous ligaments)** (Fig. 264) consist of longitudinal bands of fibres of varying lengths. They extend from spine to spine, being attached to their tips, and are situated superficial to, although in continuity with, the ligamenta interspinalia.

In the cervical region this series of ligaments is extensively developed, where they project backwards from the spinous processes between the muscles of the two sides of the neck in the form of an elastic partition called the **ligamentum nuchæ**.

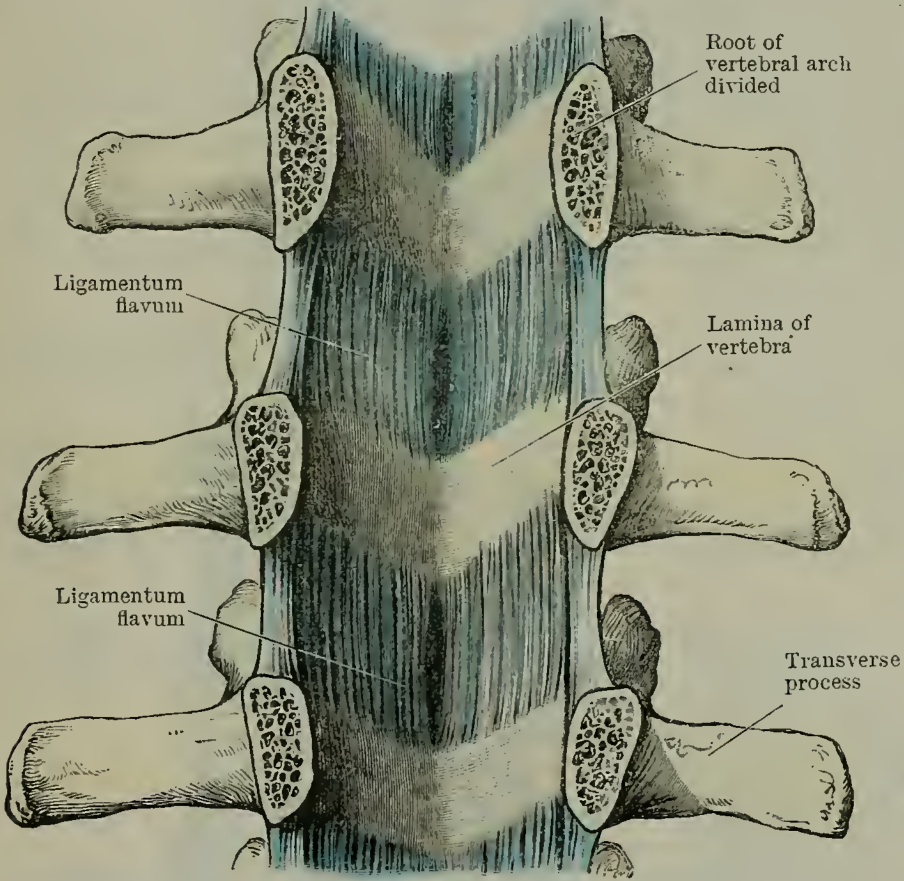

Fig. 267.—Ligamenta Flava as seen from the front after Removal of the Bodies of the Vertebræ by sawing through the Roots of the Vertebral Arches.

The antero-posterior extent of the ligamentum nuchæ increases as it approaches the occiput, where it is attached to the external occipital crest from the external occipital protuberance to the posterior border of the foramen magnum. Its posterior margin is free, and extends from the external occipital protuberance to the spine of the vertebra prominens.

Between the transverse processes there are **ligamenta intertransversaria**, which consist of vertical fibres extending from the postero-inferior aspect of one transverse process to the superior margin of that next below. These ligaments are generally absent from the cervical and upper thoracic regions.

Sacro-coccygeal Symphysis.—The last piece of the sacrum is joined to the first piece of the coccyx by an intervertebral fibro-cartilage, and the junction is rendered more secure by the presence of certain strong ligaments. A **lig. sacrococcygeum anterius**, continuous with the lig. longitudinale anterius, is placed in front. A **lig. sacrococcygeum posterius**, which stretches downwards from the sharp border of the lower opening of the sacral canal, strengthens the joint behind. A **lig. sacrococcygeum laterale** supports the joint on each side, whilst strong bands pass between the cornua of the two bones and constitute the **interarticular ligaments.**

Intercoccygeal Joints.—So long as they remain separate, the different pieces of the coccyx are joined by intervertebral fibro-cartilages and by anterior and posterior ligaments.

Movements of the Vertebral Column.—Although the amount of movement permissible between any two vertebræ is extremely limited, yet the total range of movement capable of being attained by the entire vertebral column is very considerable.

Flexion may occur both forwards and backwards at the articulations of vertebral bodies, but more freely in the lumbar and cervical regions than in the thoracic region, where the limited amount of intervertebral fibro-cartilage and the imbrication of the laminæ and spines restrict the movement. Backward flexion is most pronounced in the cervical region, and forward flexion in the lumbar region. Between the articular surfaces of the articulations between vertebral arches a variety of movements are permitted, dependent upon the directions of these surfaces. Thus **lateral flexion** is permitted in the lumbar, but not in the cervical or thoracic regions. Again, in the lumbar region **rotation** does not occur, owing to the shape of the articular processes, while it is possible in the thoracic region. In the cervical region the shape and position of the articular surfaces prevent the occurrence both of lateral flexion and of rotation as isolated movements, but a combination of these two movements may take place, whereby rotatory movement in an oblique median axis results. Finally, in the lumbar region, by combining the four forms of flexion, viz., forward, backward, and right and left lateral, a certain amount of **circumduction** is possible.

ARTICULATIO ATLANTOEPISTROPHICA.

Between the **atlas** and **epistropheus** vertebræ three diarthroses occur. Two of them are situated laterally, in relation to the articular processes, and are called arthrodial diarthroses, because of the flattened nature of the articulating surfaces. The third articulation is median in position. It is found between the smooth anterior surface of the dens of the epistropheus and the articular facet on the posterior aspect of the anterior arch of the atlas. This joint is a rotatory diarthrosis.

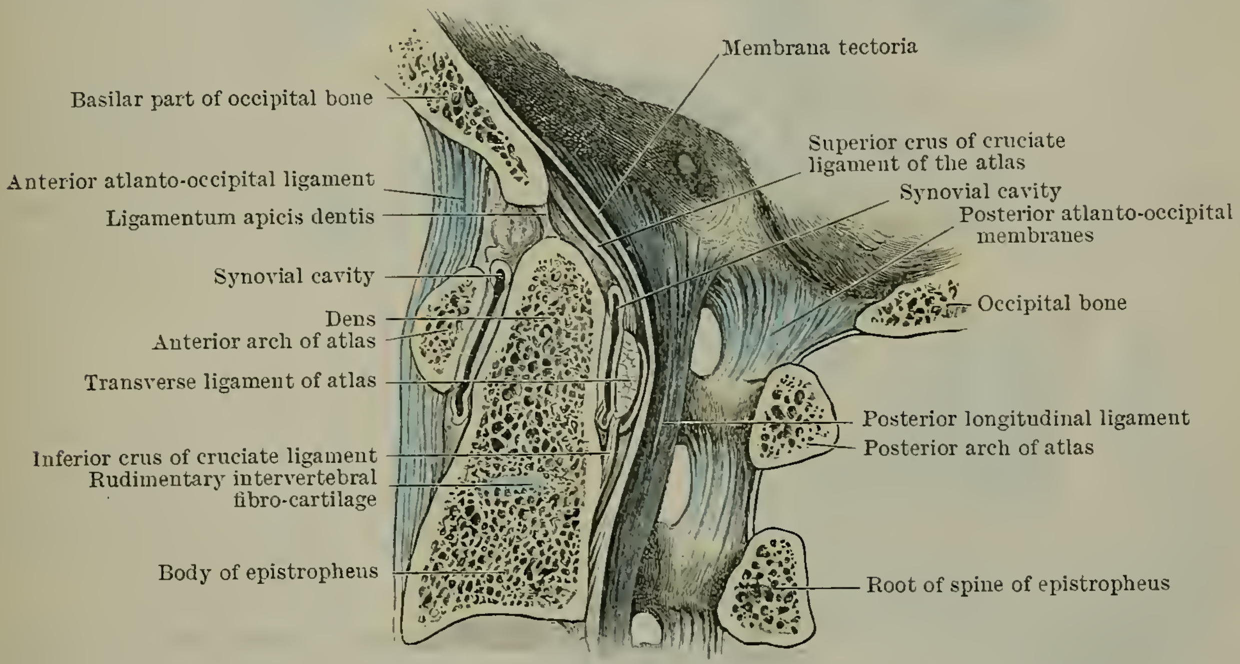
Membrana tectoria
Basilar part of occipital bone
Superior crus of cruciate ligament of the atlas
Anterior atlanto-occipital ligament
Synovial cavity
Ligamentum apicis dentis
Posterior atlanto-occipital membranes
Synovial cavity
Occipital bone
Dens
Anterior arch of atlas
Transverse ligament of atlas
Posterior longitudinal ligament
Posterior arch of atlas
Inferior crus of cruciate ligament
Rudimentary intervertebral fibro-cartilage
Body of epistropheus
Root of spine of epistropheus

FIG. 268.—MEDIAN SECTION THROUGH THE ATLANTO-OCCIPITAL AND ATLANTO-EPISTROPHEAL JOINTS.

Ligamenta.—Each of the joints is furnished with a **capsula articularis**, whereby the articular cavity is circumscribed. In the case of the lateral articulations, each articular capsule presents a distinct band, named the **accessory ligament**, which is situated within the vertebral canal (Fig. 269), and passes downwards and medially from the lateral mass of the atlas to the posterior aspect of the body of the epistropheus.

The following additional ligaments constitute the leading bonds of union :—

Lig. Obturatorium Atlantoepistrophicum Anterius.—The **anterior covering atlanto-epistropheal ligament** (O.T. **anterior atlo-axoid ligament**) (Fig. 268) is a membranous structure which is thin laterally, but strong in the median plane, where it is thickened by a prolongation of the lig. longitudinale anterius. It extends from the anterior arch of the atlas to the front of the body of the epistropheus.

Lig. Obturatorium Atlantoepistrophicum Posterius.—The **posterior covering atlanto-epistropheal ligament** (**O.T. posterior atlo-axoid ligament**) (Fig. 268) occupies the position which is elsewhere taken by the ligamenta flava. It extends from the posterior arch of the atlas to the upper border of the vertebral arch of the epistropheus.

Lig. Transversum Atlantis.—The **transverse ligament of the atlas** (Figs. 268 and 269) is a strong band, placed transversely, which arches backwards behind the neck of the dens of the epistropheus. By its extremities it is attached to the tubercle on the medial aspect of each lateral mass of the atlas. A thin plate of fibro-cartilage is developed in its central part.

A **stratum synoviale (synovial membrane)** lines each of the three articular capsules, and in addition a synovial sac is developed between the dens and the lig. transversum atlantis. This is more extensive than the synovial cavity between the dens and the atlas.

ARTICULATIO ATLANTO-OCCIPITALIS.

There are two articulations between the atlas and the occipital bone. Each is a diarthrosis in which movement takes place in relation to two axes, viz. the transverse and the antero-posterior. The condyle of the occipital bone is bi-convex, and fits into the bi-concave superior articular surface of the atlas, while the long axes of the two joints are directed horizontally forwards and medially.

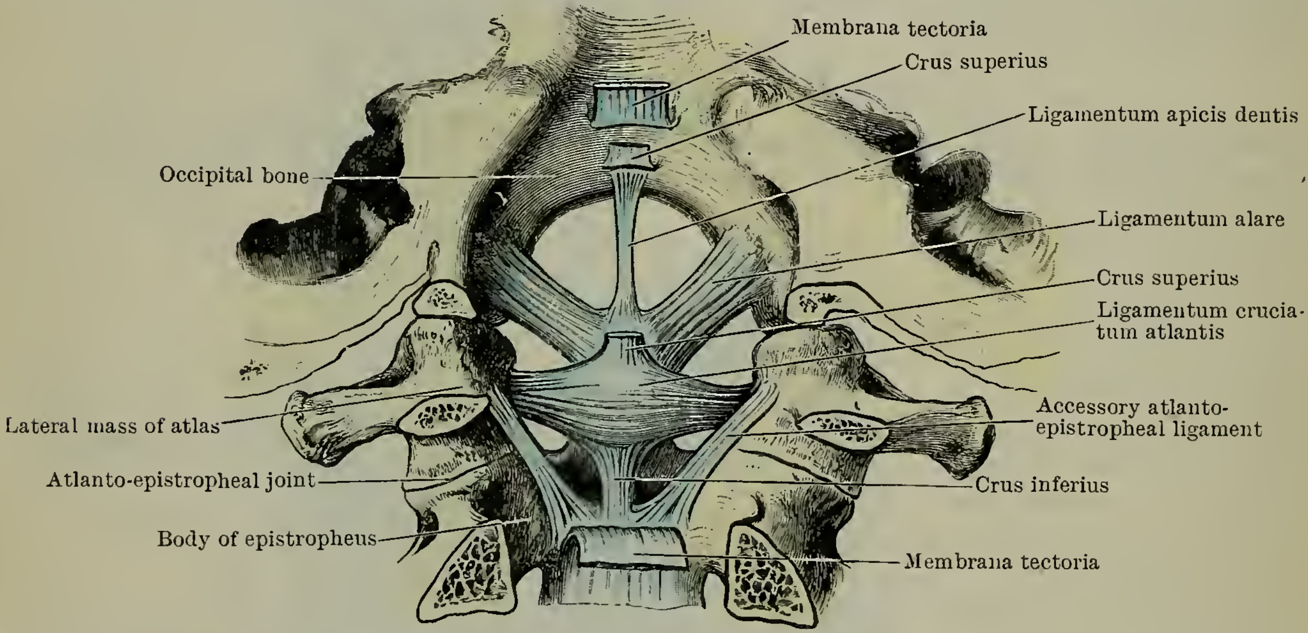

FIG. 269.—DISSECTION FROM BEHIND OF THE LIGAMENTS CONNECTING THE OCCIPITAL BONE, THE ATLAS, AND THE EPISTROPHEUS WITH EACH OTHER.

Ligamenta.—Each articulation is provided with a **capsula articularis** which is thin but complete. It is attached to the rough non-articular surfaces surrounding the articular areas on the atlas and occipital bone.

The following supplementary ligaments are the chief structures which bind the atlas to the occipital bone:—

The **membrana atlanto-occipitalis anterior (anterior occipito-atloid membrane)** (Fig. 268) is a strong although thin membrane, attached inferiorly to the anterior arch of the atlas, and superiorly to the anterior half of the circumference of the foramen magnum. Laterally it is in continuity with the articular capsules, while in the median plane, where it extends from the anterior tubercle of the atlas to the basilar part of the occipital bone, it presents a specially well-defined thickened band which might be regarded as a separate accessory ligament or as the beginning of the anterior longitudinal ligament of the vertebræ.

The **membrana atlanto-occipitalis posterior (posterior occipito-atloid membrane)** (Fig. 268) is another distinct but still thin membrane which is attached superiorly to the posterior half of the circumference of the foramen magnum, and inferiorly to the upper border of the posterior arch of the atlas. Laterally it is also continuous with the articular capsules. On each side of the median plane its inferior border is arched in relation to the vertebral groove, and is therefore to some extent free, in order to permit the passage of the posterior ramus of the first cervical nerve and the vertebral artery. Not infrequently this arched border becomes ossified, thus converting the groove on the bone into a foramen.

A **synovial stratum** lines each of the articular capsules.

There is no direct articulation between the epistropheus and the occipital bone, but union between them is effected by means of the following accessory ligaments :—

The **membrana tectoria** (Fig. 269) is situated within the vertebral canal, and is usually regarded as the upward continuation of the posterior longitudinal ligament of the vertebral bodies. It extends from the posterior surface of the body of the epistropheus to the basilar groove on the superior surface of the basilar part of the occipital bone, spreading laterally on the circumference of the foramen magnum. Some of its deepest fibres are attached to the atlas immediately above the atlanto-epistropheal articulation.

Anterior to the membrana tectoria there is the **ligamentum cruciatum atlantis** (Fig. 269), a structure which is very closely associated with the lig. transversum atlantis. It consists of a *crus transversum,* formed by the superficial fibres of the transverse ligament of the atlas; a *crus inferius,* consisting of median longitudinal fibres which are attached below to the posterior surface of the body of the epistropheus, and above to the crus transversum; and a *crus superius,* also median and longitudinal, whose fibres extend from the crus transversum upwards to the posterior surface of the basilar part of the occipital bone, immediately anterior to the membrana tectoria.

Ligamenta Alaria.—The **alar ligaments** (O.T. **check ligaments**) (Fig. 269) are two very powerful, short, and somewhat rounded bands. They are attached medially to the sides of the summit of the dens, and laterally to the tubercle on the medial aspect of the condylar portions of the occipital bone.

Ligamentum Apicis Dentis.—The **ligament of the apex of the dens** (O.T. **middle odontoid**) (Fig. 269) consists of fibres running vertically upwards from the apex of the dens to the median part of the anterior margin of the foramen magnum. This ligament to some extent represents an intervertebral fibro-cartilage, in the centre of which remains of the notochord may be regarded as present.

Even in advanced life a small lenticular mass of cartilage, completely surrounded by bone, persists in the plane of fusion between the dens and the body of the epistropheus.

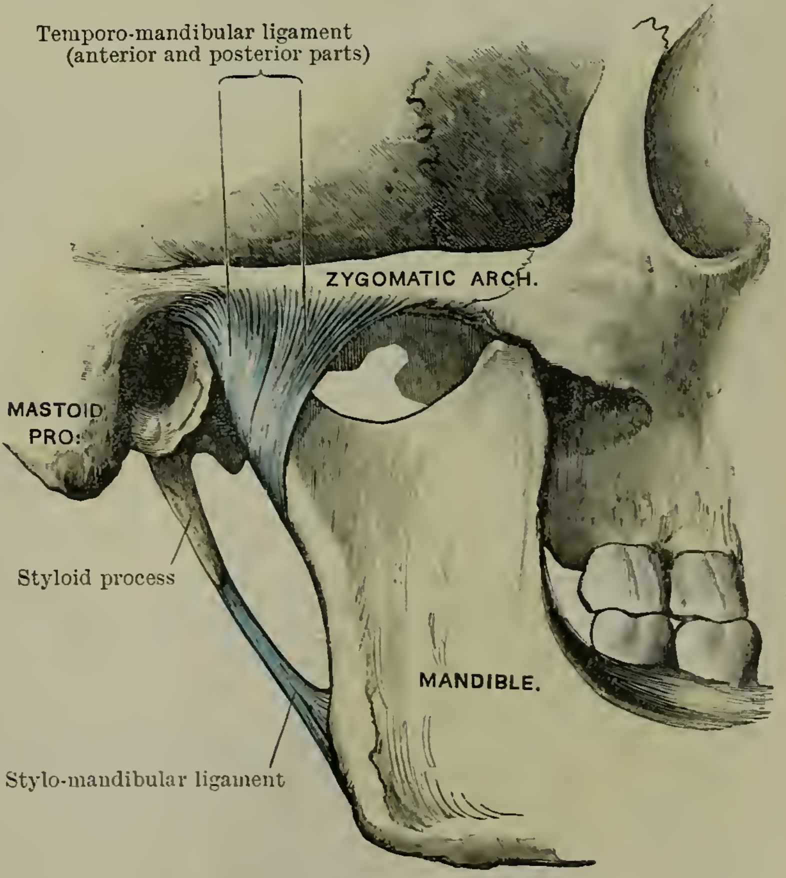
Temporo-mandibular ligament
(anterior and posterior parts)
ZYGOMATIC ARCH.
MASTOID PRO.
Styloid process
MANDIBLE.
Stylo-mandibular ligament

FIG. 270.—MANDIBULAR JOINT.

Movements at these Joints.—At the joints between occipital bone and atlas the movements are very simple, and consist essentially of movements whereby the head is elevated and depressed upon the vertebral column (nodding movements). In addition a certain amount of oblique movement is possible, during which great stability is attained by resting the anterior and posterior parts of opposite condyles upon corresponding parts of the atlas.

The head and the atlas rotate together upon the epistropheus, the pivot of rotation being the dens, and the amount of rotation is limited by the ligamenta alaria. No rotation can occur between the occiput and atlas, and stability between atlas and epistropheus is best attained after a slight amount of rotation, similar to the oblique movement between occipital bone and atlas.

ARTICULATIO MANDIBULARIS.

The **mandibular joint** (O.T. **temporo-mandibular**) is an arthrodial **diarthrosis**. It occurs between the mandibular fossa of the temporal bone and the condyle of the mandible. These two articular surfaces are markedly dissimilar both in size and shape. In its general outline the articular surface of the head of the mandible is cylindrical, having its long axis directed from the medial side laterally and forwards. On the other hand, the mandibular fossa is concavo-convex from behind forwards. Its articular surface includes the tuberculum articulare—the eminence at the base of the anterior root of the zygoma. The articular surfaces of the bones are clothed with hyaline encrusting cartilage, whilst the articular cavity is divided into a superior and inferior part by a disc of fibro-cartilage.

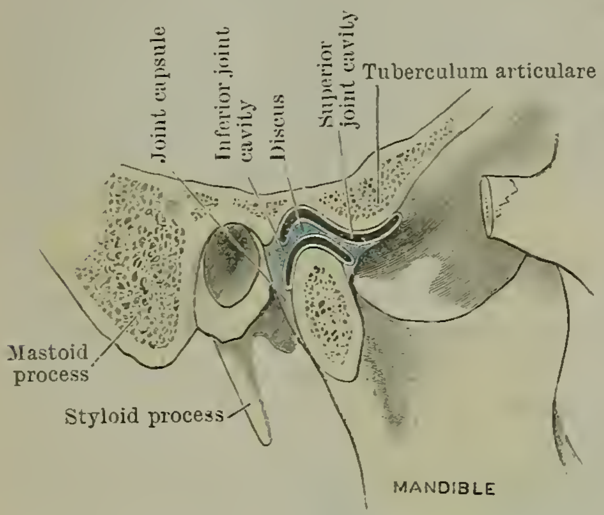

Fig. 271.—Section through the Mandibular Joint.

Ligaments.—The joint is invested by an **articular capsule** which is quite complete, but is very thin on the medial side. The lateral part of the fibrous stratum of the capsule—the **temporo-mandibular ligament** (Fig. 271)—is divisible into anterior and posterior portions which are attached superiorly to the root tubercle and inferior border of the zygomatic process of the temporal bone, and inferiorly to the lateral side and posterior border of the neck of the mandible. The direction of its fibres is downwards and backwards.

Within the capsule there is a disc of fibro-cartilage, the **discus articularis** (Fig. 271), which is moulded upon the condyle of the mandible below, and on the articular surface of the temporal bone above. It thus compensates for the incongruity between the articular surfaces of the two bones. The disc is attached circumferentially to the capsule. It is widest in the transverse direction, thicker posteriorly than anteriorly, and thinnest towards the centre, where it may be perforated. Its anterior margin is intimately associated with the insertion of the external pterygoid muscle.

A **synovial stratum** lines each of the compartments into which the joint cavity is divided by the disc. As a rule these membranes are separate from each other, but they become continuous when the disc is perforated. The superior synovial stratum is larger and more loosely disposed than the lower.

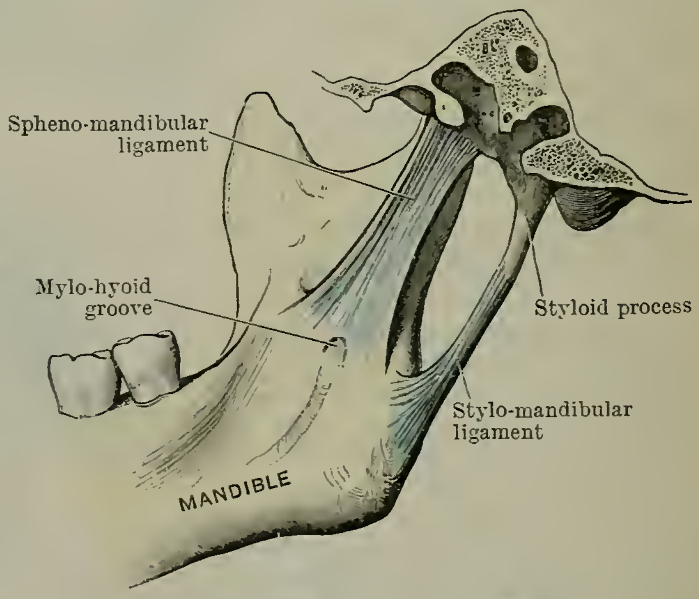

Fig. 272.—Spheno-Mandibular Ligament of the Mandibular Joint.

Situated on the medial aspect of the joint, but at a short distance from it, and quite distinct from the capsule, there is an accessory band called the lig. **spheno-mandibulare** (Fig. 272). Superiorly the **spheno-mandibular ligament** is attached to the angular spine of the sphenoid bone, and inferiorly to the inferior as well as the anterior border or lingula of the inferior alveolar foramen. It is not an articular ligament in the true sense; for, instead of being connected with the joint, it is developed in the tissue surrounding part of Meckel's cartilage.

Portions of the following structures are found in the interval between the spheno-mandibular ligament and the ramus of the mandible—viz., the external pterygoid muscle; internal maxillary vessels; inferior alveolar vessels and nerve; middle meningeal vessels; auriculo-temporal nerve; and sometimes a deep portion of the parotid gland.

Movements of the Mandible.—The nature of the movements which the mandible can perform is determined partly by the character of the articular surfaces of the mandibular joint, and partly by the fact that, while the two joints always act simultaneously, they may also, to some extent, perform the same movement alternately.

When movement takes place through the long or transverse horizontal axis of each joint, the mandible may be elevated, as in clenching the teeth, or it may be depressed, as in gaping. In the latter movement the condyle leaves the mandibular fossa, and, along with the disc, it moves forwards until they rest upon the tuberculum articulare. Meantime the chin describes the arc of a circle, of which the centre or point of least movement corresponds to the position of the inferior alveolar foramen, and thus the structures which enter at that foramen are protected against stretching. Coincidently with the forward movement of the condyle, it glides in a revolving manner upon the inferior aspect of the disc.

At any stage in the movement of depressing the chin the mandible may be protruded, so that the inferior incisor teeth are projected in front of the upper set, a movement which results from the condyles of the mandible being drawn forwards upon the articular tubercles. A similar relation of the condyle to the articular tubercle occurs during the exaggerated depression of the mandible which results from yawning, in which position the articulation is liable to be dislocated. When the two joints perform the same movement alternately, a certain amount of lateral motion results, from the fact that the long axis of each joint presents a slight obliquity to the transverse axis of the skull, and consequently a grinding or oblique movement in the horizontal plane is produced. Excessive depression, with the risk of dislocation, is resisted by the fibres of the temporo-mandibular ligament, which becomes tense.

In all movements of the mandible the disc conforms closely to the position of the condyle, and they move forwards and backwards together, but at the same time the disc does not restrict the movements of the condyle. Thus while the disc, along with the condyle, is gliding upon the temporal aspect of the joint, the condyle itself revolves upon the inferior surface of the disc.

Cranial Ligaments not directly associated with Articulations.

Lig. Stylomandibulare.—The **stylo-mandibular ligament** (Figs. 270 and 272) is a specialised portion of the deep cervical fascia which extends from the anterior aspect of the tip of the styloid process of the temporal bone to the posterior border of the angle of the mandible, between the insertions of the masseter and internal pterygoid muscles.

Lig. Pterygospinosum.—The **pterygo-spinous ligament** is a membrane extending from the upper part of the posterior free margin of the lateral pterygoid lamina, posteriorly and slightly laterally, to the angular spine of the sphenoid. An interval is left between its upper border and the floor of the skull for the outward passage of those branches of the inferior maxillary nerve which supply the external pterygoid, temporal, and masseter muscles. This ligament has a tendency to ossify either wholly or partially.

Lig. Stylohyoideum.—The **stylo-hyoid ligament** may be regarded as the downward continuation of the styloid process of the temporal bone. Inferiorly it is attached to the lesser cornu of the hyoid bone. It is not infrequently ossified, in which case it constitutes the epihyal bone found in many animals.

THE JOINTS OF THE THORAX.

Articulationes Costovertebrales (Costo-vertebral Articulations).—The typical rib articulates with the vertebral column both by its head and by its tubercle. Thus, two sets of articulations, with their associated ligaments, exist between the ribs and the vertebræ, but each set is constructed upon a common plan, with the exception of certain joints situated at the upper and lower ends of the series, where the ribs themselves deviate from the typical form.

Articulationes Capitulorum.

The **articulations of the heads of the ribs** with the bodies of the vertebræ (Fig. 265) are all diarthroses, which, from their somewhat hinge-like action, may be classed as ginglymoid.

The head of every typical rib is wedge-shaped, and presents two articular facets, an upper and a lower, separated from each other by an antero-posterior ridge which abuts against an intervertebral fibro-cartilage, while the articular facets articulate with similar surfaces on the contiguous margins of the two vertebræ adjoining the fibro-cartilage. These surfaces form a wedge-shaped depression or cup, the bottom of which is more elastic than the sides, and thus an arrangement is provided which tends to reduce the shock of blows upon the walls of the chest.

Each of these articulations is provided with an **articular capsule** which surrounds and encloses the joint, and is attached to contiguous non-articular margins on the head of the rib and the two vertebral bodies. On its anterior or ventral aspect the capsule presents three radiating fasciculi which collectively form the **lig. capituli costæ radiatum (radiate ligament of the head of the rib)** (Fig. 265). These fasciculi radiate from a centre on the anterior surface of the head of the rib, so that the middle fasciculus becomes attached to the intervertebral fibro-cartilage while the upper and lower fasciculi proceed to the adjacent margins of the two vertebræ between which the fibro-cartilage is situated, and with which the rib articulates. To a slight extent these radiating fasciculi pass under cover of the lateral margin of the anterior longitudinal ligament of the vertebral bodies. In those joints in which the head of the rib does not articulate with an intervertebral fibro-cartilage the central fasciculus of the radiate ligament is wanting, but the other two retain the same general arrangement.

Lig. Capituli Costæ Interarticulare.—The **interarticular ligament of the head of the rib** consists of short horizontal fibres within the capsule. These are attached, on the one hand, to the ridge which intervenes between the two facets on the head of the rib, and on the other to the lateral aspect of the intervertebral fibro-cartilage. This ligament is not a disc or meniscus, but merely an interarticular ligament, of width sufficient to divide the joint cavity into an upper and a lower compartment. It is absent from those joints which do not articulate with an intervertebral fibro-cartilage, *i.e.* from those ribs which articulate with the body of only one vertebra.

The interarticular ligament is supposed to represent the lateral end of a ligament which, under the name of the **lig. conjugale costarum**, connects the heads of the ribs of certain mammals across the posterior aspect of the intervertebral fibro-cartilage, and, in the human subject, until the seventh month of fœtal life, connects the posterior aspects of the necks of a pair of ribs with each other across the median plane.

A **stratum synoviale** lines each joint cavity, and therefore, in all cases where the joint is divided into two compartments, each one has its own synovial lining.

ARTICULATIONES COSTOTRANSVERSARIÆ.

In the **costo-transverse joints** the tubercle of each *typical* rib articulates with the transverse process of the lower of the two thoracic vertebræ with which the head of the rib is associated. Near the tip of the transverse process there is an articular facet, on its anterior aspect, for articulation with the corresponding facet on the medial articular part of the rib tubercle. The joint so formed is an arthrodial diarthrosis.

The joint cavity is surrounded by a comparatively feeble **capsula articularis**, which is attached immediately beyond the margins of the articular facets, and in which no special bands can be distinguished.

A simple **stratum synoviale** lines the capsule in all cases where the latter is present.

The following accessory ligaments, in connexion with this joint, strengthen and support the articulation:—

Ligamentum Costotransversarium Anterius.—The **anterior costo-transverse ligament** (Fig. 265) consists of strong bands of fibres which are attached to the superior border of the neck of the rib, extending from the head laterally to the non-articular part of the tubercle. All these fibres may be traced upwards. Those situated nearest to the head of the rib proceed obliquely upwards and laterally, to be attached to the transverse process immediately above, but with extensions to the adjoining rib and its costo-transverse articular capsule. Others proceed almost vertically upwards to the adjoining transverse process, while those which ascend from the upper surface of the tubercle pass obliquely upwards and medially to reach the postero-inferior aspect of the adjoining transverse process. Some posterior fibres connected with the transverse process at its junction with the lamina are called the **posterior costo-transverse ligament.**

Lig. Tuberculi Costæ.—The **ligament of the tubercle of the rib** is a band of transverse fibres applied to the postero-lateral aspect of the capsule. By one end these fibres are attached to the tip of the transverse process behind its articular facet, and by the other to the rough surface of the tubercle of the rib.

Lig. Colli Costæ.—The **ligament of the neck of the rib** consists of short fibres which stretch from the posterior aspect of the neck of the rib, backwards and medially, to the anterior aspect of the transverse process, but, in addition, a proportion of the fibres passes to the posterior aspect of the inferior articular process of the upper of the two vertebræ with which the head of the rib articulates.

The following exceptions to the general plan of rib-articulation indicated above must be noted:—

1. There is no articulation between the eleventh and twelfth ribs and the transverse processes of the corresponding vertebræ.
2. The anterior costo-transverse ligament is wanting from the first rib, and is either rudimentary or wanting in the case of the twelfth rib.
3. The lig. colli costæ is rudimentary in the eleventh and twelfth ribs.

The **ligamentum lumbocostale** extends from the superior surface of the base of the transverse process of the first lumbar vertebra to the inferior surface of the neck of the twelfth rib, as well as to the inferior surface of the transverse process of the twelfth thoracic vertebra.

Articulationes Costochondrales.

Each rib possesses an unossified portion, termed its costal cartilage. As age advances, this cartilage may undergo a certain amount of superficial ossification, but it never becomes entirely transformed. The line of demarcation between bone and cartilage is clear and abrupt, and usually the bone forms an oval cup, in which the end of the cartilage is retained by means of the continuity which exists between the periosteum and the perichondrium. There is no articulation in the proper sense between the rib and its cartilage, although a synovial cavity has occasionally been found between the first rib and its cartilage.

Articulationes Interchondrales.

Interchondral joints are arthrodial diarthroses, and they are found between adjoining margins of certain of the costal cartilages, viz., from the fifth to the eighth or ninth. The cartilages which thus articulate develop flattened, somewhat conical, prolongations of their substance, and thereby the intercostal spaces are interrupted where these flat articular facets abut against each other. Each joint is closed by a surrounding **articular capsule**, the superficial and thoracic aspects of which are specially strengthened by **external** and **internal interchondral ligaments**. These bands extend obliquely between adjacent cartilages.

A **stratum synoviale** lines each joint capsule.

Articulationes Sternocostales.

The upper seven pairs of costal cartilages, as a rule, extend to the lateral margins of the sternum to form **sterno-costal joints**. Of these, the *first pair* is implanted directly upon the manubrium sterni. The ossific process ends abruptly in connexion with the rib, and also ceases as suddenly in connexion with the sternum, and hence the cartilage does not normally present an articulation at either end. From the *second to the seventh* pairs of ribs inclusive, the sterno-costal joints are constructed upon the type of arthrodial diarthroses, although, in the case of the sixth and seventh cartilages, the joint cavity is always small, and is frequently obliterated.

The sternal end of each of these costal cartilages presents a slight antero-posterior ridge which fits into a shallow V-shaped depression upon the lateral margin of the sternum. With the exception of the sixth cartilage, they articulate opposite the lines of union between the primary segments of the sternum; the sixth articulates upon the side of the lowest segment of the body of the sternum.

Each joint is enclosed by a **capsula articularis**, the fibrous stratum of which is attached to the adjacent borders of the articulating elements. Specially strong fibres distinguish the superficial and deep aspects of the capsule.

The **lig. sternocostale radiatum** (O.T. **anterior costo-sternal ligament**) (Fig. 273) is composed of strong fibres which radiate from the anterior surface of the costal cartilage, near its sternal end, to the front of the sternum. The ligaments of opposite sides interlace with each other, and so cover the front of the sternum with a felted membrane—the **membrana sterni**.

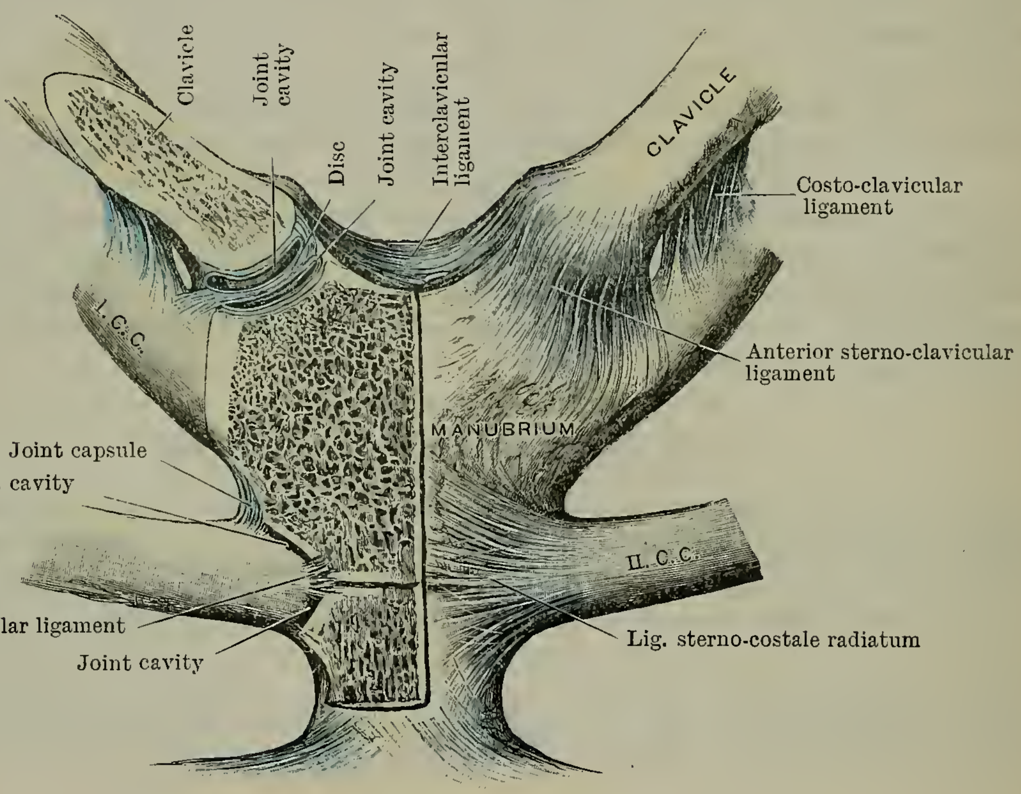

Fig. 273.—Sterno-clavicular and Sterno-costal Joints.

The **lig. sternocostale posterius (posterior costo-sternal ligament)**—also a part of the capsule—has attachments similar to the foregoing, but the arrangement of its fibres is not so powerful.

The **ligamentum costoxiphoideum** passes from the front of the upper part of the xiphoid process, obliquely upwards and laterally to the front of the seventh, and sometimes to the front of the sixth costal cartilage.

Within the capsules of these joints **ligamenta sternocostalia interarticularia (interarticular ligaments)** (Fig. 273) may be found. Their disposition is somewhat uncertain, for whereas, in the case of the second pair of cartilages, they invariably divide the joint cavity into two distinct compartments—an upper and a lower—such an arrangement is very uncertain in the other joints, and they occasionally, especially in the cases of the sixth and seventh cartilages, entirely obliterate the joint cavity. These ligaments extend horizontally between the ends of the costal cartilages and the side of the sternum.

The **stratum synoviale** is found wherever a joint cavity is developed, and therefore there may be one or two synovial strata, according to the presence or absence of a proper interarticular ligament. When the joint cavity is obliterated by the fibrous structure which represents the interarticular ligament, a synovial stratum is also absent.

ARTICULATIONES STERNI.

Primarily the sternum consists of an elongated plate of hyaline cartilage, which becomes subdivided into segments by the process of ossification.

The four segments of which the body of the sternum is originally composed unite with each other after the manner of typical synchondroses.

Similarly the xiphoid process and the body ultimately become united. It is not usual to find the joint between the manubrium and the body obliterated by the ossification of the two bony segments. Even in advanced life it remains open, and the joint, which is named the **synchondrosis sternalis**, partakes of the nature of an amphiarthrosis (Fig. 273), although a joint cavity is not found under any circumstances in the plate of fibro-cartilage which intervenes between the manubrium and the body of the sternum.

The **membrana sterni**, to which reference has already been made, assists in strengthening the union between the different segments of the sternum.

Movements of the Ribs and Sternum.—These movements may be considered either independently of, or as associated with, respiration.

In the former case the ribs move in connexion with flexion and extension of the vertebral column, being more or less depressed and approximated in flexion, and elevated or pulled apart in extension. Considered in connexion with respiration, it is necessary to observe that, to all intents and purposes, the vertebral column and the sternum are rigid structures. Next, we must remember that the heads of all the ribs occupy fixed positions, and similarly the anterior ends of seven pairs of cartilages are fixed to the lateral margins of the sternum. The ribs thus form arches, presenting a large amount of obliquity from behind forwards. Therefore, during inspiration, when the rib is elevated, the arch becomes more horizontal, and the transverse diameter of the chest is increased. At the same time, the anterior ends of the sternal ribs tend to thrust the sternum forwards and upwards; but the nature of the attachment of the first pair of ribs to the sternum, as well as the attachment of the diaphragm to the xiphoid process, prevents this movement from becoming excessive, and hence the sternum becomes a line of resistance to the forward thrust of the ribs. As a consequence, the ribs rotate upon themselves about an oblique axis which passes downwards, laterally, and posteriorly through the capitular joint and the neck of the rib anterior to the costo-transverse joint.

In this way increase, both of the antero-posterior and transverse diameters of the thorax, is provided for, although the amount of increase is not equally pronounced in all planes. Thus at the level of the first rib very little eversion is possible, because the axis of rotation is nearly transverse, and therefore any increase in the transverse or antero-posterior thoracic diameters at this level may be disregarded, although a certain amount of elevation of the manubrium sterni and anterior end of the first rib is evident.

Below the level of the sixth rib elevation and rotation of the rib during inspiration are usually said to be complicated by a certain amount of backward movement, due to the character of the costo-transverse joint, until, in the case of the last two ribs, which are destitute of costo-transverse joints, a movement backwards is almost entirely substituted for elevation. It is probable, however, that the movements of the asternal ribs exactly correspond to those of the sternal series, and that by the contraction of the costal digitations of the diaphragm the anterior ends of the false ribs are provided with fixed positions comparable to those supplied by the sternum to the ribs of the sternal series.

We may therefore say that during inspiration the ribs move upwards and laterally between their fixed ends, while as a whole the rib rotates, and its anterior end is thrust slightly forwards.

During expiration these movements are simply reversed.

THE ARTICULATIONS OF THE SUPERIOR EXTREMITY.

The bony arch formed by the clavicle and scapula articulates directly with the axial skeleton only at one point, viz., the sterno-clavicular joint.

ARTICULATIONS OF THE CLAVICLE.

ARTICULATIO STERNOCLAVICULARIS.

The **sterno-clavicular joint** is an example of an arthrodial diarthrosis. The articular surfaces concerned in its formation present the following appearances:—

1. The sternal end of the clavicle is somewhat triangular in outline, having its most prominent angle directed downwards and backwards. The anterior and

posterior sides of the triangle are slightly roughened for the attachment of ligaments, while the base or inferior side is smooth and rounded, owing to the prolongation of the articular surface to the inferior aspect of the bone. In the antero-posterior direction the articular surface tends to be concave, while vertically it is slightly convex.

2. An articular facet, situated on the superior lateral angle of the manubrium sterni, but in a plane slightly behind the supra-sternal notch, articulates with the clavicle. This facet is considerably smaller than the clavicular facet with which it articulates.

3. The superior surface of the first costal cartilage close to the sternum also participates to a small extent in the articulation.

It should be noted that the articular surfaces of the clavicle and sternum are covered mainly by **fibro-cartilage.**

A **capsula articularis** is well marked on all sides except inferiorly, where it is very thin. The epiphyseal line of the clavicle is intra-capsular.

Lig. Sternoclaviculare Anterius. — The **anterior sterno-clavicular ligament** (Fig. 273) forms part of the fibrous stratum of the articular capsule, and consists of short fibres which extend obliquely downwards and medially from the anterior aspect of the sternal end of the clavicle to the adjoining anterior surface of the sternum and the anterior border of the first costal cartilage.

Lig. Sternoclaviculare Posterius. — The **posterior sterno-clavicular ligament** also forms part of the fibrous stratum of the capsule. Its fibres are not so strong as those of the anterior ligament, but they are similarly disposed on the posterior aspect of the articulation.

Discus Articularis.—A fibro-cartilaginous **articular disc** (Fig. 273) divides the joint cavity into two compartments. It is nearly circular in shape,' and adapts itself to the articular surfaces between which it lies. It is thickest at the circumference and thinnest at the centre, where it occasionally presents a perforation, thereby permitting the two synovial cavities to inter-communicate. By its circumference it is in contact with, and adherent to, the surrounding capsule, but its superior margin is attached to the apex of the articular surface of the clavicle, while by its inferior margin it is fixed to the sternal end of the first costal cartilage.

Two **accessory ligaments** are associated with this joint, viz., the interclavicular and the costo-clavicular.

Lig. Interclaviculare.—The **interclavicular ligament** (Fig. 273) is a structure of considerable strength, forming a broad band of fibrous tissue which is attached to the superior rounded angle or apex of the sternal end of the clavicle as well as to the adjacent margins of the articular surface. Its fibres pass across the interclavicular notch to become attached to corresponding parts of the opposite clavicle, but in their course they dip down into the supra-sternal notch, in which many of them are fixed to the sternum. In this way their presence neither bridges nor obliterates the notch between the two clavicles, and the ligament really becomes a superior sterno-clavicular ligament for each joint.

Lig. Costoclaviculare.—The **costo-clavicular ligament** (Fig. 273) consists of short, strong fibres which are attached inferiorly to the superior surface of the first costal cartilage. They pass obliquely upwards, laterally and backwards, to a rough impression situated on the inferior aspect of the sternal end of the clavicle, and are distinct from the articular capsule. Occasionally a bursa is found in the interior of this ligament.

As a rule there is a **synovial stratum** lining each of the two joint cavities (Fig. 273), separated from each other by the articular disc. Sometimes, however, the two membranes establish continuity through a perforation in the disc.

ARTICULATIO ACROMIOCLAVICULARIS.

The **acromio-clavicular joint** is another instance of an arthrodial diarthrosis. It is situated between the acromial end of the clavicle and the medial aspect of the acromion. Each articular surface is an oval flattened facet, covered with **fibro-cartilage.**

The ligaments which surround this small joint form a complete articular capsule, of which the superior and inferior parts are specially strong, and are therefore named the **superior** and **inferior acromio-clavicular ligaments** (Fig. 275). These consist of short fibres passing between the adjacent rough margins of the two bones in the positions indicated by their names.

An **articular disc**, which is nearly always incomplete, and may occasionally be wanting, is usually found within the joint cavity, where it lies obliquely, with its superior margin farther from the median plane than its inferior margin, and having its borders attached to the surrounding capsule. Frequently the disc is wedge-shaped, with its base directed upwards and its apex free.

A **synovial stratum** is found forming either a single or a double sac, according to the condition of the disc. Complete division of the joint cavity, however, is rare.

Ligamentum Coracoclaviculare.—Accessory to this articulation there is the strong **coraco-clavicular ligament** which binds the acromial end of the clavicle to the coracoid process of the scapula. It is readily divisible into two parts, viz., lig. conoideum and the lig. trapezoideum.

The **conoid ligament** (Fig. 275) is situated medial to and slightly posterior to the trapezoid. It is narrow and pointed at its inferior end, by which it is attached to the superior aspect of the coracoid process, in close proximity to the scapular notch. Its superior end widens out in the manner expressed by its name, and is attached to the coracoid tuberosity of the clavicle.

The **trapezoid ligament** (Fig. 275) is attached inferiorly to the superior surface of the posterior half of the coracoid process, lateral and anterior to the attachment of the conoid ligament. Superiorly it is attached to the ridge on the inferior surface of the acromial end of the clavicle. Its lateral and medial borders are free. Its anterior surface is principally directed upwards, and its posterior surface, to a similar extent, looks downwards.

A **mucous** or **synovial bursa** usually occupies the re-entrant angle between these two ligaments.

Movements at the Clavicular Joints.—The movements of the medial end of the clavicle at the **sterno-clavicular joint** are limited in their range, owing to the tension of the ligaments. When the shoulder is raised or depressed the acromial end of the clavicle moves upwards and downwards, whilst its sternal end glides upon the surface of the articular disc; when, on the other hand, the shoulder is carried forwards or backwards, the sternal end of the clavicle along with the articular disc moves upon the sternal facet. In addition to these movements of elevation, depression, forward movement and backward movement of the clavicle, there is also allowed at the sterno-clavicular joint a certain amount of circumduction of the clavicle.

The part which is played by certain of the ligaments in restraining movement requires careful consideration. The **costo-clavicular ligament** checks excessive elevation of the clavicle, and restrains within certain limits both backward and forward movement of the clavicle. When the clavicle is depressed, as in cases where a heavy weight, such as a bucket of water, is carried in the hand, it receives support by resting upon the first rib, and the tendency for the medial end of the bone to start up out of its sternal socket is obviated by the tension of the **articular disc**, the **interclavicular ligament**, and the **anterior** and **posterior sterno-clavicular ligaments.**

The **articular disc** not only acts as a cushion which lessens the shock of blows received upon the shoulder, but it also acts as a most important bond of union, and prevents the medial end of the clavicle from being driven upwards upon the top of the sternum when force is applied to its lateral end.

The movements at the **acromio-clavicular joint** are of such a kind as to allow the inferior angle, and to some extent the vertebral border of the scapula, to remain more or less closely applied to the chest-wall during the various movements of the shoulder. The strong connexion between the coracoid process and the acromial end of the clavicle, by means of the conoid and trapezoid ligaments, renders it necessary that the scapula should follow the clavicle in its various excursions. The presence of the acromio-clavicular joint, however, enables the scapula to change its position somewhat with reference to the clavicle as the shoulder is moved. Thus, when the shoulder is raised and depressed, a marked difference takes place in the angle between the two bones; again, when the shoulder is thrown forwards or backwards, these movements can be performed without altering in a material degree the direction of the glenoid cavity of the scapula, or in other words, the socket of the shoulder-joint.

The **conoid** and **trapezoid ligaments** set a limit upon the movements of the scapula at the acromio-clavicular joint. They both, but more particularly the trapezoid ligament, prevent the acromion from being carried medially below the lateral end of the clavicle when blows fall upon the lateral aspect of the shoulder.

LIGAMENTS OF THE SCAPULA.

These ligaments are not directly connected with any articulation.

Lig. Coracoacromiale.—The **coraco-acromial ligament** (Fig. 274) completes the arch between the coracoid process and the acromion, and thus provides a secondary socket for the greater protection and security of the shoulder-joint. It is a flat triangular structure stretched tightly between its attachments. By its base it is fixed to a varying amount of the postero-lateral border of the coracoid process, and by its narrower apical end to the tip of the acromion, immediately lateral to the acromio-clavicular joint. Its surfaces look upwards and downwards, and its free borders laterally and medially. It is thinnest in the centre, where it is sometimes perforated by a prolongation of the tendon of the pectoralis minor muscle.

Lig. Transversum Scapulæ Superius.—The **superior transverse scapular ligament** is a distinct but short band which bridges the scapular notch. It may be continuous with the conoid ligament, and it is frequently ossified. As a rule the foramen completed by this ligament transmits the suprascapular nerve, while the transverse scapular vessels pass superior to the ligament to reach the supraspinous fossa.

A small duplicate of this ligament may often be found bridging the foramen on its costal aspect, subjacent to which small branches of the transverse scapular artery return from the supraspinous to the subscapular fossa.

Lig. Transversum Scapulæ Inferius.—The **inferior transverse scapular ligament** consists of another set of bridging fibres which are situated on the posterior aspect of the neck of the scapula. By one end they are attached to the lateral border of the scapular spine, and by the other to the adjacent part of the posterior aspect of the head of the scapula. The suprascapular nerve and the transverse scapular vessels pass subjacent to this ligament.

ARTICULATIO HUMERI.

The **shoulder-joint** is one of the largest as well as the most important of the joints of the upper limb. It is an example of the enarthrodial, *i.e.* ball-and-socket, variety of a diarthrosis, and, at the cost of a certain amount of security, it has obtained an extended range of movement.

The bones which enter into its formation are the glenoid cavity of the scapula and the head of the humerus.

The glenoid cavity is a shallow piriform articular surface, having its narrow end directed upwards and slightly forwards. The superior half of the anterior margin of the fossa is characterised by a shallow notch which accommodates the narrow part of the subscapularis muscle as it runs laterally to its insertion. At the apex of the cavity there is a flat area for the attachment of the long tendon of the biceps brachii muscle. The head of the humerus is hemispherical and articular, while, lateral to its articular margin, there is a slight constriction (the anatomical neck of the humerus), which is most strongly marked in relation to the greater and lesser tubercles of the humerus.

Under ordinary conditions the two articular surfaces are maintained in apposition by muscular action, aided by atmospheric pressure, and thus, when the muscles are removed, the bones fall asunder to the full extent of the restraining ligaments. Only a small part of the head of the humerus is in contact with the glenoid cavity at any particular moment, because the humeral head is much larger than the cavity, but, by reason of the shallow character of the cavity, all parts of the two articular surfaces may successively be brought into contact with each other.

In the position of rest, as the limb hangs parallel to the vertical axis of the trunk, the inferior aspect of the neck of the humerus is brought into close relation with the inferior part of the glenoid cavity.

Labrum Glenoidale.—The **labrum glenoidale** (Fig. 275) deepens the glenoid cavity, and thus extends the articular surface. It is situated within the fibrous stratum of the articular capsule, and to some slight extent increases the security of the articulation. It consists of a strong ring of dense fibrous tissue attached to the margin of the glenoid cavity. Many of its fibres are short, and pass obliquely from the inner to the outer aspect of the ridge, so that its attached base is broader than its free edge, and therefore in cross section it appears somewhat triangular. The long tendon of the biceps, which arises from the apex of the glenoid cavity, becomes to a considerable extent incorporated with the labrum glenoidale.

Capsula Articularis.—The **fibrous stratum** (Fig. 274) of the articular capsule presents the general shape which is characteristic of the corresponding part in other ball-and-socket joints, viz., a hollow cylinder. By its proximal end the fibrous stratum is attached to the circumference of the glenoid cavity, external to the labrum glenoidale, and also, to a considerable extent, to the labrum glenoidale itself.

By its distal end it is attached to the neck of the humerus, and therefore beyond the articular area of the head. The fibrous stratum is strongest on its superior aspect, while inferiorly, where the neck of the bone is least defined, it extends distally for a short distance upon the humeral shaft. Its fibres for the most part run longitudinally, but a certain number of them pursue a circular direction.

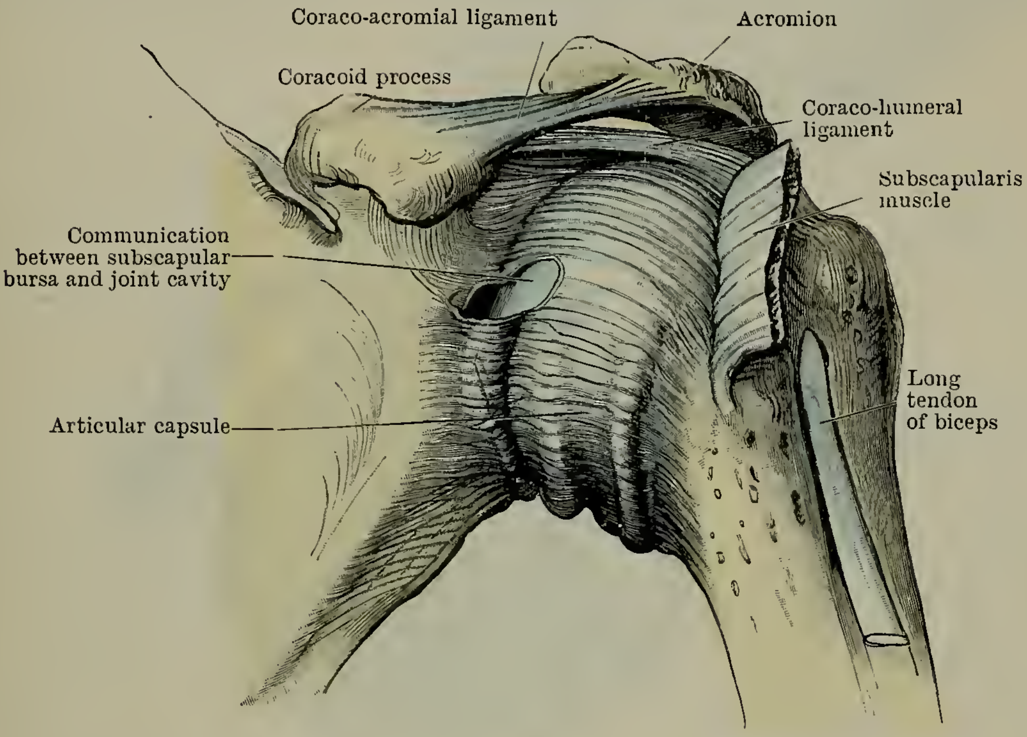

FIG. 274.—CAPSULE OF THE SHOULDER-JOINT AND CORACO-ACROMIAL LIGAMENT.

The greater part of the epiphyseal line of the proximal end of the humerus is extra-capsular, but it is intra-capsular on the medial side of the bone.

A prolongation of the fibrous stratum, the **transverse humeral ligament** presenting both longitudinal and transverse fibres, bridges that part of the intertubercular groove which is situated between the tubercles of the humerus. At this point an interruption in the fibrous stratum, beneath the transverse humeral ligament, permits the long tendon of the biceps to escape from its interior. In addition to the opening just referred to, there is another very constant deficiency in the superior and anterior part of the fibrous stratum, where the narrowing tendon of the subscapularis muscle is brought into contact with a bursa formed by a protrusion of the synovial stratum. This defect in the fibrous stratum has its long axis in the direction of the longitudinal fibres. Occasionally there is a similar but smaller opening under cover of the tendon of the infraspinatus muscle. Through the two latter openings the joint cavity communicates with bursæ situated between the capsule and the muscles referred to.

The tendons of the subscapularis, supraspinatus, and infraspinatus muscles fuse with, and so strengthen, the articular capsule as they approach their respective insertions.

On the superior aspect of the articulation the capsule is augmented by an accessory structure, the **ligamentum coracohumerale** (Fig. 274). By its proximal end, which is situated immediately above the glenoid cavity, but subjacent to the coraco-acromial ligament, it is attached to the lateral border of the root of the coracoid process, while its distal end is attached to the humeral neck close to the greater tubercle. This ligament forms a flattened band, having its posterior and inferior border fused with the articular capsule, but its anterior and superior margin presents a free edge, slightly raised above the level of the capsule. This structure is believed to represent that portion of the pectoralis minor to which reference has already been made in connexion with the coraco-acromial ligament (p. 322).

The **coraco-glenoid ligament** is another accessory structure, which is not always present. It springs from the coracoid process along with the former ligament, and extends to the superior and posterior margin of the head of the scapula.

Gleno-humeral Ligaments (Fig. 275).—If the articular capsule is opened from behind, and the head of the humerus removed, it will be seen that the longitudinal fibres of the anterior part of the fibrous stratum are specially developed in the form of thick flattened bands which extend from the anterior border of the glenoid cavity to the anterior aspect of the neck of the humerus. These gleno-humeral ligaments are three in number, and occupy the following positions: the superior is placed *above* the aperture in the front of the capsule; the **middle** and **inferior** on the antero-inferior aspect of the capsule, and *below* the aperture mentioned.

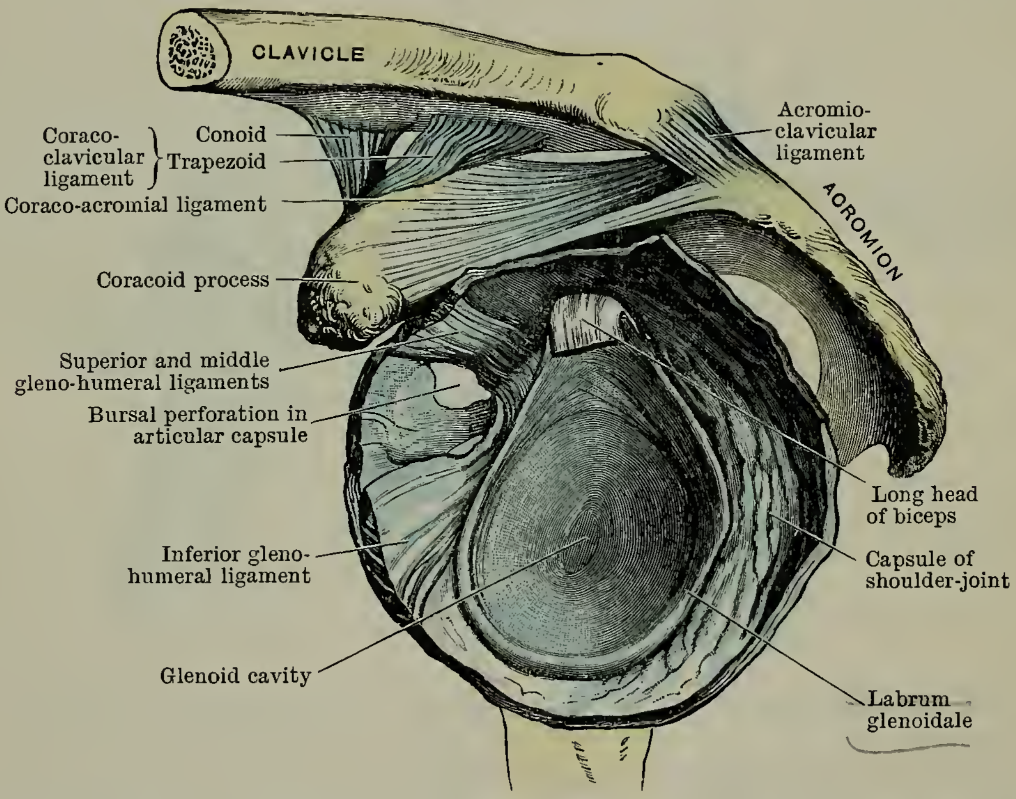
CLAVICLE
Coraco-clavicular ligament
Conoid
Trapezoid
Coraco-acromial ligament
Coracoid process
Superior and middle gleno-humeral ligaments
Bursal perforation in articular capsule
Inferior gleno-humeral ligament
Glenoid cavity
Acromio-clavicular ligament
ACROMION
Long head of biceps
Capsule of shoulder-joint
Labrum glenoidale

Fig. 275.—Capsular Ligament of Shoulder-Joint cut across and Humerus removed.

The superior gleno-humeral ligament, which some believe to represent the ligamentum teres of the hip-joint, springs, along with the middle gleno-humeral band, from the superior part of the cavity. The inferior ligament is the strongest of the three, and springs from the inferior part of the anterior margin of the glenoid.

Intra-capsular Structures.—1. The labrum glenoidale, already described. 2. The long tendon of the biceps passes laterally from its attachment to the apex of the glenoid cavity and the adjoining part of the labrum glenoidale, above the head and neck of the humerus, to escape from the interior of the capsule by the opening between the tubercles of the humerus, subjacent to the transverse humeral ligament.

A **synovial stratum** (Fig. 276) lines the fibrous stratum of the capsule, and extends from the margin of the glenoid cavity to the humeral attachments of the fibrous stratum, where it is reflected towards the margin of the articular cartilage. It is therefore important to note that the inferior aspect of the humeral neck has the most extensive clothing of the synovial stratum. Further, the synovial stratum envelops the intra-capsular part of the tendon of the biceps, and although this tubular sheath is prolonged upon the tendon into the proximal part of the intertubercular sulcus, yet the closed character of the synovial cavity is maintained. Thus, while the tendon is within the capsule, it is not within the synovial cavity. The synovial stratum is continuous with those bursæ which communicate with the joint cavity through openings in the fibrous stratum of the capsule.

Bursæ (*a*) *Communicating with the Joint Cavity.*—Practically there is only one bursa which is constant in its position, viz., the **subscapular**, between the capsule and the tendon of the subscapularis muscle. It varies considerably in its dimensions, but its lining membrane is always continuous with the synovial stratum of the capsule (Figs. 275 and 276), and therefore it may be regarded merely as a prolongation of the articular synovial stratum. Occasionally a similar but smaller bursa occurs between the capsule and the tendon of the infraspinatus muscle.

(*b*) *Not communicating with the Joint Cavity.*—The **sub-deltoid** or **sub-acromial bursa** is situated between the muscles on the superior aspect of the shoulder-joint on the one hand and the deltoid muscle on the other. It is an extensive bursa, and is prolonged subjacent to the acromion and the coraco-acromial ligament. It does not communicate with the shoulder-joint, but it greatly facilitates the movements of the proximal end of the humerus against the inferior surface of the coraco-acromial arch.

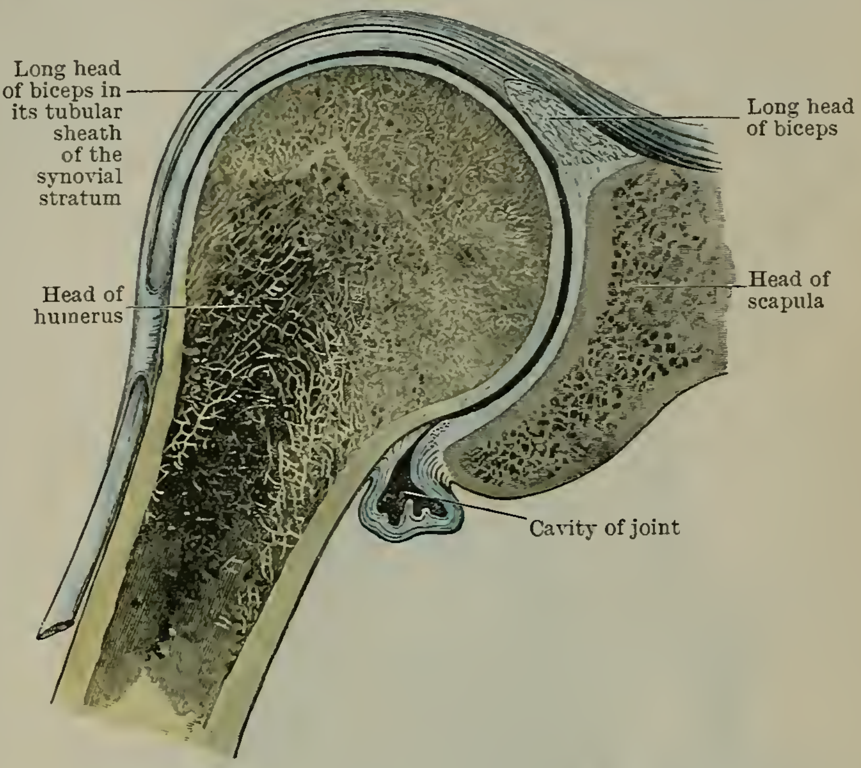
Long head of biceps in its tubular sheath of the synovial stratum
Long head of biceps
Head of scapula
Head of humerus
Cavity of joint

Fig. 276.—Vertical Section through the Shoulder-Joint.

Movements at the Shoulder-Joint.—A ball-and-socket joint permits of a great variety of movements, practically in all directions; but if these movements are analysed, it will be seen that they resolve themselves into movements around **three** primary axes at right angles to each other, or around axes which are the possible combinations of the primary ones.

Thus, around a transverse axis, the limb may move forwards **(flexion)** or backwards **(extension)**. Around an antero-posterior axis it may move laterally, *i.e.* away from the median plane of the trunk **(abduction)**, or medially, *i.e.* towards, and to some extent up to, the median plane **(adduction)**.

Around a vertical axis, the humerus may **rotate** upon its axis in a medial or lateral direction to the extent of a quarter of a circle.

Since these axes all pass through the shoulder-joint, and since each may present varying degrees of obliquity, it follows that very elaborate combinations are possible until the movement of **circumduction** is evolved. In this movement the head of the humerus acts as the apex of a **cone of movement** with the distal end of the humerus, describing the base of the cone.

The range of the shoulder-joint movements is still further increased owing to the mobility of the scapula as a whole, and owing to its association with the movements of the clavicle already described.

ARTICULATIO CUBITI.

The **elbow-joint**[1] provides an instance of a diarthrosis capable of performing the movements of flexion and extension around a single axis placed transversely, *i.e.*, a typical ginglymus diarthrosis or hinge-joint.

The bones which enter into its formation are the humerus, ulna, and radius. The trochlea of the humerus articulates with the semilunar notch of the ulna **(articulatio humeroulnaris)**; the capitulum of the humerus articulates with the shallow depression or cup on the proximal aspect of the head of the radius **(articulatio humeroradialis)**. The articular cartilage clothing the trochlea of the humerus terminates in a sinuous or concave margin both anteriorly and posteriorly, so that it does not line either the coronoid or the olecranon fossa. Medially, it merely rounds off the medial margin of the trochlea, but laterally it is continuous with the encrust-

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[1] The articulatio cubiti or elbow-joint includes the humero-radial, humero-ulnar, and the proximal radio-ulnar joints; but, for convenience, the description given here is limited to the humero-radial and humero-ulnar joints.

ing cartilage covering the capitulum, to the margin of which the cartilage extends in all directions, and thus it presents a convex edge in relation to the radial fossa. The cartilage which lines the semilunar notch of the ulna presents a transverse interruption, considerably wider on its medial as compared with its lateral aspect. Thereby the coronoid and olecranon segments of the notch are separated from each other. The cartilage which clothes the coronoid segment is continuous with that which clothes the radial notch of the ulna. The shallow cup-shaped depression on the head of the radius is covered with cartilage which rounds off the margin, and is prolonged without interruption upon the vertical aspect of the head, extending to its most distal level on that part opposed to the radial notch of the ulna.

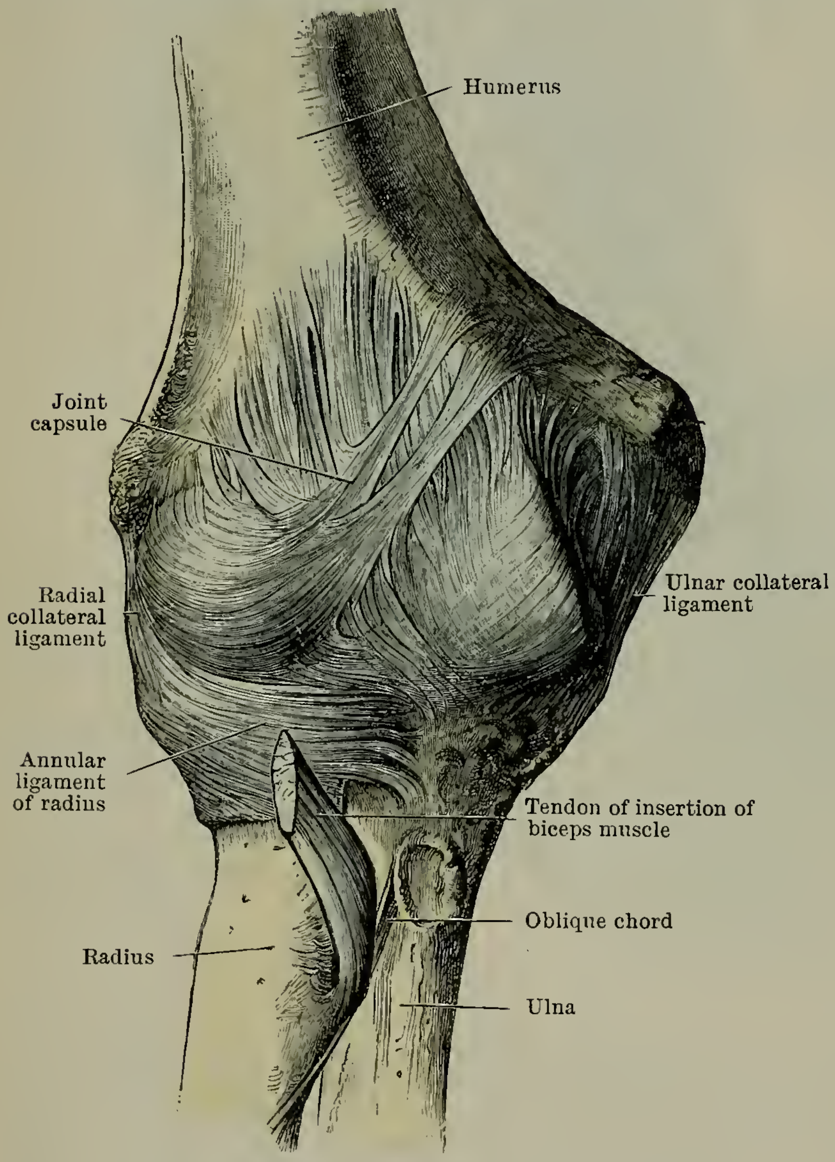
Humerus
Joint capsule
Radial collateral ligament
Ulnar collateral ligament
Annular ligament of radius
Tendon of insertion of biceps muscle
Oblique chord
Radius
Ulna

Fig. 277.—Anterior View of Elbow-Joint.

Capsula Articularis.—Taken as a whole, the ligaments form a complete **fibrous stratum** of the **articular capsule,** which is not defective at any point, although it is not of equal thickness throughout, and certain bands of fibres stand out distinctly because of their greater strength.

The common epiphyseal line for the trochlea, capitulum, and the lateral epicondyle of the humerus, is partly intra-capsular and partly extra-capsular; that for the medial epicondyle is extra-capsular. The epiphyseal line of the olecranon may be intra-capsular anteriorly, or it may be altogether extra-capsular.

Lig. Anterius.—The **anterior ligament** (Fig. 277) consists of a layer whose fibres run in several directions—obliquely, transversely, and longitudinally—and of these the vertical fibres are of most importance. It is attached proximally to the proximal margins of the coronoid and radial fossæ; distally, to the margins of the coronoid process and to the annular ligament of the proximal radio-ulnar joint, but some loosely arranged fibres reach as far as the neck of the radius. The marginal portions of this ligament, which are situated in front of the capitulum and the medial margin of the trochlea respectively, are much thinner and weaker than the central part. Fibres of origin of the brachialis muscle are attached to the front of this ligament.

Lig. Posterius.—The **posterior ligament** is an extremely thin, almost redundant layer. Proximally it is attached, in relation to the margin of the olecranon fossa, at a varying distance from the trochlear articular surface, and distally to the summit and sides of the lip of the olecranon. Laterally some of its fibres pass from the posterior aspect of the capitulum to the posterior border of the radial notch of the ulna. This ligament derives material support from, and participates in the movements of, the triceps brachii muscle, since they are closely adherent to each other in the region of the olecranon.

Lig. Collaterale Ulnare.—The **ulnar collateral ligament** (Figs. 277 and 278) is a fan-shaped structure of unequal thickness, but its margins, which are its strongest bands, are continuous with the adjoining parts of the anterior and posterior ligaments. By its proximal end it is attached to the anterior, distal, and posterior aspects of the medial epicondyle of the humerus. By its broad distal end it is attached to the medial margin of the semilunar notch, so that the *anterior band* is associated principally with the medial margin of the coronoid process, and the *posterior band* with the medial margin of the olecranon, while the intermediate weaker portion sends its fibres downwards to join a *transverse band*, sometimes very strong, which bridges the notch between the adjoining medial margins of the coronoid process and the olecranon.

Lig. Collaterale Radiale.—The **radial collateral ligament** (Fig. 277) is a strong flattened band attached proximally to the distal and posterior aspects of the lateral epicondyle of the humerus. It completes the continuity of the articular capsule on the lateral side, and blends distally with the lig. annulare radii, on the surface of which its fibres may be traced both to the anterior and posterior ends of the radial notch of the ulna. Both of the collateral ligaments are intimately associated with the muscles which take origin from the corresponding medial and lateral epicondyles of the humerus.

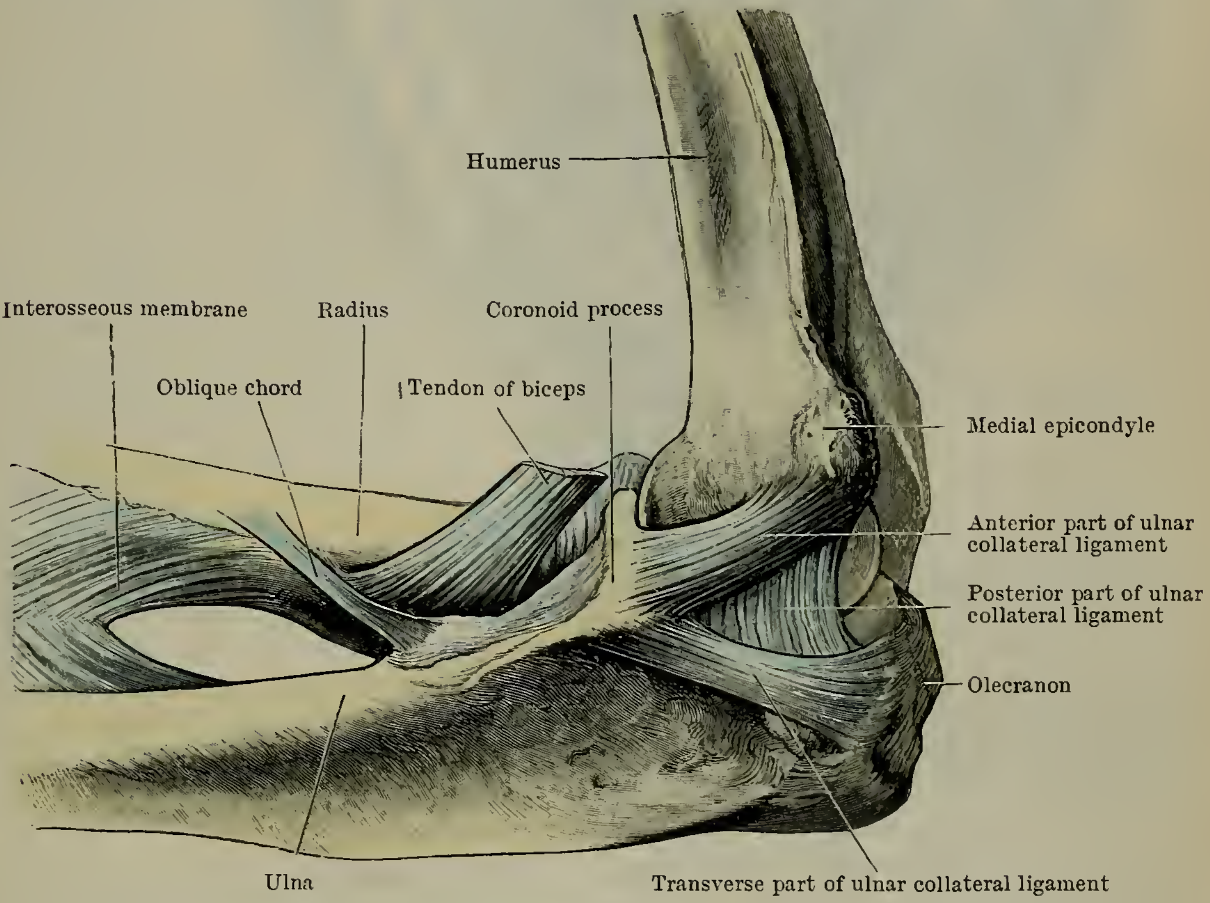
Humerus
Interosseous membrane
Radius
Coronoid process
Oblique chord
Tendon of biceps
Medial epicondyle
Anterior part of ulnar collateral ligament
Posterior part of ulnar collateral ligament
Olecranon
Ulna
Transverse part of ulnar collateral ligament

Fig. 278.—Elbow-Joint (Medial Aspect).

Synovial Pads of Fat (Fig. 279).—Internal to the fibrous stratum of the articular capsule, there are several pads of fat situated between it and the synovial stratum. Small pads are so placed as to lie immediately in front of the coronoid and radial fossæ, but a larger one projects towards the olecranon fossa.

A **stratum synoviale** (Fig. 279) lines the entire fibrous stratum and clothes the pads of fat referred to above, as well as those portions of bone enclosed within the capsule which are not covered by articular cartilage. By its disposition the elbow and the proximal radio-ulnar joints possess a common joint cavity. It should be specially noted that the proximal part of the neck of the radius is surrounded by this synovial layer.

Movements at the Elbow-Joint.—The movements of the radius and ulna upon the humerus have already been referred to as those characterising a uniaxial joint constructed on the plan of a hinge. In this case the axis of the joint is obliquely transverse, so that in the extended position the humerus and ulna form an obtuse angle open towards the radius, whereas in the flexed position the hand is carried medially in the direction of the mouth. Extreme flexion is checked by the soft parts in front of the arm and of the forearm coming into contact, and extreme extension by the restraining effect of the ligaments and muscles. In each case the movement is checked before either the coronoid process or the olecranon comes into contact with the humerus. The anterior and posterior bands of the ulnar collateral ligament are important factors in these results. Lateral movement of the ulna is not a characteristic movement, although it may occur to a slight extent, owing to a want of complete adaptation between the trochlear surface of the humerus and the semilunar notch of the ulna. This incongruence is noteworthy since the medial lip of the trochlea is prominent in front, and the lateral lip is prominent behind. Consequently, this latter part is associated with a surface on the lateral side of the olecranon which is only utilised in complete extension.

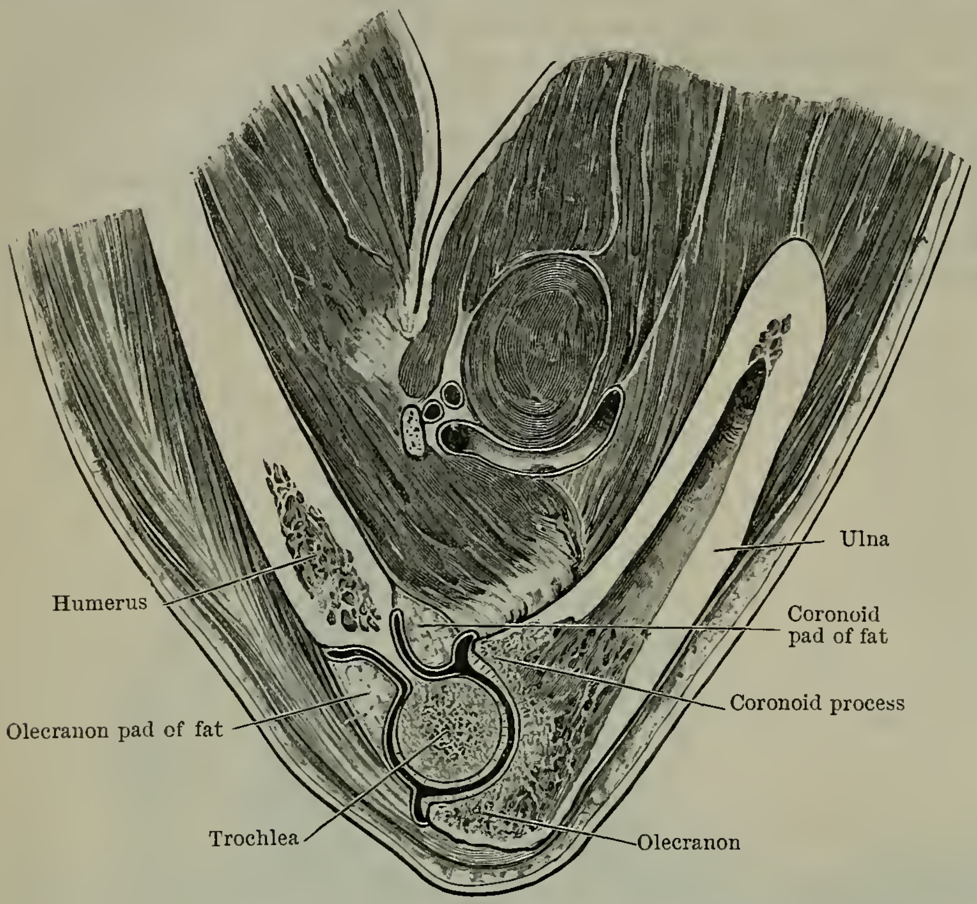

Fig. 279.—Vertical Section through the Humero-ulnar Part of the Elbow-Joint.

The capitulum and the opposing surface upon the head of the radius are always in varying degrees of contact. The head of the radius participates in the movements of flexion and extension, and is most closely and completely in contact with the humerus during the position of semi-flexion and semi-pronation. In complete extension a very considerable part of the capitulum is uncovered by the radius.

THE RADIO-ULNAR JOINTS.

These articulations, which are two in number, are situated at the proximal and distal ends of the radius and ulna. They provide an adaptation whereby the radius rotates around a longitudinal axis in the movements of pronation and supination, and hence this form of uniaxial diarthrosis is termed **lateral ginglymus**.

Articulatio Radioulnaris Proximalis.—The **proximal radio-ulnar joint** forms a part of the elbow-joint. The articular surfaces which enter into its formation are the radial notch of the ulna and the articular margin of the head of the radius. In each case the articular cartilage is continuous with an articular surface entering into the formation of the humero-radial and humero-ulnar joints, consequently the joint cavity is continuous with the cavities of those joints, and therefore, in a sense, it lies within the cover of the articular capsule of the elbow-joint; but its special feature is the annular ligament of the radius.

Lig. Annulare Radii.—The **annular ligament of the radius** (Figs. 277 and 280) has been mentioned above as the distal line of attachment of the radial collateral ligament and parts of the anterior and posterior ligaments of the elbow-joint.

It is a strong, well-defined structure, attached by its extremities to the volar and dorsal margins of the radial notch of the ulna, and thus it forms nearly four-fifths of an osseo-tendinous circle or ring. The circle is somewhat wider at the proximal than at the distal margin of the annular ligament of the radius, which, by encircling the proximal part of the neck of the radius, tends to prevent displacement of the head of that bone in a distal direction. The distal margin of this ligament is not directly attached to the radius.

The **synovial stratum** is continuous with that which lines the elbow-joint. It closes the joint cavity at the distal unattached margin of the annular ligament, where it is somewhat loosely arranged in its reflexion from the ligament to the neck of the radius. The epiphyseal line at the proximal end of the radius is intra-capsular.

Articulatio Radioulnaris Distalis. — The **distal radio-ulnar joint** is situated between the lateral aspect of the head of the ulna and the ulnar notch on the medial side of the distal end of the radius. In addition, it includes the distal surface of the head of the ulna, which articulates with the proximal surface of a triangular articular disc by means of which the joint is excluded from the radio-carpal articulation.

Discus Articularis.—The **triangular articular disc** (Figs. 281 and 282), besides presenting articular surfaces to two separate joints, is an important ligament concerned in binding together the distal ends of the radius and ulna. It is attached by its apex to the depression at the lateral side of the root of the styloid process of the ulna, and by its base to the sharp line of demarcation between the ulnar notch and the carpal articular surface of the radius.

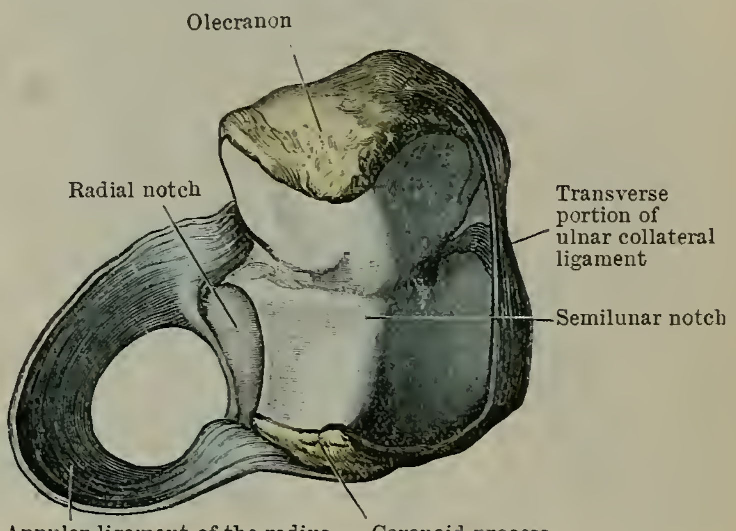
Olecranon
Radial notch
Transverse portion of ulnar collateral ligament
Semilunar notch
Annular ligament of the radius
Coronoid process

Fig. 280.—Annular Ligament of the Radius.

Capsula Articularis.—The **fibrous stratum** is very imperfect, and consists of scattered fibres, termed the **anterior** and **posterior radio-ulnar ligaments** (Fig. 282). These ligaments pass transversely between adjoining non-articular surfaces on the radius and ulna, and are of sufficient length to permit of the movements of the radius in pronation and supination.

The **synovial stratum** completes the closure of the joint cavity. It forms a loose bulging projection (**recessus sacciformis**), passing proximally between the distal ends of the shafts of the radius and ulna, and it also clothes the proximal surface of the articular disc (Fig. 281). The cavity of this joint is quite distinct from that of the radio-carpal articulation, except when the articular disc presents a perforation.

Between the proximal and distal radio-ulnar articulations there are two **accessory ligaments**, viz., the chorda obliqua and the interosseous membrane, which connect together the shafts of the radius and ulna.

Chorda Obliqua.—The **oblique chord** (Fig. 277) is a slender fibrous band of very varying strength which springs from the tuberosity of the ulna, and stretches obliquely, distally, and laterally, to the radius where it is attached immediately distal to the tuberosity of the radius.

Membrana Interossea Antibrachii.—The **interosseous membrane of the forearm** (Fig. 278) is a strong fibrous membrane which stretches across the interval between the radius and ulna, and is firmly attached to the interosseous crest of each. Distally it extends to the distal limit of the space between the bones, whilst proximally it only reaches a point about one inch distal to the tuberosity of the radius. A gap, called the *hiatus interosseus*, is thus left between its proximal margin and the chorda obliqua, and through this the dorsal interosseous artery passes back-

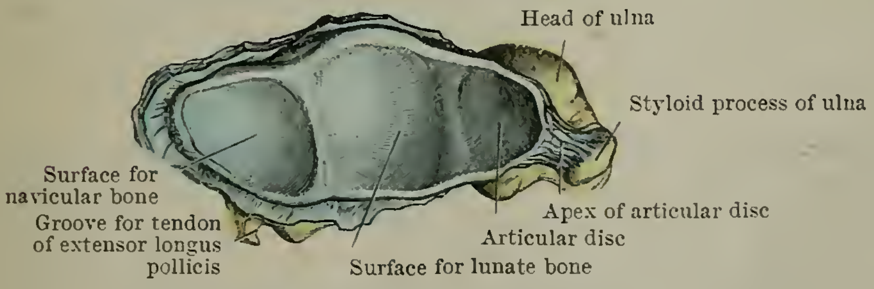

Fig. 281.—Carpal Articular Surface of the Radius, and Articular Disc of the Wrist.

wards between the bones to reach the dorsal aspect of the forearm. The fibres which compose the interosseous membrane run for the most part distally and medially from the radius to the ulna, although on its dorsal aspect several bands may be observed stretching in an opposite direction. The interosseous membrane augments the surface available for the origin of the muscles of the forearm; it braces the radius and ulna together; and when shocks are communicated from the hand to the radius, owing to the direction of its fibres, the interosseous membrane transmits them, to a large extent, to the ulna.

Movements of the Radius on the Ulna.—The axis around which the radius moves is a longitudinal one, having one end passing through the centre of the head of the radius and the other through the styloid process of the ulna and the line of the ring-finger. In this axis the head of the radius is so secured that it can only rotate upon the radial notch of the ulna within the annular ligament of the radius, and consequently the radial head remains upon the same plane as the ulna; but the distal end of the radius being merely restrained by the articular disc, is able to describe nearly a half-circle, of which the apex of this ligament is the centre. In this movement the radius carries the hand from a position in which the palm is directed forwards, and in which the radius and ulna lie parallel to each other **(supination)**, to one in which the palm is directed backwards, and the radius lies diagonally across the front of the ulna **(pronation)**.

The ulna is unable to rotate upon a long axis, but while the radius is travelling through the arc of a circle from lateral to medial side in front of the ulna, it will usually be seen that the ulna appears to move through the arc of a smaller circle in the reverse direction, viz., from medial to lateral side. If the humerus is prevented from moving at the shoulder-joint, a very large proportion, if not the entire amount, of this apparent movement of the ulna will disappear. At the same time some observers maintain that it really occurs at the elbow-joint, associated with lateral movement during slight degrees of flexion and extension at that joint.

ARTICULATIO RADIOCARPEA.

The **radio-carpal joint** is a bi-axial diarthrosis, frequently called a condyloid joint.

The articular elements which enter into its formation are: on its *proximal side*, the carpal surface of the distal end of the radius, together with the distal surface of the discus articularis; on its *distal side*, the proximal articular surfaces of the navicular, lunate, and triquetral bones, and the interosseous ligaments between them. The articular surface of the radius is concave both in its antero-posterior and transverse diameters, in order to adapt itself to the opposing surfaces of the navicular and lunate, which are convex in the two axes named. In the ordinary straight position of the hand the articular disc is in contact with the lunate bone, and the proximal articular surface of the triquetral bone is in contact with the capsule of the joint. When, however, the hand is bent towards the ulna the triquetral bone is carried laterally as well as the lunate and navicular and the articular disc comes into contact with the triquetral. The articular surface of the radius is subdivided by an antero-posterior, slightly elevated ridge, into a lateral triangular facet which usually articulates with the navicular, and a medial quadrilateral facet for articulation with a portion of the lunate bone.

In the intervals between the navicular, lunate, and triquetral bones, the continuity of the distal articular surface is maintained by the presence of interosseous ligaments which are situated upon the same level as the articular cartilage.

Capsula Articularis.—An articular capsule completely surrounds the joint. It is somewhat loosely arranged, and its fibrous stratum permits of subdivision into the following four portions:—

Lig. Radiocarpeum Laterale.—The **lateral radio-carpal ligament** (Fig. 282) is a well-defined band which is attached by one end to the tip of the styloid process of the radius, and by the other to a rough area at the base of the tuberosity of the navicular bone, *i.e.* lateral to its radial articular surface.

Lig. Ulnocarpeum Mediale.—The **medial ulno-carpal ligament** (Fig. 282) is also a distinct rounded structure, having one end attached to the tip of the styloid process of the ulna, and the other to the rough non-articular border of the triquetral bone, some of its fibres being prolonged to the pisiform bone.

Lig. Radiocarpeum Volare.—The **volar radio-carpal ligament** (Fig. 282) is attached proximally to the volar margin of the distal end of the radius, as well as slightly to the base of the styloid process of the ulna. Some transverse fibres may be seen, but the greater number pass obliquely, distally, and medially, to the volar non-articular surfaces of the navicular, lunate, and triquetral bones, while some of them may even be continued as far as the capitate bone. Those fibres from the ulna run obliquely laterally. On its deeper aspect this ligament is closely adherent to the volar border of the articular disc of the distal radio-ulnar articulation.

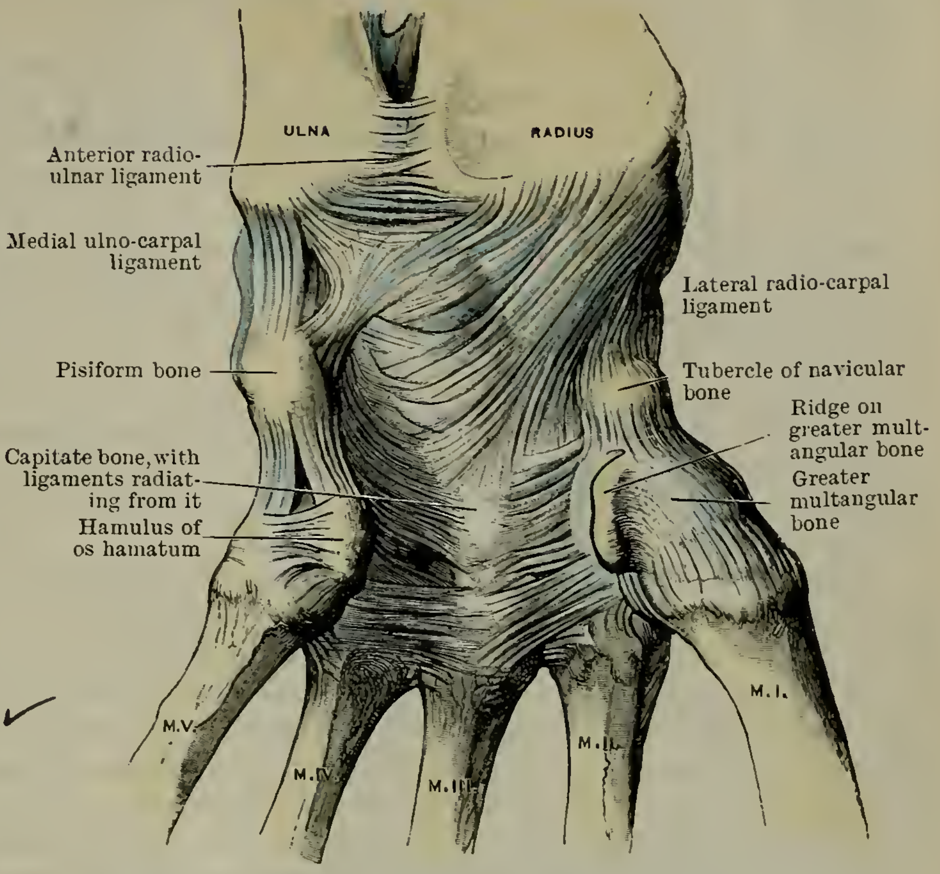
ULNA
RADIUS
Anterior radio-ulnar ligament
Medial ulno-carpal ligament
Lateral radio-carpal ligament
Pisiform bone
Tubercle of navicular bone
Ridge on greater multangular bone
Capitate bone, with ligaments radiating from it
Greater multangular bone
Hamulus of os hamatum
M.V.
M.IV.
M.III.
M.II.
M.I.

FIG. 282.—LIGAMENTS ON VOLAR ASPECT OF RADIO-CARPAL, CARPAL, AND CARPO-METACARPAL JOINTS.

Lig. Radiocarpeum Dorsale.—The **dorsal radio-carpal ligament** extends from the dorsal margin of the distal end of the radius, in an oblique direction distally and medially, to the dorsal non-articular areas on the proximal row of the carpal bones. The medial portion assists in forming the fibrous sheath through which the tendon of the extensor carpi ulnaris muscle travels to its insertion. The principal bundle of fibres is connected with the triquetral bone.

The **stratum synoviale** (Fig. 283) is simple, and is confined to the articulation, except in those cases in which the articular disc is perforated, or in which one of the interosseous ligaments between the carpal bones of the first row is absent. The epiphyseal lines at the distal ends of radius and ulna are extra-capsular.

Movements at the Radio-carpal Joint.—The radio-carpal joint affords an excellent example of a bi-axial articulation, in which a long transverse axis of movement is situated more or less at right angles to a short axis placed in the antero-posterior direction. The nature of the movements which are possible around these two axes is essentially the same in both cases, viz., **flexion** and **extension.** The movements around the longer transverse axis are anterior or volar flexion, extension, and its continuation into dorsi-flexion. Around the shorter antero-posterior axis we get movements which result from combined action by certain flexor and extensor muscles, whereby the radial or ulnar borders of the hand may be approximated towards the corresponding borders of the forearm. Lateral movement also may be possible to a slight extent. The range of movement in connexion with either of the principal axes is largely a matter of individual peculiarity, for, with the exception of the lateral ligaments, there is no serious obstacle to the cultivation of greater mobility at the radio-carpal joint.

ARTICULATIONES INTERCARPEÆ.

Carpal Joints.—The articulations subsisting between the individual carpal bones are all diarthroses, and although the total amount of movement throughout the series is considerable, yet the extent of movement which is possible between the two rows or between any two carpal bones is extremely limited. For this reason, as well as because of the nature of the movement, these articulations are called gliding joints (arthrodia).

It is advisable to consider, *first*, the articulations between individual bones of the proximal row; *second*, the articulations between the separate bones of the distal row; *third*, the articulation of the proximal and distal rows with each other; *fourth*, the pisiform articulation.

The **proximal row of carpal articulations** (Fig. 283) comprises the joints between the navicular, lunate, and triquetral bones. On their adjacent aspects these bones are partly articular and partly non-articular.

Three sets of simple but strong, although short, ligamentous bands bind these three carpal bones together, and form an investment for three sides of their intercarpal joints. These are—(1) the **ligamenta intercarpea volaria (anterior or volar ligaments)**, two in number, which consist of transverse fibres passing between the adjacent rough volar surfaces of the bones; (2) the **ligamenta intercarpea dorsalia (posterior or dorsal ligaments)**, also two in number, and composed of similar short transverse fibres passing between the adjacent dorsal surfaces; (3) the **ligamenta intercarpea interossea (interosseous ligaments)** (Fig. 283), again two in number, and transverse in direction, situated on a level with the proximal articular surfaces, and extending from the volar to the dorsal aspect of the bones while attached to non-articular areas of the opposing surfaces. The radio-carpal joint is entirely shut off from the intercarpal joints, and also from the joint between the two rows of carpal bones, except in rare cases, when an interosseous ligament is wanting.

The **distal row of carpal articulations** (Fig. 283) includes the joints between the greater multangular, lesser multangular, capitate, and hamate bones. Articular facets occur on the opposing faces of the individual bones.

Associated with this row there are again simple bands of considerable strength, and presenting an arrangement similar to that seen in the proximal row. As in the former case, they invest the intercarpal articulations, except on the proximal and distal aspects, where the distal intercarpal joints communicate respectively with the transverse carpal and carpo-metacarpal joint cavities.

The **ligamenta intercarpea volaria (anterior or volar ligaments)** are three in number. They extend in a transverse direction between contiguous portions of the rough volar surfaces of the bones. The **ligamenta intercarpea dorsalia (posterior or dorsal ligaments)**, also three in number, are similarly disposed on the dorsal aspect. The **ligamenta intercarpea interossea (interosseous ligaments)** (Fig. 283) are two or three in number. That which joins the capitate to the os hamatum is the strongest; that between the lesser multangular and the capitate bone is situated towards the dorsal parts of their opposing surfaces; the third, situated between contiguous non-articular surfaces of the greater and lesser multangular bones, is always the feeblest, and is frequently absent.

The **transverse carpal articulation** (Fig. 283) is situated between the proximal and distal rows of the carpus. The bones of the proximal row present the following characters on their distal aspect. The lateral part of the articular surface is strongly convex, both in the antero-posterior and in the transverse directions, but the medial part of the same surface is concavo-convex, more especially in the transverse direction.

Proximally, the articular surfaces of the distal row of carpal bones present an irregular outline. That part pertaining to the greater and lesser multangular bones is concave in the antero-posterior and transverse directions, and lies at a considerably more distal level than the portion belonging to the capitate and os hamatum, which is, moreover, markedly convex in the antero-posterior and transverse directions, with the exception of the most medial part of the os hamatum, where it is concavo-convex in both of these directions.

This articulation is invested by a complete short **articular capsule** (Fig. 283) which binds the two rows of the carpus together, and sends prolongations to the investing capsules of the proximal and distal articulations. The ligament, as a whole, is very strong, and individual bands are not readily defined, although certain special bands may be described. The **lig. carpi radiatum (radiate carpal ligament (volar ligament))** radiates from the capitate bone to the navicular, triquetral, and pisiform bones. The interval between the capitate and lunate is occupied by oblique fibres, some of which pass from navicular to triquetral, while these are joined by others, prolonged obliquely, distally, and medially, from the radial end of the anterior radio-carpal ligament. By these different bands the volar aspect of the joint is completely closed.

The **ligamenta intercarpea dorsalia (dorsal ligaments)** are more feeble than the volar. They form a thin, loosely arranged stratum, in which the only noteworthy bands are one which joins the navicular to the capitate, and another which joins the triquetral to the os hamatum.

Lig. Collaterale Carpi Radiale.—The **radial collateral carpal ligament** (Fig. 283) extends between contiguous rough areas on the lateral aspects of the navicular and greater multangular bone. By its margins it is continuous both with the volar and dorsal ligaments.

Lig. Collaterale Carpi Ulnare.—The **ulnar collateral carpal ligament** (Fig. 283) is arranged like the former in regard to its margins, and by its ends it is attached to the contiguous rough ulnar surfaces of the triquetral and the os hamatum.

Both of these collateral ligaments are directly continuous with the corresponding collateral ligaments of the radio-carpal joint.

A **lig. interosseum (interosseous ligament)** (Fig. 283) is occasionally found within the capsule, extending across the joint cavity between the capitate and the navicular.

Articulatio Ossis Pisiformis.—The **piso-triquetral articulation** is an arthrodial diarthrosis. The mutual articular surfaces of the two bones are flattened and circular, and permit of only a small amount of gliding movement.

The joint is provided with a thin but complete **articular capsule**, the fibrous stratum of which is specially strengthened distally by two strong bands, viz., lig. pisohamatum and lig. pisometacarpeum (Fig. 282). Both of these bands extend from the distal and medial aspect of the pisiform to adjoining parts of the hook of the os hamatum and base of the fifth metacarpal bone respectively. To a great extent these ligamentous bands may be regarded as extensions of the insertion of the tendon of the flexor carpi ulnaris muscle, which is attached to the proximal part of the pisiform bone. Looked at as ligaments, however, they are specially strong to prevent the displacement of the pisiform bone during contraction of the muscle inserted into it.

The **synovial strata (synovial membranes)** (Fig. 283) of the carpal joints are two in number. Of these, one is restricted to the piso-triquetral articulation, and is correspondingly simple, although occasionally the joint cavity may communicate with that of the radio-carpal joint.

The other synovial stratum is associated with the transverse carpal joint which extends transversely between the two rows of carpal bones, with prolongations into the intervals between the adjoining bones of each row, *i.e.* the intercarpal articulations. It is, therefore, an elaborate cavity, which may be still further extended, by the absence of interosseous ligaments, so as to reach the radio-carpal and carpo-metacarpal series of joints. The first condition is rare, but the second is not uncommon, and may result from the absence of the interosseous ligament between the greater and lesser multangular bones, or of that between the lesser multangular and the capitate bones, but it may occur when all the interosseous ligaments are present.

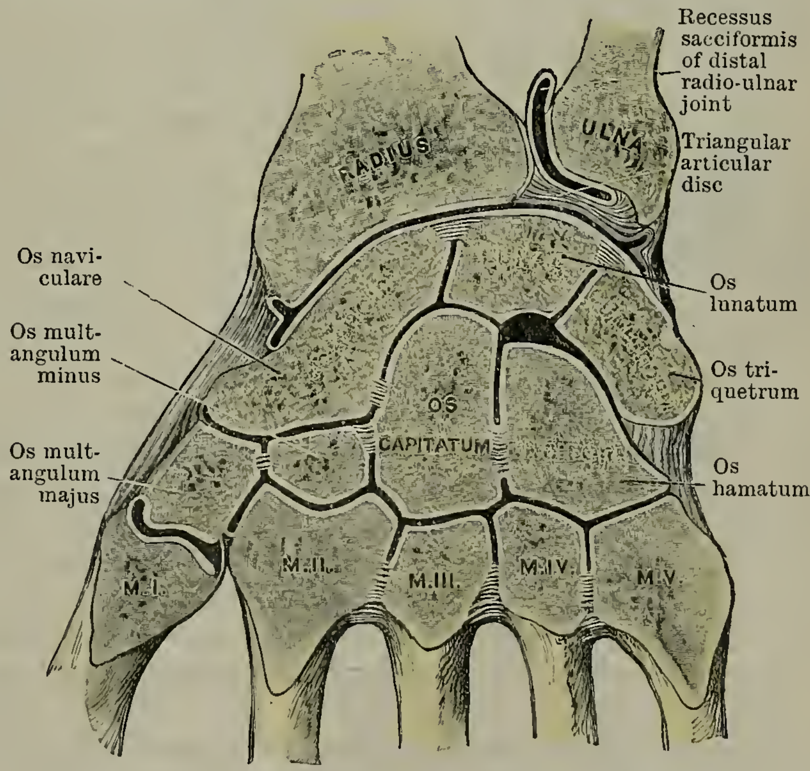

FIG. 283.—FRONTAL SECTION through the radio-carpal, carpal, carpometacarpal, and intermetacarpal joints, to show joint cavities and interosseous ligaments (diagrammatic).

ARTICULATIONES INTERMETACARPEÆ.

Intermetacarpal Joints.—The four medial metacarpal bones articulate with each other at their proximal ends or bases, between the opposing surfaces of which joint cavities are found—arthrodial diarthroses. These cavities are continuous with the carpo-metacarpal joint (not yet described), and hence the ligamentous arrangements only enclose three aspects of each joint.

Three strong **transverse ligaments** (Figs. 282 and 283) bind adjacent volar, dorsal, and interosseous areas of the bases of the metacarpal bones, and hence they are called **ligamenta basium** (oss. metacarp.) **volaria, dorsalia et interossea.** A synovial stratum is associated with each of these joints, but it may be regarded as a prolongation from the carpo-metacarpal articulation.

ARTICULATIONES CARPOMETACARPEÆ.

Carpo-metacarpal Joints.—The articulation of the metacarpal bone of the thumb with the greater multangular differs in so many respects from the articulation between the other metacarpal bones and the carpus, that it must be considered separately.

(*A*) The **articulatio carpometacarpea pollicis** (Figs. 282 and 283) is the joint between the disto-lateral surface of the greater multangular and the proximal surface of the base of the first metacarpal bone. Both of these surfaces are saddle-shaped, and they articulate by mutual co-aptation.

The joint cavity is surrounded by an **articular capsule**, in the fibrous stratum of which we may recognise volar, dorsal, lateral, and medial bands, the last being the strongest and most important.

A **synovial stratum** lines the fibrous stratum, and the joint cavity is isolated and quite separate from the other carpal and carpo-metacarpal articulations.

At this joint movements occur around at least three axes. Thus, around a more or less transverse axis, **flexion** and **extension** take place; in an antero-posterior axis **abduction** and **adduction** (movements which have reference to the middle line of the hand) are found; while a certain amount of rotation is possible in the longitudinal axis of the digit. The very characteristic movement of **opposition**, in which the tip of the thumb may be applied to the tips of all the fingers, results from a combination of flexion, adduction, and rotation, and by combining all the movements possible at the various axes a considerable degree of **circumduction** may be produced.

thumb (fingers)

(*B*) The **articulationes carpometacarpeæ digitorum** are the joints between the bases of the four medial metacarpal bones and the four bones of the distal row of the carpus. They are all arthrodial diarthroses, and the opposed articular surfaces present alternate elevations and depressions which form a series of interlocking joints. The joint cavities between the carpal bones of the distal row, and also the more extensive intermetacarpal joint cavities, open into this articulation.

This series of joints is invested by a common articular capsule which is weakest on its radial side, but is otherwise well defined. Its fibres arrange themselves in small slips, which pass obliquely in different directions, and vary in number for each metacarpal bone. Thus the **ligamenta carpometacarpea volaria (volar carpo-metacarpal ligaments)** (Fig. 282) usually consist of one slip for each metacarpal bone, but there may be two slips, and the third metacarpal bone frequently has three, of which one lies obliquely in front of the tendon of the flexor carpi radialis muscle.

The **ligamenta carpometacarpea dorsalia (dorsal carpo-metacarpal ligaments)** are similar short bands, of greater strength and clearer definition, by which the index metacarpal is bound to the greater and lesser multangular bones; the middle metacarpal to the capitate, and frequently to the lesser multangular; the ring metacarpal to the capitate and os hamatum, and the metacarpal of the little finger to the os hamatum.

Ligamenta interossea (interosseous ligaments), one or sometimes two in number, occur within the capsule. They are usually situated in relation to one or both of the contiguous margins of the bases of the third and fourth metacarpal bones, from which they extend proximally to adjacent margins of the capitate and os hamatum. Occasionally they are sufficiently developed to divide the joint cavity into radial and ulnar sections.

The **synovial stratum** (Fig. 283) is usually single and lines the fibrous stratum, but, as already explained, it has prolongations into the intermetacarpal and intercarpal series of joints. In connexion with the intercarpal series, the frequent absence of the interosseous ligament between the greater and lesser multangular bones permits the free communication of this joint cavity with that of the transverse carpal joint.

ARTICULATIONES METACARPOPHALANGEÆ.

Metacarpo-phalangeal Joints.—In the case of the pollex this joint is constructed on the plan of a ginglymus diarthrosis; the four corresponding joints of the fingers are also diarthroses of a slightly modified ball-and-socket variety. With the exception of the metacarpal bone of the pollex, each metacarpal bone has a somewhat spherical head articulating with a shallow oval cup upon the base of the first phalanx. It is important to note that the articular surface upon the head of each of these metacarpal bones is wider on the volar aspect and narrower on the dorsal aspect. The articulation in the thumb presents features similar to those of an interphalangeal joint.

Each joint possesses a capsula articularis (Fig. 284) which presents very different degrees of strength in different aspects of the articulation. Thus, on the dorsal aspect, it cannot be demonstrated as an independent structure, but the necessity for dorsal ligaments is to a large extent obviated by the presence of the strong flattened expansions of the extensor tendons.

The epiphyseal lines are extra-capsular.

Ligamenta Collateralia.—The **collateral ligaments** (Fig. 284) are strong cord-like bands which pass from the tubercles and adjacent depressions on the sides of the heads of the metacarpal bones to the contiguous non-articular areas on the bases of the proximal phalanges. They are intimately connected on their volar aspects with the volar ligaments.

Ligamenta Accessoria Volaria.—The **volar accessory ligaments** consist of thick plates of fibro-cartilage loosely connected to the metacarpal bones, but firmly adherent to the phalanges. They are placed between the collateral ligaments, to both of which they are in each case connected. Each plate is grooved on the volar surface for the long flexor tendons, whilst on its dorsal or joint surface it supports and glides upon the head of the metacarpal bone during flexion and extension of the joint. In the case of the thumb this plate of fibro-cartilage is usually replaced by sesamoid bones, and in the case of the index finger one such sesamoid nodule is frequently found at the radial side of the plate (Fig. 285).

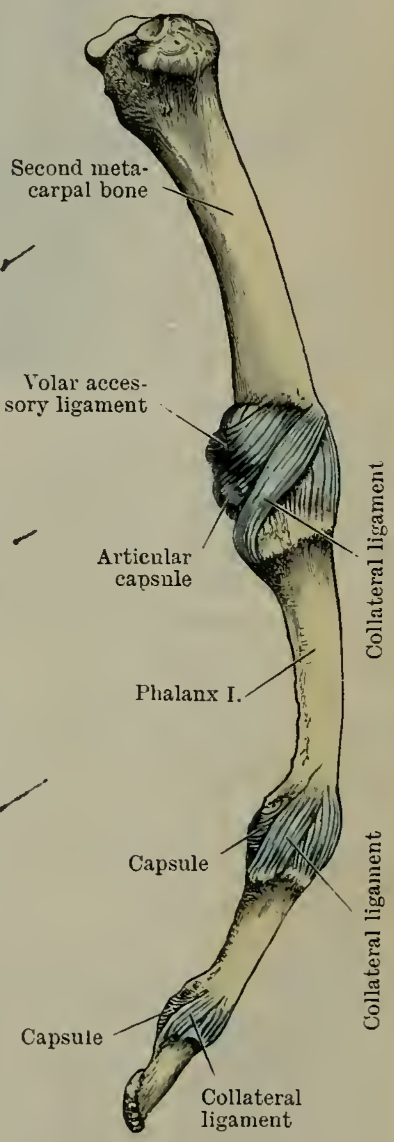

FIG. 284.—METACARPO-PHALANGEAL AND INTERPHALANGEAL JOINTS.

An important accessory ligament is found in connexion with the four medial metacarpo-phalangeal articulations, viz.:—

Ligamenta Capitulorum (Oss. Metacarpalium) Transversa.—The **transverse ligament of the heads of the metacarpal bones** (or **transverse metacarpal ligament**) binds together the distal extremities of the four medial metacarpal bones. The name is applied to three sets of transverse fibres of great strength which are situated in front of the three medial interosseous spaces. These fibres are continuous with the ligamenta accessoria volaria (volar metacarpo-phalangeal ligaments).

A **stratum synoviale** lines the capsula articularis of each joint.

ARTICULATIONES DIGITORUM MANUS.

Interphalangeal Joints.—Of these joints there are two for each finger and one for the thumb. They all correspond, in being ginglymus diarthroses in which the trochlear character of their articular surfaces is associated with one axis of movement directed transversely.

In their general arrangement they correspond with each other, and to a large extent with the metacarpo-phalangeal series already described. Each is provided with a definite **articular capsule** (Fig. 284), of which the volar, and the cord-like lateral portions are well marked, while on the dorsal aspect the extensor tendons act as the chief support. The volar portions contain fibrous plates of considerable thickness, and are attached to the two collateral ligaments and to the intervening rough surface on the distal phalanges, while their proximal margins are not attached to bone. Each ligament has its lateral margins prolonged proximally to the adjacent sharply defined lateral ridges on the phalangeal shafts.

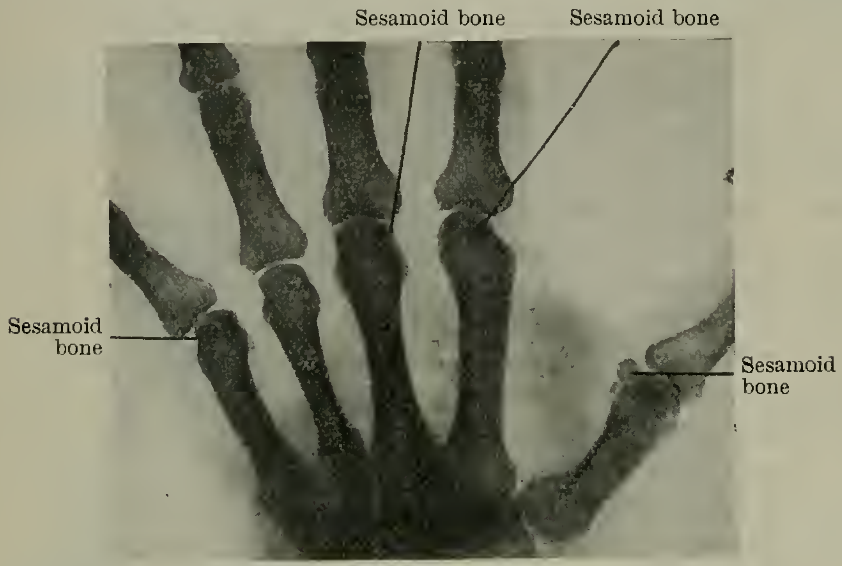

Fig. 285.—Radiograph of Hand showing Sesamoid Bones.

The **collateral ligaments** (Fig. 284) are strong, rounded, short bands, continuous with the preceding, and attached to the non-articular sides of adjacent heads and bases of the phalanges.

Each joint possesses a **synovial stratum** which lines its fibrous stratum, but its arrangement presents no special peculiarity. The epiphyseal lines of the bases of the phalanges are extra-capsular.

MOVEMENTS OF THE CARPAL, INTERMETACARPAL, METACARPO-PHALANGEAL AND INTERPHALANGEAL JOINTS.

The amount of movement which is possible at individual joints of the intercarpal, intermetacarpal, and carpo-metacarpal series is extremely limited, both on account of the interlocking nature of the articular surfaces and the restraining character of the ligamentous bands. Taken as a whole, however, the movements of the carpus and metacarpus enable the hand to perform many varied and important functions. This is largely due to the greater mobility of those joints on the radial and ulnar borders of the hand, as well as to the general elasticity of the arches formed by the carpus and metacarpus. These conditions particularly favour the movements of opposition and prehension. In the opposite direction, *i.e.* when pressure is applied from the volar aspect, the metacarpal and carpal arches tend to become flattened, but great elasticity is imparted by the tension of the various ligaments.

The four medial metacarpo-phalangeal joints are ball-and-socket joints, and movements of **volar-flexion** and **extension** are freely performed about a transverse axis. In exceptional cases a certain amount of **dorsi-flexion** is possible. About an antero-posterior axis movements occur which are usually referred to the middle line of the hand, and hence called **abduction** and **adduction**, but in consequence of the difference in the width of the articular surface on the dorsal and volar aspects of the heads of the four medial metacarpal bones it is only possible to obtain complete abduction when the joints are extended, while in the flexed position the joints become locked and abduction is almost impossible.

The movements of the index finger are less hampered than in the case of the others, but each of them can perform a modified kind of **circumduction**.

The metacarpo-phalangeal joint of the thumb and all the interphalangeal joints are uniaxial or hinge-joints acting about a transverse axis, which permits of **volar-flexion** and **extension** being freely performed, but **dorsi-flexion** is, as a rule, entirely prevented by the volar and lateral ligaments.

ARTICULATIONES ET LIGAMENTA CINGULI EXTREMITATIS INFERIORIS.

Articulations and Ligaments of the Pelvis.—Although we may consider the pelvis as a separate part of the skeleton, yet it is essential to remember that the bones which enter into its composition belong to the vertebral column (sacrum, coccyx) and the lower limb (hip bone). Accordingly, the articulations, with their corresponding ligaments, may be arranged as follows :—

(*a*) Those by which the segments of the coccyx are joined together (already described, *v.* p. 311);
(*b*) That by which the sacrum articulates with the coccyx (already described, *v.* p. 310);
(*c*) Those by which the sacrum articulates with the last lumbar vertebra (Lumbo-sacral joints);
(*d*) Those by which the hip bones are attached to the vertebral column (Sacro-iliac joints);
(*e*) That by which the hip bones are attached to each other (Symphysis pubis).

ARTICULATIONES SACROLUMBALES.

Lumbo-sacral Joints.—The articulation of the sacrum with the fifth lumbar vertebra is constructed precisely on the principle of the articulations between two typical vertebræ, and the usual ligaments associated with such joints are repeated. There is, however, an additional accessory ligament, termed the **lateral lumbo-sacral ligament.** This extends from the anterior aspect of the inferior border of the transverse process of the last lumbar vertebra, downwards and slightly laterally, to the ala of the sacrum, close to the sacro-iliac joint. Further, a variable membranous band extends between the lateral aspect of the inferior part of the body of the last lumbar vertebra and the front of the ala of the sacrum. This band lies in front of the anterior ramus of the fifth lumbar nerve.

ARTICULATIO SACROILIACA.

Each hip bone articulates with the sacral section of the vertebral column on each side through the intervention of a diarthrosis, termed the **sacro-iliac joint.**

This joint is formed between the contiguous auricular surfaces of the sacrum and ilium. Each of these surfaces is more or less completely clothed with hyaline articular cartilage. The joint cavity, which is little more than a capillary interval, may be crossed by fibrous bands.

The cavum articulare (joint cavity) is surrounded by ligaments of varying thickness and strength, which constitute the fibrous stratum of its **articular capsule.** Thus, its anterior part is thin, and consists of short but strong fibres which pass between adjoining surfaces on the ala of the sacrum and the iliac fossa of the hip bone; they form the **anterior sacro-iliac ligament.** On the posterior aspect there are three ligaments. The **interosseous sacro-iliac ligament** (Fig. 286) consists of numerous strong fasciculi, which pass from the rough area on the medial aspect of the ilium, above and behind its auricular surface, downwards and medially to the tubercles of the transverse processes and the depressions behind the first and second segments of the sacrum. This ligament is of great strength, and with its fellow it is responsible for suspending the sacrum and the weight of the superimposed trunk from the hip bones.

The **long posterior sacro-iliac ligament** (Fig. 287) is a superficial thickened portion of the interosseous ligament. It consists of a definite band of fibres passing from the posterior superior iliac spine to the tubercles of the transverse processes of the third and fourth segments of the sacrum.

The **short posterior sacro-iliac ligament** consists of superficial fibres of the interosseous ligament passing from the posterior superior iliac spine to the tubercles of the first and second transverse processes of the sacrum.

The **articular cavity** of this joint is very imperfect and rudimentary.

Several accessory ligaments are associated with the articulation of the hip bone to the sacral section of the vertebral column.

Lig. Iliolumbale.—The **ilio-lumbar ligament** (Fig. 287), which is merely the thickened anterior lamina of the lumbo-dorsal fascia, extends from the tip of the transverse process of the last lumbar vertebra, almost horizontally laterally, to the inner lip of the iliac crest at a point a short distance behind its highest level. A proportion of these fibres is attached to the medial rough surface of the ilium between the iliac crest and the auricular impression. To these the name of the **lig. iliolumbale inferius** is applied.

Lig. Sacrotuberosum.—The **sacro-tuberous ligament** (Fig. 286) is somewhat triangular in outline. It occupies the interval between the sacrum and the hip bone, and is attached medially to the posterior superior and the posterior inferior spines of the ilium; to the posterior aspects of the tubercles of the transverse processes and lateral margins of the third, fourth, and fifth segments of the sacrum, as well as to the side of the first segment of the coccyx. It passes downwards and laterally, becoming narrower as it approaches the ischium, near to which, however, it again expands, to be attached to the medial side of the tuber ischiadicum, immediately below the groove for the tendon of the obturator internus muscle, *i.e.* the lesser sciatic notch. A continuation of the medial border of the ligament—the **processus falciformis** (Fig. 287)—runs upwards and forwards on the medial aspect of the ramus of the ischium.

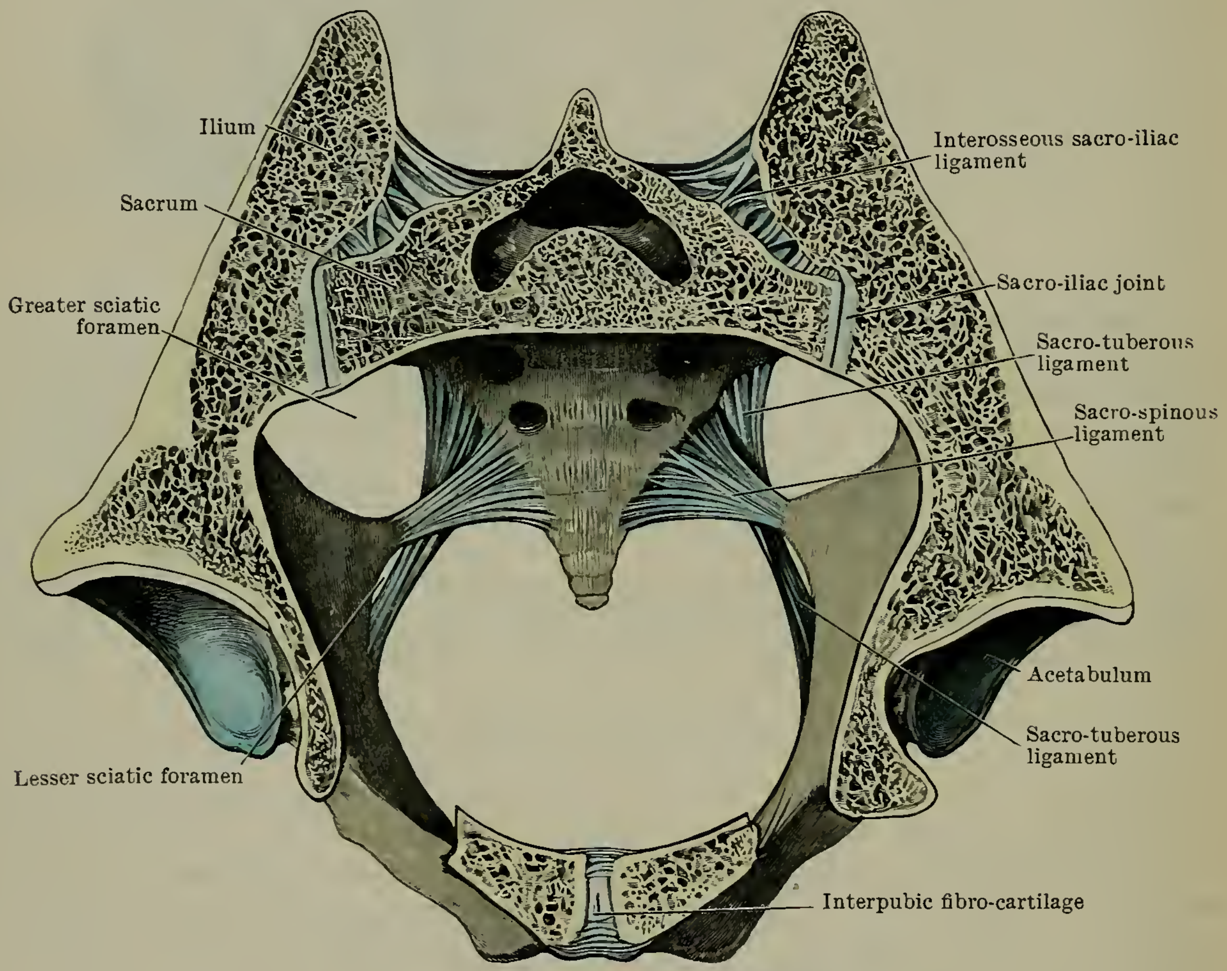

Fig. 286.—Frontal Section of Pelvis.

The ligamentum sacrotuberosum is believed by many to represent the original or proximal end of the long or ischial head of the biceps femoris muscle.

Ligamentum Sacrospinosum.—The **sacro-spinous ligament** (Figs. 286 and 287) is situated in front, and in a measure under cover of the sacro-tuberous ligament. Triangular in form, it is attached by its base to the last two segments of the sacrum and the first segment of the coccyx, and by its pointed apex to the tip and superior aspect of the spina ischiadica. This ligament is intimately associated with the coccygeus muscle, and by some it is regarded as being derived from it by fibrous transformation of the muscle fasciculi.

By the sacro-tuberous and sacro-spinous ligaments the two sciatic notches of the hip bone are converted into foramina. Thus the sacro-spinous ligament completes the boundaries of the greater sciatic foramen (foramen ischiadicum majus); while the sacro-tuberous ligament, assisted by the sacro-spinous ligament, closes the lesser sciatic foramen.

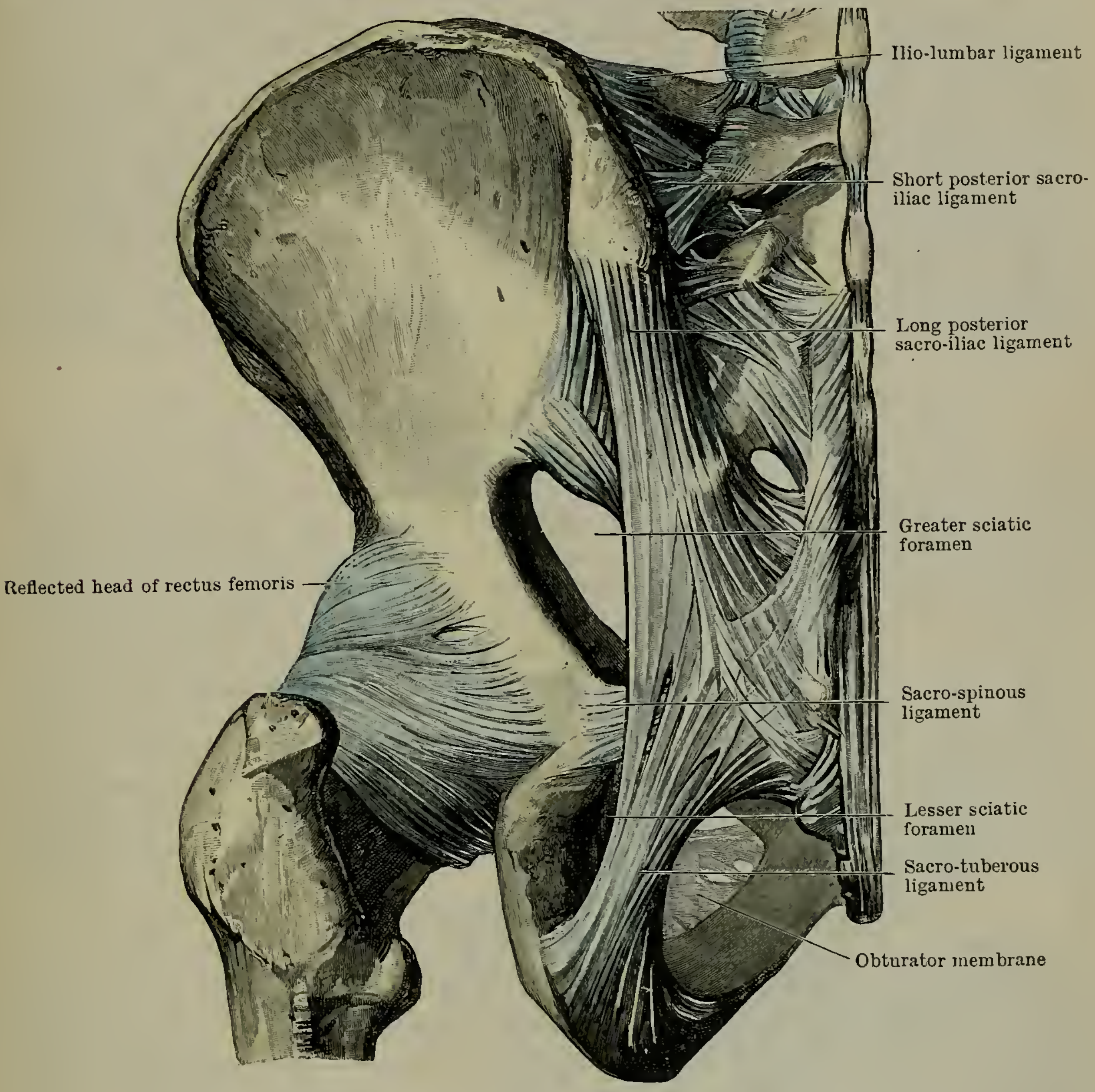

Fig. 287.—Posterior View of the Pelvic Ligaments and of the Hip-Joint.

SYMPHYSIS OSSIUM PUBIS.

The anterior wall of the osseous pelvis is completed by the articulation of the bodies of the two pubic bones, which constitutes the **symphysis pubis.** This joint conforms in its construction to the general plan of an amphiarthrosis. Thus it is median in position; each pubic bone is covered by a layer of hyaline cartilage, which closely adapts itself to the rough tuberculated surface of the pubic bone; while between these two hyaline plates there is an interposed fibro-cartilage called the *lamina fibrocartilaginea interpubica,* in the interior of which there is usually a vertical antero-posterior cleft. This cavity, which is placed nearer the posterior than the anterior aspect of the joint, does not appear until between the seventh and tenth years, and as it is not lined by a synovial stratum, it is supposed to result from the breaking down of the interpubic lamina.

Lig. Pubicum Anterius.—The **anterior pubic ligament** (Fig. 286) is a structure of considerable thickness and strength. Its superficial fibres, which are derived very largely from the tendons and aponeuroses of adjoining muscles, are oblique, and form an interlaced decussation. The deeper fibres are short, and extend transversely from one pubic bone to the other.

Lig. Pubicum Posterius.—The **posterior pubic ligament** (Fig. 286) is very weak and consists of scattered fibres which extend transversely between contiguous pubic surfaces posterior to the articulation.

Lig. Pubicum Superius.—The **superior pubic ligament** also is weak; it consists of transverse fibres passing between the two pubic crests.

Lig. Arcuatum Pubis.—The **arcuate ligament of the pubis** (O.T. **inferior** or **subpubic ligament**) occupies the arch of the pubis, and is of considerable strength. It gives roundness to the pubic arch and forms part of the boundary of the inferior aperture of the pelvis. It has considerable vertical thickness immediately below the interpubic fibro-cartilage, to which it is attached. Laterally it is attached to adjacent sides of the inferior rami of the pubis. Its inferior border is free, and separated from the upper border of the fascia of the urogenital diaphragm by a transverse oval interval, through which the dorsal vein of the penis passes backwards to the interior of the pelvis.

FASCIA DIAPHRAGMATIS UROGENITALIS INFERIOR.

The **inferior fascia of the urogenital diaphragm** is a membranous structure which occupies the pubic arch below and distinct from the arcuate ligament of the pubis. It assists in completing the pelvic walls anteriorly in the same manner that the obturator membrane does laterally. Indeed, these two structures occupy the same morphological plane. The fascia presents two surfaces—one superficial or perineal, the other deep or pelvic—and both of these surfaces are associated with muscles. Its lateral borders are attached to the sides of the pubic arch, while its base is somewhat ill-defined, by reason of its fusion with the fascia of Colles in the urethral region of the perineum.

The apex of the fascia is truncated, free, and well defined, constituting the **transverse perineal ligament**, above which there is the interval for the dorsal vein of the penis. It is pierced by a number of vessels and nerves, but the principal opening is situated in the median plane one inch below the pubic arch, and transmits the urethra.

MEMBRANA OBTURATORIA.

The **obturator membrane** (Fig. 287) occupies the obturator foramen. It is attached to the pelvic aspect of the circumference of this foramen. It consists of fibres irregularly arranged and of varying strength, so that sometimes it almost appears fenestrated. At the highest part of the foramen it is incomplete and forms a U-shaped border, between which and the bony circumference of the foramen the obturator canal is formed. In this position the membrane is continuous with the parietal pelvic fascia which clothes the medial side of the obturator internus muscle, above the superior free margin of the muscle. From the lateral or femoral aspect of the membrane some of its fibres are prolonged to the antero-inferior aspect of the capsule of the hip-joint.

Mechanism and Movements of the Pelvis.—The human pelvis presents a mechanism the principal requirement of which is stability and not movement, for, through the pelvis, the weight of the trunk, superimposed upon the sacrum, is transmitted to the lower limbs. Moreover, its stability is largely concerned in the maintenance of the erect attitude. The movements of its various parts are therefore merely such as are consistent with stability, without producing absolute rigidity.

The two hip bones, being bound together by powerful ligaments at the pubic articulation, constitute an inverted arch, of which the convexity is directed downwards and forwards, while its piers are turned upwards and backwards, and considerably expanded in relation to the posterior parts of the iliac bones. Between the piers of this inverted arch the sacrum is situated. This bone is in no sense a key-stone to an arch, because, as may readily be seen in antero-posterior transverse section, the sacrum is wider in front than behind, and the superposed weight naturally tends to make the sacrum fall towards the pelvic cavity, and so fit less closely between the hip bones. The sacrum is in reality an oblique platform, in contact with each hip bone through its articular auricular surfaces, and in this position it is suspended by the interosseous and posterior sacro-iliac ligaments, and kept securely in place by the "grip" due to the irregularity of the opposed surfaces of the two sacro-iliac articulations. Since the weight of the trunk is transmitted to the anterior and superior end of this sacral platform, there is a natural tendency for the sacrum to revolve upon the transverse axis which passes through its sacro-iliac joints. If this were permitted, the promontory of the sacrum would rotate downwards and forwards towards the pelvic cavity, as really does occur in certain deformities. This revolution or tilting downwards of the anterior part of the sacrum is prevented by the action of the sacro-tuberous and sacro-spinous ligaments, extending from the ischial tuberosity to the posterior and inferior end of the suspended platform of the sacrum. Not only so, but these ligaments, acting on a rigid sacrum, tend to hold up the weight upon the sacral promontory.

The various ligaments passing between the last lumbar vertebra and the sacrum and ilium retain the weight of the trunk in position upon the anterior end of the sacrum, and resist its tendency to slip forwards and downwards towards the pelvic cavity. The entire weight of the trunk and pelvis is transmitted to the heads of the thigh bones in the most advantageous position, both for effectiveness and the strengthening of the inverted arch of the hip bones, for it will be evident that the heads of the femora thrust inwards upon the convex side of the arch, very much at the place where the arches are weakest, viz., at the springing of the arch from its piers. The forces which tend to cause movement of the pelvic bones during parturition act from within the pelvis, and have for their object the increase of the various pelvic diameters, in order that the fœtal head may more readily be transmitted. For this purpose the wedge-like dorsal surface of the sacrum is driven backwards, and a certain amount of extra space may thereby be obtained. An important factor, however, in the increase of the pelvic capacity at this period is found in the relaxation of its various ligaments.

ARTICULATIONES EXTREMITATIS INFERIORIS.

ARTICULATIO COXÆ.

The Hip-Joint.—The human body provides no more perfect example of an enarthrodial diarthrosis than the hip-joint. Combined with all that variety of movement which characterises a multi-axial joint, it nevertheless presents great stability, which has been obtained by simple arrangements, for restricting the range of its natural movements. This stability is of paramount importance for the maintenance of the erect attitude, and the mechanical adaptations whereby this result is obtained are such that the erect attitude may be preserved without any great degree of sustained muscular effort.

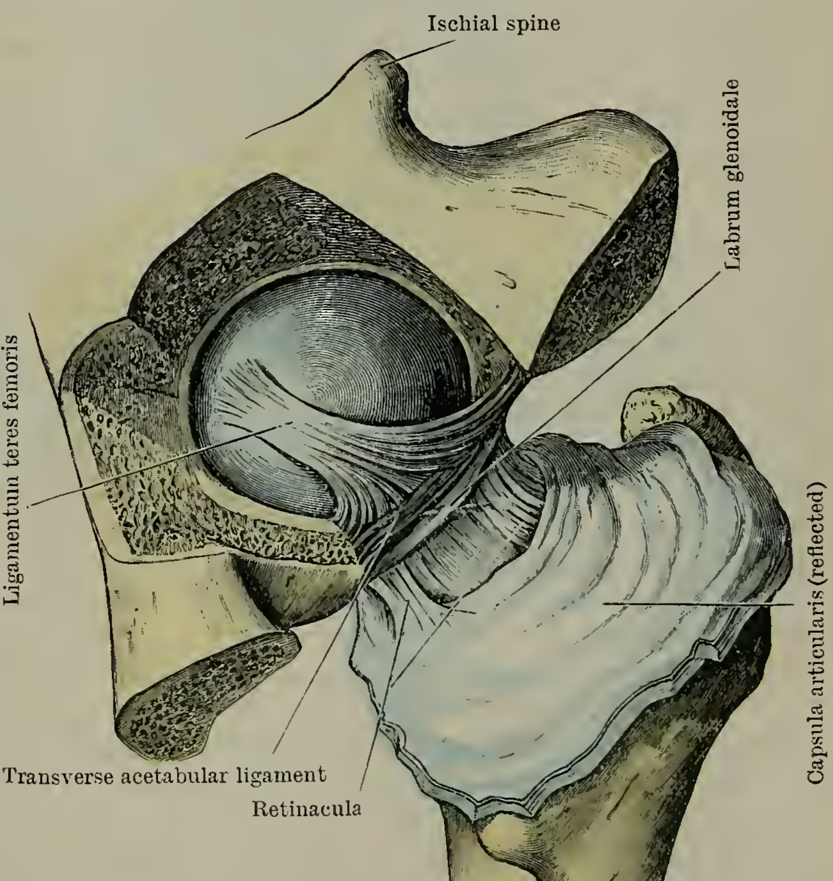

Fig. 288.—Dissection of the Hip-Joint.
Bottom of the acetabulum removed, and capsule of the joint thrown laterally towards the trochanters.

Articular Surfaces.—The head of the femur is globular in shape, and considerably exceeds a hemisphere. It is clothed with hyaline articular cartilage on those parts which come into direct contact with the acetabulum. There is frequently more or less of extension of the articular cartilage from the head to the adjoining anterior part of the neck, an extension which is accounted for by the close and constant apposition of this portion of the neck with the posterior aspect of the ilio-femoral ligament. The limit of the articular cartilage covering the head is indicated by a sinuous border. Further, there is an absence of articular cartilage from the fovea or pit on the head of the femur.

The acetabulum is a deep cup-shaped cavity which presents a notch on its antero-inferior margin. The interior of the cup is lined with a ribbon-like band of articular cartilage which extends to the brim of the cavity, but does not cover its floor. This articular ribbon-shaped band is widest on its supero-posterior aspect, and narrowest at the anterior margin of the acetabular notch.

Lig. Transversum Acetabuli.—The **transverse ligament** (Fig. 288) bridges the acetabular notch, and consists of strong transverse fibres which are attached to both of its margins, but more extensively to the postero-inferior. This ligament does not entirely fill the notch, but leaves an open interval between its inferior border and the bottom of the notch through which vessels and nerves enter the cup. The acetabular aspect of this ligament constitutes an articular surface.

The acetabulum is deepened by the **labrum glenoidale** (Figs. 288 and 289), which consists of a strong ring of fibro-cartilaginous tissue attached to the entire rim of the cup. The attached surface of the ring is broader than its free edge, and, moreover, the latter is somewhat contracted, so that the ligament grasps the head of the femur which it encircles. Its fibres are partly oblique and partly circular in their direction. By the former it is firmly implanted on the rim of the acetabulum and the lig. transversum acetabuli; by the latter the depth of the cup is increased through the elevation of its edge, and its mouth slightly narrowed. By one surface this ligament is also articular.

Capsula Articularis.—An **articular capsule** (Figs. 288 and 289) completely invests the joint cavity. Its fibrous stratum is of great strength, although it is not of equal thickness throughout, being considerably thicker on the supero-anterior aspect than at any other part. Unlike the corresponding structure of the shoulder-joint, it does not permit of the withdrawal of the head of the femur from contact with the acetabular articular surfaces, except to a very limited extent. Its fibres are arranged both in the circular and in the longitudinal direction, the former, known as the **zona orbicularis**, being best marked posteriorly, while the longitudinal fibres stand out more distinctly in front, where they constitute special ligaments. Looked at as a whole, the fibrous stratum of the capsule has the following attachments: *proximally* it surrounds the acetabulum, on the superior and posterior aspects of which it is attached directly to the hip bone, while on the anterior and inferior aspects it is attached to the non-articular surfaces of the labrum glenoidale and transverse ligaments of the acetabulum; *distally* it encircles the neck of the femur, where it is attached in front to the intertrochanteric line; above, to the medial aspect of the root of the greater trochanter; below, to the lower part of the neck of the femur, in close proximity to the lesser trochanter; behind, to the line of junction of the lateral and middle thirds of the neck of the femur. It is a matter of some importance to note that only part of the posterior surface of the neck of the femur is enclosed within the articular capsule. The femoral attachments of the fibrous stratum of the capsule vary considerably in their strength, being particularly firm above and in front, but much weaker below and posteriorly, where the orbicular fibres are well seen. Many fibres of the fibrous stratum are reflected from its deep aspect proximally upon the neck of the femur, where they form ridges, and to these the term **retinacula** (Fig. 288) is applied.

The epiphyseal line of the head of the femur is intra-capsular; the epiphyseal lines of the two trochanters are extra-capsular.

The longitudinal fibres of the fibrous stratum of the capsule are arranged so as to form certain definite bands, viz.:—

(1) **Lig. Iliofemorale.**—The **ilio-femoral ligament** (Fig. 289) consists of a triangular set of fibres attached proximally, by their apex, to the inferior part of the anterior inferior iliac spine and the immediately adjoining part of the rim of the acetabulum, and distally, by their base, to the intertrochanteric line of the femur. This ligament is the thickest part of the fibrous stratum, but its sides are more pronounced than its centre, especially towards its base. Consequently the ilio-femoral ligament presents some resemblance to an inverted Y (⅄), and therefore was formerly named the Y-shaped ligament of Bigelow.

The lateral or upper limb of the ilio-femoral ligament may be somewhat extended by the inclusion of additional longitudinal fibres, and described as the **ilio-trochanteric** ligament. This band arises from the anterior part of the dorsum of the acetabulum, and extends to the femoral neck, close to the anterior end of the medial surface of the greater trochanter.

(2) **Lig. Pubocapsulare.**—The **pubo-capsular ligament** (Fig. 289) is composed of some bands of fibres of no great strength, which extend from the lateral end of the superior ramus of the pubis, the ilio-pectineal eminence, the obturator crest and the obturator membrane, to lose themselves, for the most part, in the capsule, although a certain proportion of them may be traced to the inferior aspect of the femoral neck, where they adjoin the distal attachment of the ilio-femoral ligament.

(3) **Lig. Ischiocapsulare.**—The **ischio-capsular ligament** consists of a broad band of short, fairly strong longitudinal fibres, which, by their proximal ends, are attached to the ischium between the lesser sciatic notch and the obturator foramen, while their distal ends become merged in the zona orbicularis of the general capsule.

Within the capsule, and quite distinct from it, there are the ligamentum teres and the Haversian gland.

Lig. Teres Femoris.—The **round ligament** (Fig. 288) is a strong, somewhat flattened band of fibrous tissue, attached by one end to the superior half of the pit or depression on the head of the femur. By its medial end it is attached to the lower edge of the articular surface of the transverse ligament, with extensions to the opposite borders of the acetabular notch, but chiefly to the posterior or ischial border. This ligament varies very greatly in its strength and development in different subjects, and in certain rare cases it is absent.

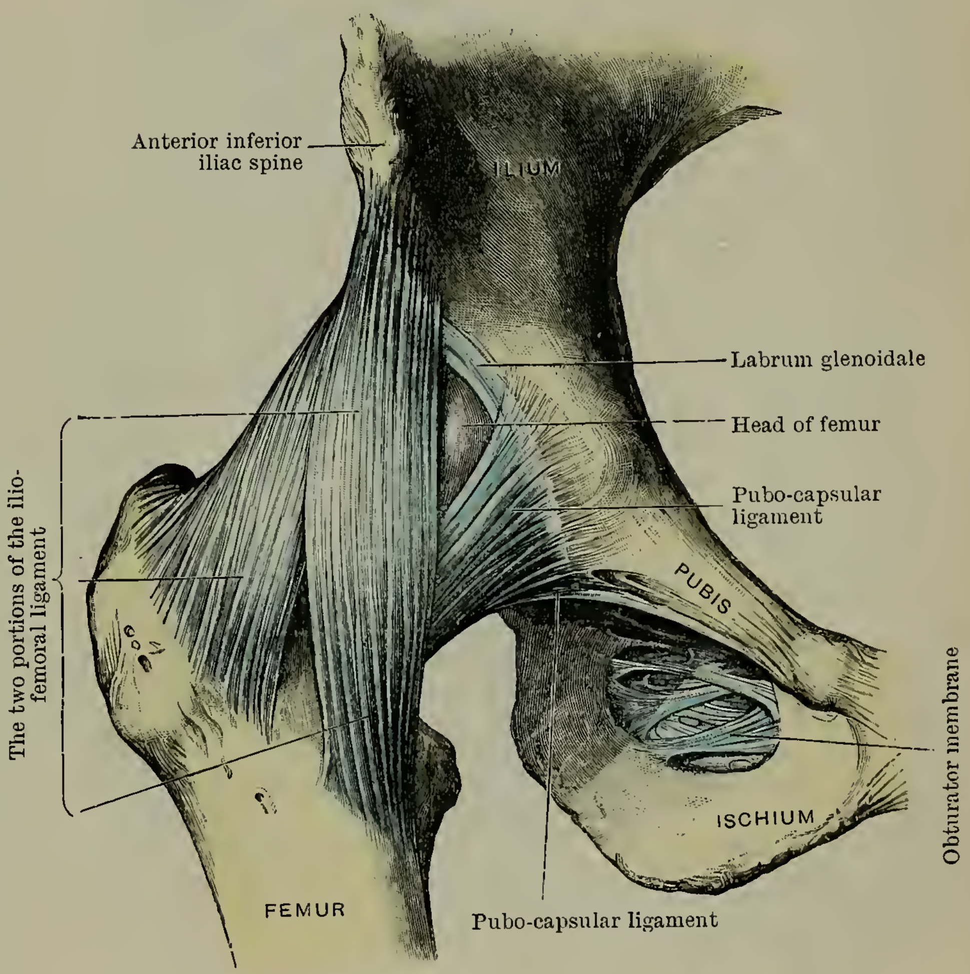

Fig. 289.—Dissection of the Hip-Joint from the front.

The so-called **Haversian gland** occupies the bottom or non-articular area of the acetabulum. It consists of a mass of fat covered by the synovial stratum of the joint. This pad of fat is continuous with the extra-capsular fat through the passage subjacent to the transverse ligament of the acetabulum.

A **synovial stratum** lines the fibrous stratum of the capsule from which it is reflected to the neck of the femur along a line which corresponds to the femoral attachments of the fibrous stratum. Thus the synovial stratum clothes more of the femoral neck anteriorly than in any other position. Posteriorly, where the fibrous stratum is feebly attached to the neck of the femur, the synovial stratum may be seen from the outside of the capsule. The synovial stratum extends close up to the articular margin of the head of the femur, and on the superior and inferior aspects of the neck it is gathered into loose folds upon the retinacula. These folds or plicæ synoviales are best marked along the line of synovial reflexion, and do not reach as far as the femoral head. At its acetabular end the synovial stratum is prolonged from the inside of the capsule to the outer non-articular surface of the labrum glenoidale and transverse ligament, upon which it is continued as a lining for their acetabular or articular surfaces, and further, it provides a covering for the fat at the bottom of the acetabular fossa, as well as a complete tubular investment for the ligamentum teres femoris.

Occasionally the **mucous** or **synovial bursa**, which is subjacent to the tendon of the ilio-psoas muscle, communicates with the interior of the hip-joint through an opening in the anterior wall of the capsule (Fig. 289), situated between the pubo-capsular ligament and the medial or lower limb of the ilio-femoral ligament.

Movements at the Hip-Joint.—The movements which occur at the hip-joint are those of a multiaxial joint. These are **flexion, extension, abduction, adduction, rotation**, and **circumduction.** The range of each of these movements is less extensive than in the case of the shoulder-joint, because, at the hip, the freedom of movement is subordinated to that stability which is essential alike for the maintenance of the erect attitude and for locomotion. When standing at rest in the erect attitude the hip-joint occupies the position of **extension**, and as the weight of the trunk is transmitted in a perpendicular which falls behind the centres of the hip-joints, both the erect attitude and the extended position are maintained to a large extent mechanically, by means of the tension of the ilio-femoral ligament, without sustained muscular action. Moreover, the tension of this ligament is sustained by the pressure of the front of the head and neck of the femur against its synovial surface. In this association of parts it is important to note that the articular cartilage of the femoral head may be, and in certain races is, prolonged to the front of the femoral neck; and further, that the constant friction does not destroy the synovial stratum of the capsule. Again, the same mechanism which preserves the erect attitude prevents an excessive degree of extension or dorsiflexion. In movement forwards, *i.e.* ventral **flexion**, the front of the thigh is approximated to the anterior abdominal wall. The amount of this movement depends upon the position of the knee-joint, because when the latter is flexed the thigh may be brought into contact with the abdominal wall, whereas when the knee-joint is straightened (*i.e.* extended) the tension of the hamstring muscles greatly restricts the amount of flexion at the hip-joint. **Abduction** and **adduction** are likewise much more restricted than at the shoulder-joint. **Abduction** is brought to a close by the tension of the pubo-capsular band and the lower part of the capsule, and, in addition, the upper aspect of the neck of the femur locks against the margin of the acetabulum. Excessive **adduction** is prevented by the tension of the upper band of the ilio-femoral ligament and the upper part of the capsule. **Rotation** or movement in a longitudinal axis may be either medially, *i.e.* towards the front, or laterally, *i.e.* towards the back. In the former the movement is brought to a close by the tension of the ischio-capsular ligament and posterior part of the capsule, aided by the muscles on the back of the joint; in the latter—rotation laterally—the chief restraining factor is the lateral or upper limb of the ilio-femoral ligament. The total amount of rotation is probably less than 60°.

Circumduction is only slightly less free than at the shoulder, but it is complicated by the preservation of the balance upon one foot.

The value and influence of the ligamentum teres femoris are not easily estimated, because it may be absent without causing any known interference with the usefulness of the joint. In the erect attitude this ligament lies lax between the lower part of the femoral head and the acetabular fat. In the act of walking it is rendered tense at the moment when the pelvis is balanced on the summit of the supporting femur. Analysis of this position shows the femur to be adducted, with probably, in addition, a small amount of flexion (*i.e.* bending forwards) and medial rotation. Again, this ligament is said to be tense when the thigh is rotated laterally. The equivalent of this movement is doubtless found in the rotation of the pelvis, which occurs in the act of walking at the moment of transition from the toe of the supporting foot to the heel of the advancing foot. The interest connected with this ligament is perhaps rather morphological than physiological. It is believed by some to represent the tendon of a muscle which in birds occupies a position external to the joint capsule.

ARTICULATIO GENU.

The **knee-joint** is the largest articulation in the body, and its structure is of a very elaborate nature. The part it plays in maintaining the erect attitude materially influences its construction, and special arrangements are provided for the mechanical retention of the joint in the extended position in view of the fact that the line of gravity falls in front of the centre of the articulation. Its principal axis of movement is in the transverse direction, consequently it belongs to the ginglymus or hinge variety of the diarthroses. At the same time a slight amount of rotation of the tibia in its long axis is permitted during flexion; but while this fact is of considerable importance in the study of certain accidents to which the joint is liable, as well as in the study of its comparative morphology, it is not sufficiently pronounced to interfere with its classification as a hinge-joint.

Articular surfaces pertaining to the femur, tibia, and patella enter into the formation of the knee-joint. The articular surface of the femur extends over a large part of both condyles, and may be divided into patellar and tibial portions by faintly-marked, almost transverse grooves, which pass across the articular surface immediately in front of the intercondylar notch. As a rule marginal indentations of the articular surface render the positions of these transverse grooves more distinct.

The **patellar portion** (Fig. 290) is situated anteriorly, and is common to both condyles, although developed to a larger extent in association with the lateral condyle, on which it ascends to a more proximal level than on the medial condyle. This surface is trochlear, and forms a vertical groove bordered by prominent borders.

The **tibial portion** of the articular surface of the femur is divided into two articular areas, in relation to the distal aspects of the two condyles, by the wide non-articular intercondyloid notch. These two surfaces are for the most part parallel, but in front the medial tibial surface turns obliquely laterally as it passes into continuity with the patellar trochlea, while posteriorly, under certain circumstances, *e.g.* the squatting posture, the articular surface of the medial condyle may extend to the adjoining portion of the popliteal area of the bone.

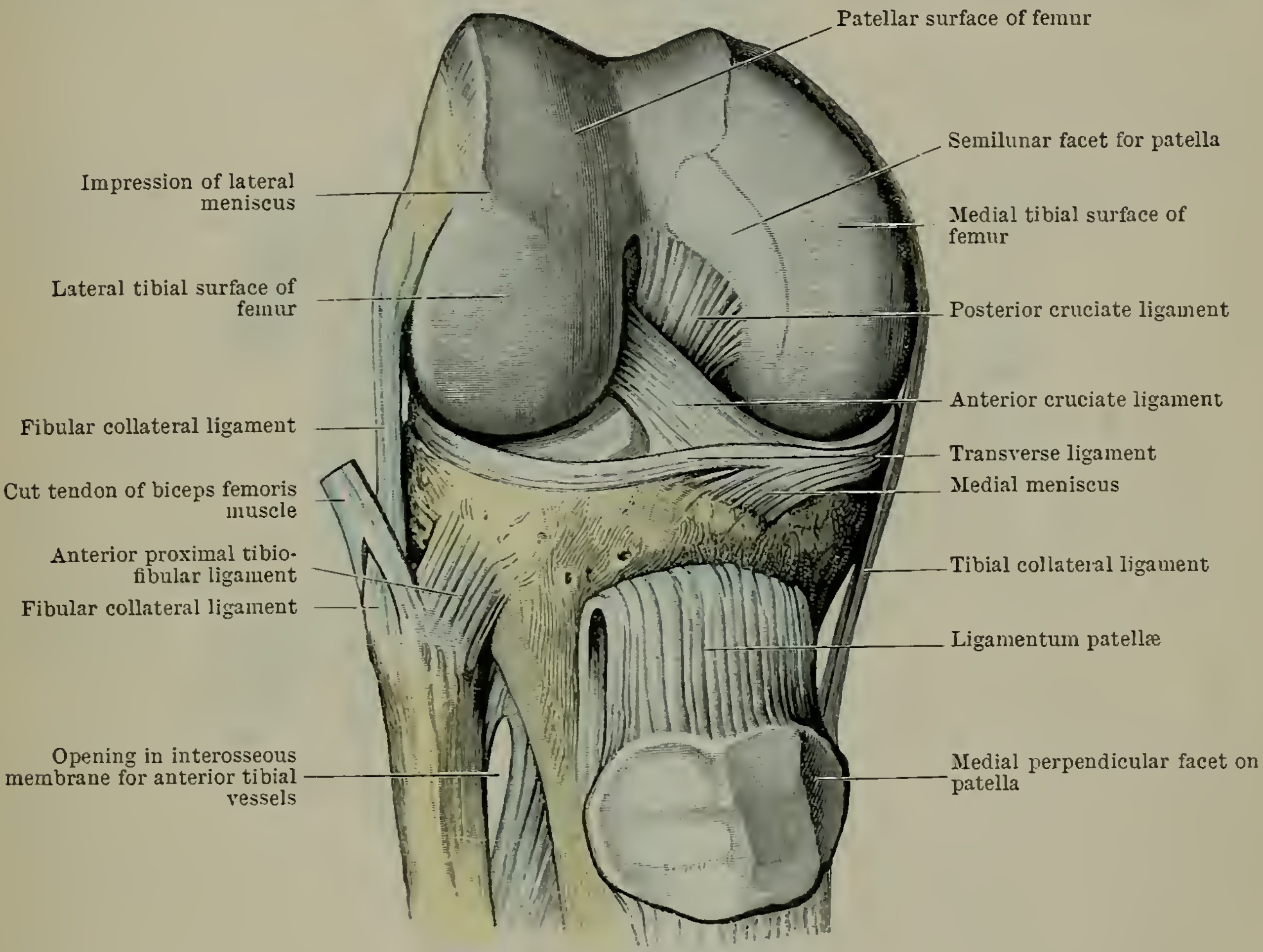
Patellar surface of femur
Semilunar facet for patella
Impression of lateral meniscus
Medial tibial surface of femur
Lateral tibial surface of femur
Posterior cruciate ligament
Anterior cruciate ligament
Fibular collateral ligament
Transverse ligament
Cut tendon of biceps femoris muscle
Medial meniscus
Anterior proximal tibio-fibular ligament
Tibial collateral ligament
Fibular collateral ligament
Ligamentum patellæ
Opening in interosseous membrane for anterior tibial vessels
Medial perpendicular facet on patella

FIG. 290.—DISSECTION OF THE KNEE-JOINT FROM THE FRONT: PATELLA THROWN DISTALLY.

When the joint is in the position of extreme flexion, the patella is brought into direct contact with that part of the articular surface on the medial condyle which bounds the intercondyloid notch upon its medial and anterior aspects. This relationship is indicated by the presence of a distinct semilunar facet on the cartilage in that situation (Fig. 290). The articular surface of the femur may therefore be regarded as presenting **femoro-patellar** and **femoro-tibial areas.**

The **patella** presents on its posterior aspect a transversely elongated oval articular facet and a distal rough, triangular, non-articular area. The articular facet is divided into two principal portions by a prominent rounded vertical ridge. Of these the lateral is the wider. A less pronounced and nearly vertical ridge marks off an additional facet called the medial perpendicular facet, close to the medial margin of the articular surface. Two faint transverse ridges cut off narrow proximal and distal facets from the general articular surface without encroaching on the narrow, most medial vertical facet (Goodsir) (Fig. 290).

The head of the **tibia** presents on its superior aspect two condylar articular surfaces, separated from each other by a non-articular antero-posterior area, which is wider anteriorly and posteriorly than in the middle, where it is elevated to form a bifid eminentia intercondyloidea.

The **lateral condylar facet** is slightly concavo-convex from before backwards and slightly concave transversely. This surface is almost circular, and extends to the free lateral border of the tibial condyle, where it is somewhat flattened. Posteriorly the articular surface is prolonged downwards on the condyle in relation to the position occupied by the tendon of the popliteus muscle. The **medial condylar facet** is oval in outline, and distinctly concave both in its antero-posterior and transverse diameters.

Ligaments.—Like all diarthroses, this joint is invested by an envelope or capsula articularis, which does not, however, entirely surround the articular cavity, for it is absent as a fibrous stratum proximal to the articular cavity, subjacent to the tendon of the quadriceps extensor muscle. Its specially named bands are not of themselves sufficient to form a complete investment, and the fibrous stratum, which largely consists of augmentations from the fascia lata and the tendons of surrounding muscles, supplies the defective areas. Thus, anteriorly, on each side of the patella and the ligamentum patellæ, expansions of the vasti tendons and fascia lata, constituting the **collateral patellar ligaments**, are evident. On the lateral side of the joint the fibular collateral ligament is hidden within a covering derived from the ilio-tibial tract of the fascia lata. On the medial side expansions from the tendons of the sartorius and semi-membranosus muscles augment the articular capsule, which here becomes continuous with the ligamentum collaterale tibiale. Posteriorly the articular capsule also receives augmentation from the tendon of the semi-membranosus muscle, but it is very thin subjacent to the origins of the

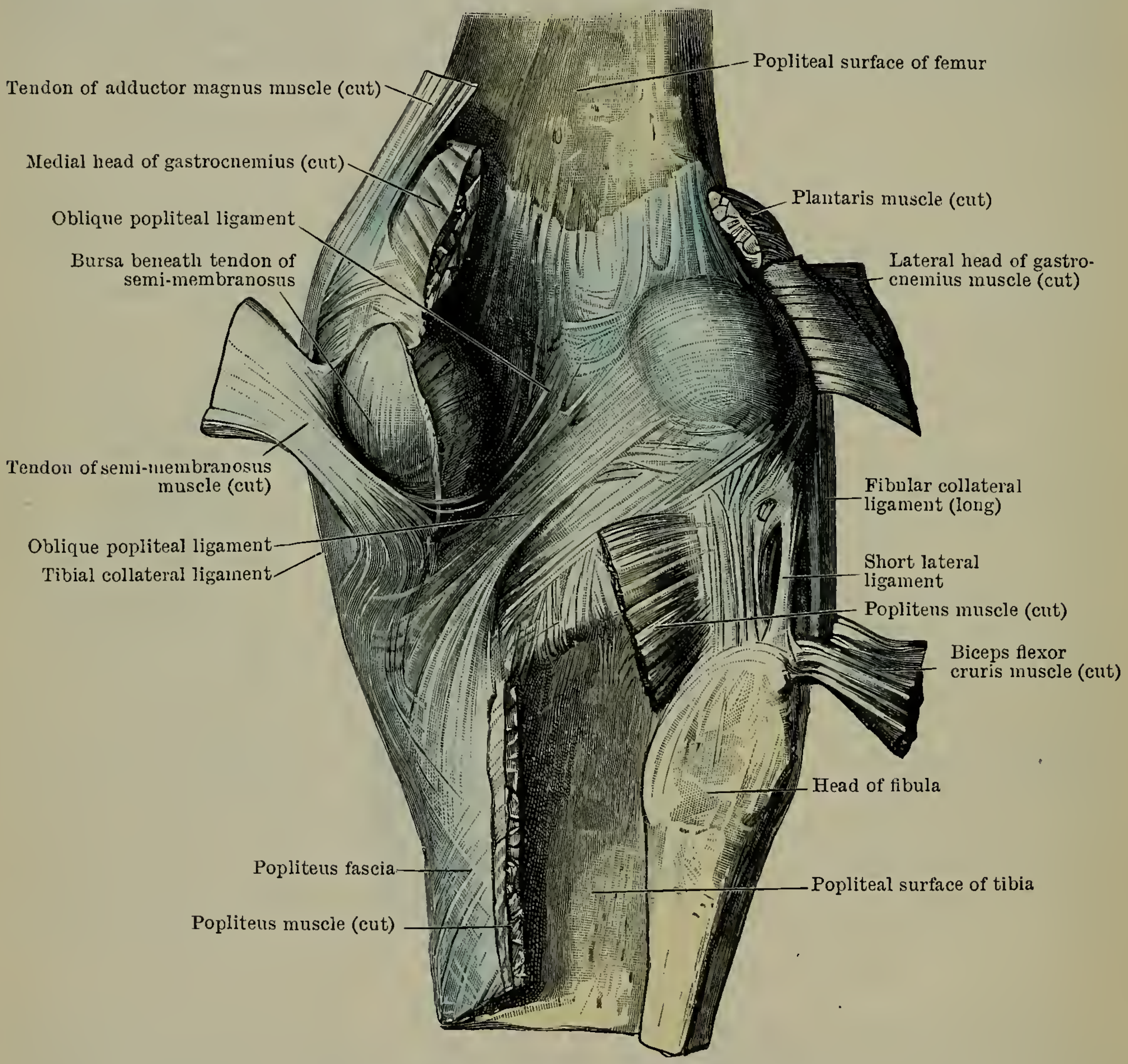
Tendon of adductor magnus muscle (cut)
Medial head of gastrocnemius (cut)
Oblique popliteal ligament
Bursa beneath tendon of semi-membranosus
Tendon of semi-membranosus muscle (cut)
Oblique popliteal ligament
Tibial collateral ligament
Popliteus fascia
Popliteus muscle (cut)
Popliteal surface of femur
Plantaris muscle (cut)
Lateral head of gastro-cnemius muscle (cut)
Fibular collateral ligament (long)
Short lateral ligament
Popliteus muscle (cut)
Biceps flexor cruris muscle (cut)
Head of fibula
Popliteal surface of tibia

FIG. 291.—THE KNEE-JOINT. POSTERIOR VIEW.

gastrocnemius muscle, where it covers the posterior parts of the condyles. Not unfrequently the articular capsule presents an opening of communication between the interior of the articular cavity and a bursa which lies under cover of the medial head of the gastrocnemius muscle.

The epiphyseal line of the distal end of the femur is partly intra-capsular and partly extra-capsular; that of the proximal end of the tibia is extra-capsular.

Ligamentum Patellæ.—The **ligamentum patellæ** or **anterior ligament** (Fig. 290) is a powerful flattened band, attached proximally to the apex and adjoining margins of the patella, and distally to the rough anterior tuberosity at the proximal end of the shaft of the tibia. This ligament also serves as a tendon of insertion for the quadriceps extensor muscle, and a certain number of the fibres of the tendon may be observed to run distally as a thin fibrous covering for the anterior surface of the patella. The deep surface of the tendon is separated from the front of the head of the tibia by a synovial bursa, and proximal to this it rests upon the infra-patellar pad of fat, which is placed between the tendon and the synovial stratum of the joint.

The **ligamentum posterius (posterior ligament)** (Fig. 291) is a compound structure of unequal strength, and those portions by which it establishes continuity with the lateral parts of the articular capsule are remarkably thin. It is attached proximally to the popliteal surface of the femur, close to the intercondyloid notch, with lateral extensions to the non-articular areas immediately proximal to the posterior articular margins of the two condyles, where it is closely associated with the origins of the gastrocnemius muscle.

Distally it is attached to the rough non-articular posterior border of the head of the tibia, where, to its fibular side, it presents an opening of exit for the tendon of the popliteus muscle (Fig. 291).

The tendon of insertion of the semi-membranosus muscle contributes an important expansion which augments the posterior ligament on its superficial aspect. This expansion—**lig. popliteum obliquum**—passes obliquely proximally and laterally to lose itself in the general ligament, but it is most distinct in the region between the femoral condyles, where it may present proximal and distal arcuate borders (lig. popliteum arcuatum). A number of vessels and nerves perforate this ligament, and hence it presents a number of apertures.

Lig. Collaterale Tibiale.—The **tibial collateral ligament** (Figs. 291 and 292) is a well-defined, strong, flat band which is applied to the medial side of the knee-joint, and is rather wider in the middle than at either end. It is frequently regarded as consisting of two portions—an anterior or long portion, and a posterior or short one. The two parts arise close together from the medial epicondyle, immediately distal to the adductor tubercle. The **short** or **posterior portion** passes distally and slightly backwards, to be attached to the postero-medial aspect of the medial part of the tibia proximal to the groove for the semi-membranosus tendon. The **long** or **anterior portion** inclines somewhat forwards, and extending distally superficial to the tendon of the semi-membranosus, it is attached to the proximal part of the medial surface of the shaft of the tibia distal to the level of the tuberosity.

On its superficial aspect the tibial collateral ligament is augmented by prolongations from the tendon of the semi-membranosus muscle, but is separated by a bursa from the tendons of the gracilis, semi-tendinosus, and sartorius. Its deep surface is adherent to the convex edge of the meniscus medialis, but more distally the distal and medial articular vessels intervene between the ligament and the body of the tibia.

Lig. Collaterale Fibulare.—The **fibular collateral ligament** (Figs. 291 and 292) is a distinct rounded band which is obscured by capsular fibres, and yet well separated from the articular cavity by intervening objects. It is attached proximally to the lateral epicondyle, immediately proximal to the groove occupied by the tendon of the popliteus muscle, superficial to which the ligament extends distally to be attached to the lateral side of the head of the fibula, in front of the styloid process. In its course it splits the tendon of insertion of the biceps femoris (Fig. 290), the portions of which are fixed to the head of the fibula anterior and posterior to the ligament, and a bursa may intervene between the tendon and the ligament. The distal lateral articular vessels pass forwards medial to this ligament and proximal to the head of the fibula. Unlike the tibial collateral ligament, it is not attached to the corresponding meniscus.

The **ligamentum laterale externum breve seu posterius** (Fig. 291) is an inconstant structure which is attached by its proximal end immediately behind the preceding, and subjacent to the lateral head of the gastrocnemius muscle. It likewise passes superficial to the popliteal tendon, and is affixed distally to the apex capituli of the fibula.

The **intra-articular structures** of the knee-joint are more important and more numerous than in any other joint of the body.

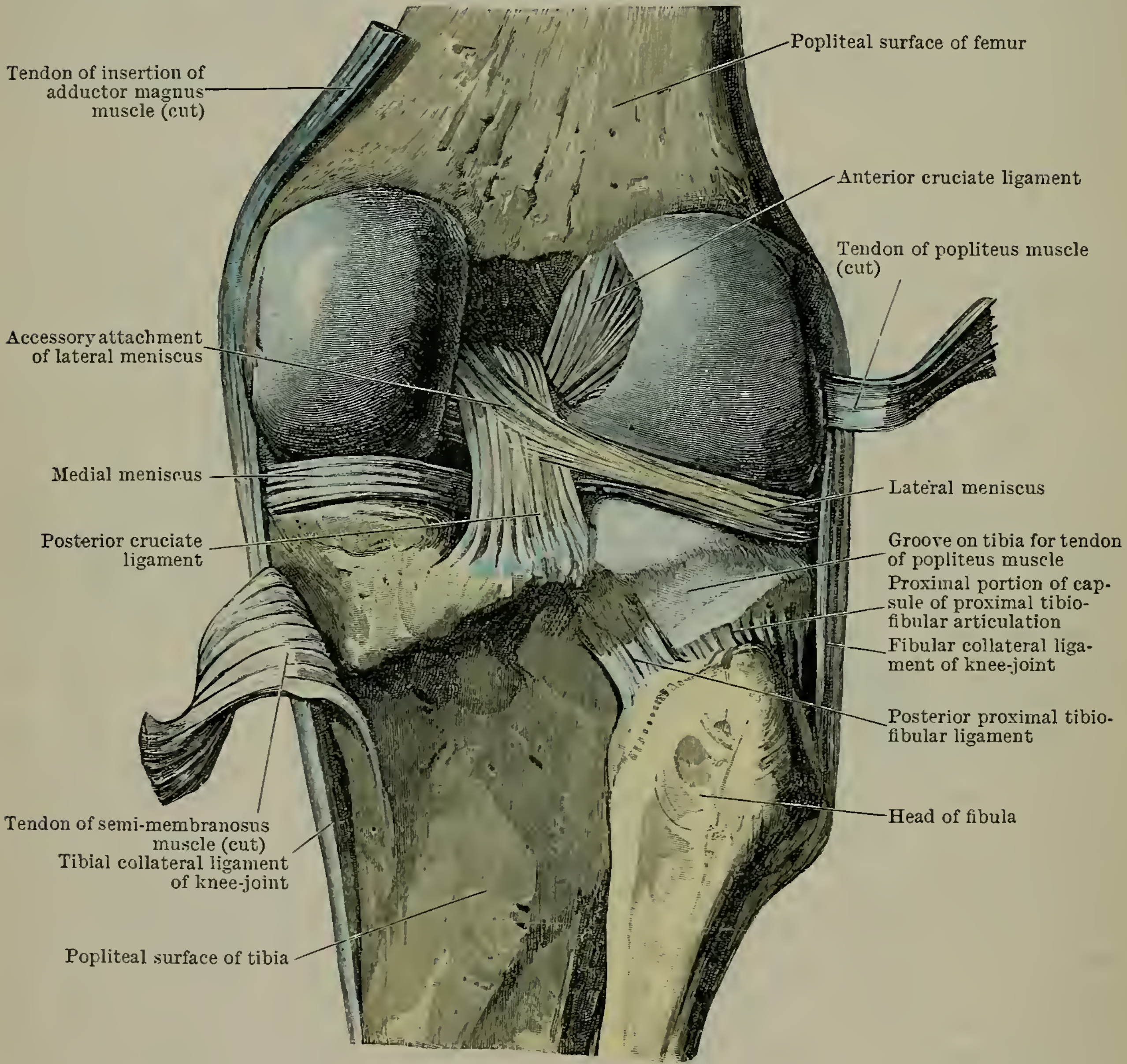
Popliteal surface of femur
Tendon of insertion of adductor magnus muscle (cut)
Anterior cruciate ligament
Tendon of popliteus muscle (cut)
Accessory attachment of lateral meniscus
Medial meniscus
Lateral meniscus
Posterior cruciate ligament
Groove on tibia for tendon of popliteus muscle
Proximal portion of capsule of proximal tibio-fibular articulation
Fibular collateral ligament of knee-joint
Posterior proximal tibio-fibular ligament
Head of fibula
Tendon of semi-membranosus muscle (cut)
Tibial collateral ligament of knee-joint
Popliteal surface of tibia

FIG. 292.—THE KNEE-JOINT OPENED FROM BEHIND BY THE REMOVAL OF THE POSTERIOR LIGAMENT.

Ligamenta Cruciata Genu.—The **cruciate ligaments** are two strong, rounded, tendinous bands, which extend from the non-articular area on the proximal surface of the head of the tibia to the non-articular sides of the intercondyloid notch of the femur. These interarticular ligaments are distinguished from each other as the anterior or lateral and the posterior or medial. They cross each other like the limbs of an X, yet they remain distinct throughout, and each has its own partial synovial covering. They lie within the articular capsule, and extend between non-articular surfaces in relation to the longitudinal axis of the limb.

The **ligamentum cruciatum anterius** (Figs. 290, 292, and 293) is attached distally to the medial part of the rough, depressed area in front of and close to the intercondyloid eminence of the tibia. It passes obliquely proximally, laterally, and backwards to the medial non-articular surface of the lateral condyle, where it finds attachment far back in the posterior part of the intercondyloid notch. This ligament is tense in the position of extension, and therefore it assists in maintaining the erect attitude.

The **ligamentum cruciatum posterius** (Figs. 291, 292, and 293) is somewhat shorter than the preceding. It is attached distally to the posterior part of the depressed surface behind the intercondyloid eminence of the tibia and close to the popliteal notch. Its fibres pass obliquely proximally, forwards, and medially, to be inserted into the lateral non-articular surface of the medial condyle, far forwards towards the anterior margin of the intercondyloid notch. It is rendered tense in the position of flexion.

The **semilunar menisci** are two in number—a medial and a lateral—placed horizontally between the articular surfaces of the femur and tibia. In general outline they correspond to the circumferential portions of the tibial facets upon which they rest. Each has a thick, convex, fixed border in relation to the periphery of the joint, and a thin, concave, free border directed towards the interior of the joint. Neither of them is sufficiently large to cover the whole of the tibial articular surface upon which it rests. The proximal and distal surfaces of each meniscus are smooth and free, and each terminates in an anterior and a posterior fibrous horn or cornu.

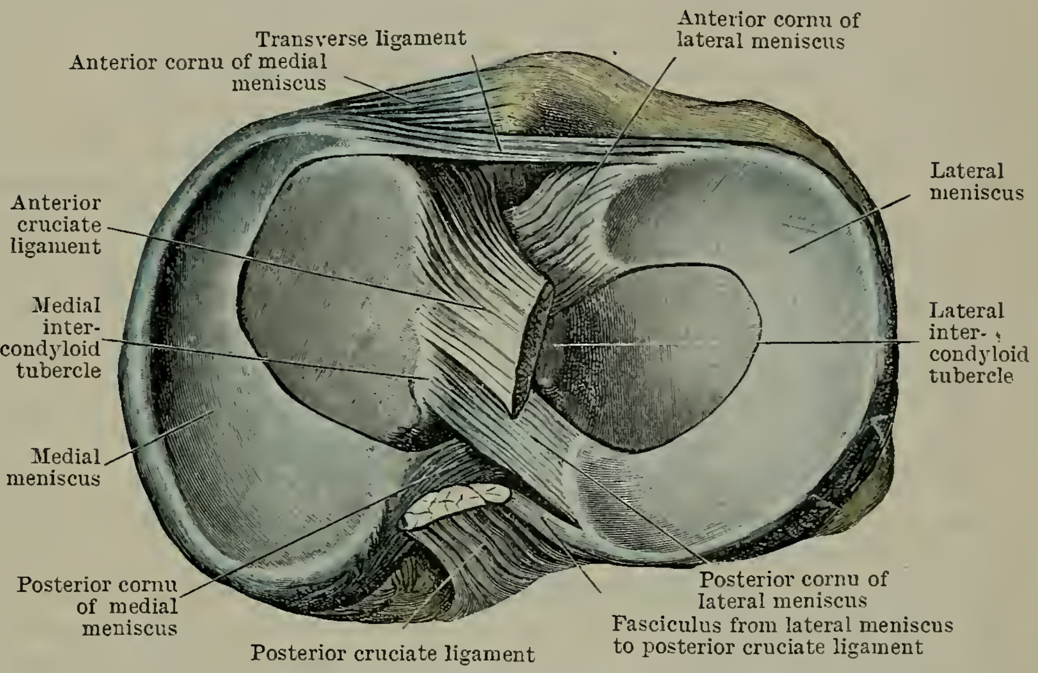
Transverse ligament
Anterior cornu of medial meniscus
Anterior cornu of lateral meniscus
Lateral meniscus
Anterior cruciate ligament
Medial inter-condyloid tubercle
Lateral inter-condyloid tubercle
Medial meniscus
Posterior cornu of medial meniscus
Posterior cruciate ligament
Posterior cornu of lateral meniscus
Fasciculus from lateral meniscus to posterior cruciate ligament

Fig. 293.—Proximal End of Tibia with Menisci and Attached Portions of Cruciate Ligaments.

Meniscus Medialis.—The **medial meniscus** (Figs. 292 and 293) forms very nearly a semicircle. It is attached by its anterior horn to the non-articular surface on the head of the tibia, in front of the tibial attachment of the anterior cruciate ligament, and by its posterior horn to the non-articular surface immediately in front of the tibial attachment of the posterior cruciate ligament. The deep or posterior part of the tibial collateral ligament is attached to its periphery.

Meniscus Lateralis.—The **lateral meniscus** (Figs. 292 and 293) is attached by its anterior horn to the non-articular surface of the tibia in front of the intercondyloid eminence, where it is placed to the lateral side, and partly under cover of the tibial end of the anterior cruciate ligament. By its posterior horn it is attached to the interval between the two tubercles which surmount the intercondyloid eminence, *i.e.* in front of the attachment of the posterior horn of the meniscus medialis. This fibro-cartilage, with its two horns, therefore forms almost a complete circle. Posteriorly it is attached by its periphery to the posterior ligament, but on the lateral side it is separated from the fibular collateral ligament by the tendon of the popliteus muscle, and on this aspect its periphery is free.

The two horns of the lateral meniscus are embraced by the two horns of the medial meniscus, and, while the anterior cruciate ligament has its tibial attachment almost between the anterior horns of the two menisci, the tibial attachment of the posterior cruciate ligament is situated behind the posterior horns of the two menisci.

Both menisci possess certain accessory attachments. Thus the lateral meniscus sends a large bundle of fibres from its convex posterior border to augment the posterior aspect of the posterior cruciate ligament by which these fibres are conducted to the femur. Again, the convex or peripheral margins of each meniscus possess certain attachments to the deep surface of the fibrous stratum of the capsule on its medial and posterior aspects, as has already been explained, but, in addition, they are attached to the non-articular circumference of the tibial head by short fibrous bands known as the **ligamenta coronaria.** Lastly, a rounded band which varies in strength, the **lig. transversum genu (transverse ligament)** (Figs. 290 and 293), stretches between the anterior convex margins of the two menisci, crossing the front part of the non-articular area on the tibial head in its course.

The **stratum synoviale** of the knee-joint is not only the largest, but the most elaborately arranged of its kind in the body. It not only lines the fibrous stratum of the capsule articularis, but it forms a more or less extensive covering for the intracapsular ligaments and the free surface of the **infra-patellar pad of fat.** This pad acts as a wedge which fits into the interval between the patella, tibia, and femoral condyles, and the synovial stratum upon its surface forms a band or fold which extends from the region distal to the level of the patellar articular surface to the anterior part of the intercondyloid notch. It is named the **plica synovialis patellaris.** At its femoral end it is narrow and attenuated, but at its patellar end it expands on each side to form wing-like fringes or membranes—the **plicæ alares**—medial and lateral. These folds are more or less loaded with fat.

Apart from these special foldings, the synovial stratum lines the deep surface of the common extensor tendon, and extends for a variable distance proximal to the patella. This extension of the articular cavity almost always communicates with a large bursa situated still more proximally on the front of the femur. Tracing the synovial stratum distally, it will be found to cover both surfaces of the two menisci. The peripheral or convex margins of these menisci are only covered by this membrane where they are unattached to the capsule. A prolongation invests the intracapsular portion of the tendon of the popliteus muscle, and separates this tendon from the posterior part of the tibial head, besides intervening between the lateral meniscus and the head of the tibia.

From the posterior part of the articular cavity the synovial stratum extends forwards, and provides a partial covering for the cruciate ligaments between which a bursa may be found.

This somewhat complicated arrangement of the synovial stratum may be readily comprehended if it is borne in mind that it really represents the fusion of three separate synovial cavities, which in some animals are permanently distinct. These are indicated in the two femoro-tibial and the single femoro-patellar parts of the articulation.

The articular cavity may communicate with **bursæ** situated in relation to the medial head of the gastrocnemius muscle and the tendon of the semi-membranosus muscle, besides the large supra-patellar bursa already described. Lastly, there may be intercommunication between this articular cavity and that of the proximal tibio-fibular articulation.

Movements at the Knee-Joint.—In studying the movements which may occur at the human knee-joint, it is necessary to bear in mind that the lower limb of man is primarily required for purposes of support and locomotion. The principal requirement of the former function is stability accompanied by rigidity, whereas in the latter function the special desideratum is regulated and controlled mobility. Thus, in the same joint, two entirely opposite conditions have to be provided. The stable conditions of support are chiefly concerned in the maintenance of the erect attitude, and the mechanism associated therewith does not call for the exertion of a large degree of sustained muscular effort.

In standing erect the attitude of the limb is that of extension, which mainly concerns the femoro-tibial parts of the joint. In this position the force of gravity acts along a vertical line which falls in front of the transverse axis of the joint, and therefore any tendency to flexion, *i.e.* bending backwards, is mechanically counteracted by the application of a force which tends to produce bending forwards (so-called over-extension). This, however, is absolutely prohibited in normal states of the joint, by the tension of the posterior and collateral ligaments aided by the anterior cruciate ligament. The value of this fact may be seen by observing the effect produced by giving the joint a sudden push from behind, which causes an immediate reversal of the positions of the transverse and vertical axes, whereby the body weight at once produces flexion of the joint.

The menisci and the infra-patellar pad of fat also assist in maintaining extension, by reason of their close adaptation to, and packing round the condyles as these rest upon the tibia.

The anterior margin of the intercondyloid fossa is also brought into contact with the front of the anterior cruciate ligament.

In the position of extension the patella is retained at such a proximal level in relation to the trochlear surface of the femur, that the distal articular facets of the patella are in contact with the trochlea.

During locomotion the movements of the knee-joint are somewhat intricate, for both the femoro-tibial and the femoro-patellar sections of the joint are brought into action. The principal movement which results is flexion, with which there is associated, both at its beginning and ending, a certain amount of screw movement or rotation. Flexion and rotation occur at the femoro-tibial sections of the joint, whereas the movement at the femoro-patellar portion produces a regulating and controlling influence upon flexion.

Taking these factors separately, we observe that each femoral condyle adapts itself to a shallow cup formed by the corresponding tibial condyle and meniscus, and as the two femoral condyles move simultaneously and parallel to each other, there is more than the characteristic hinge-joint action, for each femoral condyle glides and rolls in its cup "like a wheel restrained by a drag" (Goodsir) when the movement of bending occurs. Thus the different parts of the condyles are successively brought into relation with the transverse axis of the joint while it passes from extension to flexion and *vice versa.* From the fact that the medial femoral condyle is longer, antero-posteriorly, than the lateral, it is believed that extension is completed by a movement of rotation whereby the joint becomes locked, and the anterior cruciate, the posterior and the collateral ligaments, become tense. A similar rotation initiates the movement of flexion, and unlocks the joint by relaxing the ligaments just mentioned.

Since the tibia and foot are fixed in the act of walking, it is the femur which rotates upon the tibia in passing from extension to flexion and *vice versa* ; and as relaxation of the ilio-femoral ligament is essential for this rotation, some observers are of opinion that the body weight falls behind the transverse axis of the knee-joint, as in the case of the hip-joint, and consequently that extension of the knee-joint is maintained by the ilio-femoral ligament, as it is not possible to bend the knee without first having bent the hip-joint.

During flexion and extension the menisci glide along with the condyles, so as to maintain their close adaptation and preserve their value as packing agents. When the movement of flexion is completed, the condyles are retained upon the tibia, and prevented from slipping off by the tension of the posterior cruciate ligament. In this position a small degree of rotation of the tibia, both medially and laterally, is also permissible.

The regulating and controlling influence of the femoro-patellar portion of the articulation is brought into play during the movements of flexion and extension. In the latter position the distal pair of patellar facets is in apposition with the proximal part of the femoral trochlea. As flexion advances, the middle pair of facets adapt themselves to a deeper area of the trochlea, into which the patellar keel fits. When flexion is still further advanced, the proximal pair of patellar facets will be found fitting into that part of the trochlea adjoining the intercondyloid notch ; and finally, when flexion is complete, the patella lies opposite the intercondyloid notch, while the forward thrust of the longer medial femoral condyle brings its semilunar facet (Goodsir) into apposition with the somewhat vertical facet at the medial border of the patella. The wedge-like influence of the patella is most marked, for it is only in the position of extension that it can be moved from side to side. The movements of the patella may be described as gliding and co-aptation, as it slips or rocks from one pair of facets to another in its progress along the trough of the femoral trochlea.

ARTICULATIONES TIBIOFIBULARES.

The Tibio-Fibular Joints.—The proximal and distal ends of the fibula articulate with the tibia. Primarily, the fibula is required to form a strong lateral support for the ankle-joint, and therefore its articulations are so arranged as to provide a certain amount of elasticity without any sacrifice of the rigidity necessary for security. Hence the amount of movement is very small, but what there is enables these joints to be classified as arthrodial diarthroses.

Articulatio Tibiofibularis.—The **proximal tibio-fibular joint** is formed, on the one hand, by a flat oval or circular facet which is situated upon the postero-lateral aspect of the lateral condyle of the tibia, and is directed distally and posteriorly ; on the other hand, by a similar facet on the proximal surface of the head of the fibula in front of the apex capituli.

An articular capsule (Fig. 292) invests the joint, and it may be regarded as holding the articular surfaces in apposition, although certain special bands receive separate designations. Occasionally there is an opening in the stratum fibrosum by which communication is established between the articular cavity and the knee-joint, through the intermediation of the synovial prolongation, subjacent to the tendon of the popliteus muscle.

The proximal epiphyseal line of the fibula is extra-capsular.

Lig. Capituli Fibulæ Anterius.—The **anterior ligament of the head of the fibula** (Fig. 290) is a strong flat band whose fibres extend from the anterior aspect of the fibular head, proximally and medially, to the adjoining part of the lateral condyle of the tibia.

Lig. Capituli Fibulæ Posterius.—The **posterior ligament of the head of the fibula** (Fig. 292) is a similar, but weaker band, passing, proximally and medially, from the posterior aspect of the fibular head to the posterior aspect of the lateral condyle of the tibia, where it is attached immediately distal to the opening in the capsule of the knee-joint, from which the tendon of the popliteus muscle escapes.

Equally strong but much shorter bands are found on the lateral and medial aspects of the joint. The former is intimately associated with the tendon of the biceps flexor cruris muscle which strengthens the lateral aspect of the joint, and here also is found the occasional opening by which it communicates with the knee-joint.

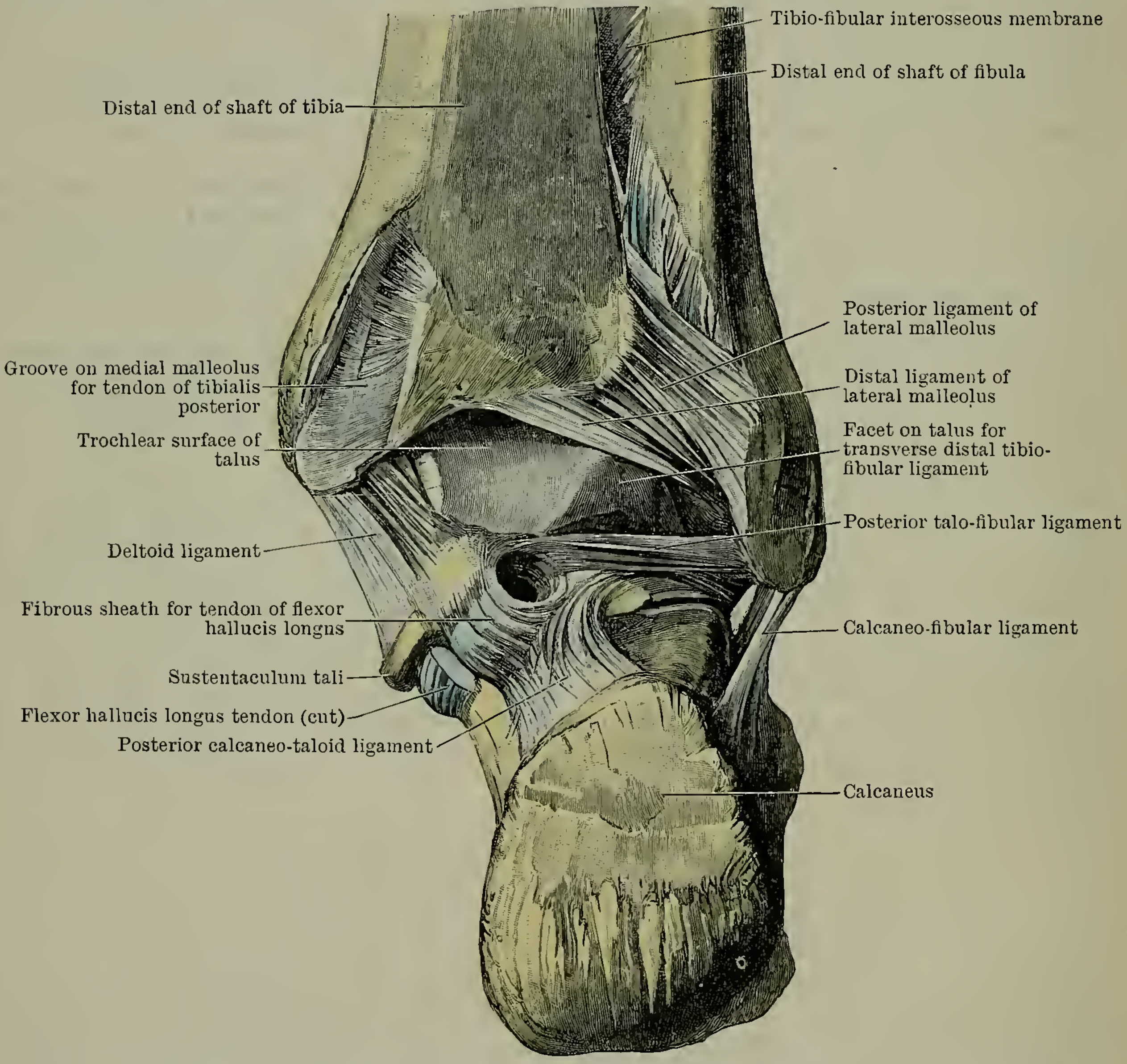
Tibio-fibular interosseous membrane
Distal end of shaft of fibula
Distal end of shaft of tibia
Posterior ligament of lateral malleolus
Groove on medial malleolus for tendon of tibialis posterior
Distal ligament of lateral malleolus
Trochlear surface of talus
Facet on talus for transverse distal tibio-fibular ligament
Posterior talo-fibular ligament
Deltoid ligament
Fibrous sheath for tendon of flexor hallucis longus
Calcaneo-fibular ligament
Sustentaculum tali
Flexor hallucis longus tendon (cut)
Posterior calcaneo-taloid ligament
Calcaneus

FIG. 294.—ANKLE-JOINT DISSECTED FROM BEHIND WITH PART OF THE ARTICULAR CAPSULE REMOVED.

The **synovial stratum** is in certain cases continuous with that of the knee-joint in the manner already described.

Membrana Interossea Cruris.—The **interosseous membrane** (Figs. 290 and 294) plays the part of an accessory ligament both for the proximal and the distal tibio-fibular joints. It is attached to the interosseous borders on the shafts of the tibia and fibula, and binds them together. The general direction of its fibres is from the tibia distally and laterally to the fibula, but many fibres pass in the opposite direction. The membrane may extend upwards until it comes into contact with the ligaments of the proximal tibio-fibular joint, but there is always a vertical oval aperture in its proximal part for the passage of the anterior tibial vessels. This aperture (Fig. 290), which is about one inch long, adjoins the shaft of the fibula at a point rather less than one inch distal to its head. Towards the distal end of the leg the distance between the tibia and the fibula rapidly diminishes, and consequently the width of the interosseous membrane is correspondingly reduced, and it is tense throughout its entire length. In the distal part of the membrane there is a small opening for the passage of the perforating peroneal vessels. There is no sharply marked demarcation between the interosseous membrane and the interosseous ligament which connects the distal ends of the tibia and fibula—the one, indeed, may be said to run into the other.

Syndesmosis Tibiofibularis.—The **distal tibio-fibular joint** is not on all occasions provided with articular cartilage, so that it may either be a separate articulation, or it may merely present a series of ligaments which are accessory to the (ankle-joint), because it is clear that, under any circumstances, the object aimed at in this articulation is to obtain additional security for the ankle-joint. The articular surface on the tibia, when present, constitutes a narrow articular strip on the lateral side of the distal end of the bone, and the joint-cavity is practically an upward extension of the ankle-joint. The corresponding fibular facet is continuous with the extensive articular area, by means of which the fibula articulates with the talus. By far the greater part of the opposing surfaces of tibia and fibula are, however, non-articular and rough.

The supporting **ligaments** are of great strength.

Lig. Malleoli Lateralis Anterius.—The **anterior ligament of the lateral malleolus** (Fig. 297) consists of strong fibres which pass obliquely distally and laterally from the front of the distal end of the tibia to the front of the lateral malleolus.

Lig. Malleoli Lateralis Posterius.—The **posterior ligament of the lateral malleolus** (Figs. 294 and 297) is equally strong, and passes in a similar direction between corresponding posterior surfaces.

Lig. Malleoli Lateralis Distale.—The **distal ligament of the lateral malleolus** (Figs. 294 and 297) stretches between the posterior border of the distal end of the tibia and the proximal end of the pit on the medial and posterior aspect of the lateral malleolus.

Ligamentum Interosseum.—An **interosseous ligament**, powerful and somewhat extensive, connects the contiguous rough non-articular surfaces. Proximally, as already mentioned, it is continuous with the interosseous membrane. Anteriorly and posteriorly it comes into contact with the more superficial ligaments. Distally it descends until it comes into intimate association with the articular cavity.

A **synovial stratum** is found lining the small articular cavity, but it is always a direct prolongation from that which lines the ankle-joint.

ARTICULATIONES PEDIS.

ARTICULATIO TALOCRURALIS.

The **ankle-joint** is a ginglymus variety of a diarthrosis. The bones which enter into its formation are the distal ends of the tibia and fibula, with the articular areas on the superior, lateral, and medial surfaces of the talus. The tibia and fibula, aided by the distal ligament of the lateral malleolus, form a three-sided socket within which the talus is accommodated. The roof or most proximal part of the socket, which is wider in front than behind, is formed, chiefly, by the quadrilateral articular surface on the distal end of the tibia, but towards its postero-lateral margin the distal ligament of the lateral malleolus assists in its formation. There also the tibial articular surface is continuous with the narrow articular facet already described as forming part of the tibio-fibular syndesmosis. The medial wall of the socket is formed by the articular facet on the lateral side of the medial malleolus, and there is no interruption of the articular cartilage between the roof and medial wall. The lateral wall of the socket is quite separate from the foregoing parts, and consists of a large triangular facet upon the medial side of the lateral malleolus. This facet is situated immediately in front of the deep pit which characterises the posterior part of this surface of the fibula.

A small lunated facet is frequently found upon the anterior surface of the distal end of the tibia, particularly among those races characterised by the adoption of the "squatting" posture. When this facet exists it is continuous with the anterior margin of the roof of the socket, and it articulates with a similar facet upon the superior surface of the neck of the talus in the extreme flexion of the ankle-joint which "squatting" entails.

The articular surface upon the body of the talus adapts itself to the tibio-fibular socket, and presents articular facets corresponding to the roof and sides of the socket. Thus the superior surface of the talus possesses a quadrilateral articular area, wider in front than behind, distinctly convex in the antero-posterior direction, and slightly concave transversely. In addition, towards its postero-lateral margin, there is also a narrow antero-posterior facet corresponding to the distal ligament of the lateral malleolus. The articular cartilage of this superior surface is continued without interruption to the tibial and fibular sides of the bone, although the margins of the superior area are sharply defined from the facets on the sides, the lateral of which is triangular in outline, while the medial is piriform, but in each case the surface is vertical.

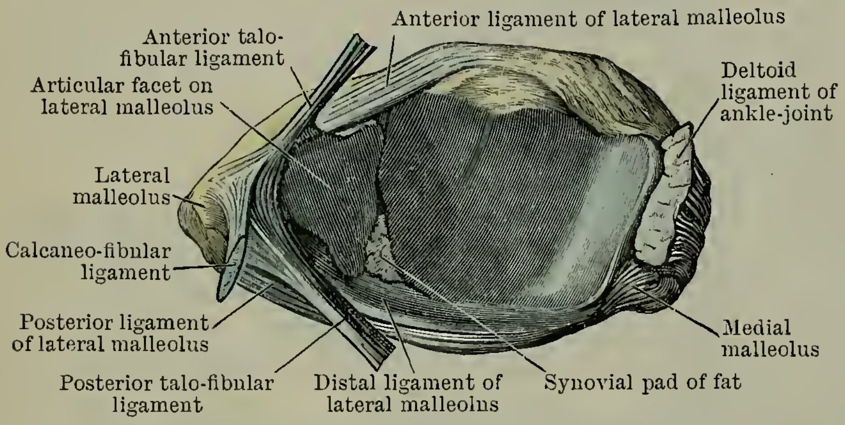
Anterior talo-fibular ligament
Anterior ligament of lateral malleolus
Articular facet on lateral malleolus
Deltoid ligament of ankle-joint
Lateral malleolus
Calcaneo-fibular ligament
Posterior ligament of lateral malleolus
Medial malleolus
Posterior talo-fibular ligament
Distal ligament of lateral malleolus
Synovial pad of fat

FIG. 295.—ARTICULAR SURFACES OF TIBIA AND FIBULA WHICH ARE OPPOSED TO THE TALUS.

Ligaments.—The ligaments form a complete investment for the joint, *i.e.* a *fibrous stratum* of an **articular capsule** in which the individual parts vary considerably in strength, and are described under separate names. Their proximal attachments are restricted to the epiphysis of the distal end of the tibia but lie proximal to the epiphyseal line of the fibula (Fig. 228). Therefore the epiphyseal line of the tibia is extra-capsular and that of the fibula partly intra-capsular.

The **anterior ligament** is an extremely thin membrane, containing very few longitudinal fibres. It extends from the distal border of the tibia to the dorsal border of the head of the talus, passing in front of a pad of fat which fills up the hollow above the neck of that bone.

The **posterior ligament** is attached to contiguous non-articular borders of the tibia and talus. Many of its fibres radiate medially from the lateral malleolus. This aspect of the joint is strengthened by the strong, well-defined, distal ligament of the lateral malleolus already described in connexion with the tibio-fibular syndesmosis.

The **lateral ligament** (Figs. 294, 295, and 297) is very powerful, and is divisible into three fasciculi, which are distinguished from each other by names, descriptive of their chief points of attachment.

Lig. Talofibulare Anterius.—The **anterior fasciculus** is the shortest. It extends from the anterior border of the lateral malleolus to the talus immediately in front of its lateral articular surface.

Lig. Calcaneofibulare.—The **middle fasciculus** is a strong and rounded cord. It is attached by one end to the front of the tip of the lateral malleolus, and by the other to the lateral side of the calcaneus immediately proximal and posterior to the groove for the peroneal tendons.

Lig. Talofibulare Posterius.—The **posterior fasciculus** is the strongest. It runs transversely between the distal part of the fossa on the medial aspect of the fibular malleolus and the posterior surface of the talus, where it is attached to the posterior process and the adjoining rough surface. Sometimes this process is detached from the talus, and represents a separate bone—the *os trigonum.*

Lig. Deltoideum.—The **deltoid ligament** is the **medial ligament** of the ankle-joint (Figs. 295 and 296). It has the general shape of a delta, and is even stronger than the lateral ligament. It is attached proximally to a marked impression on the distal part of the medial malleolus, and below, in a continuous layer, to the navicular, talus and calcaneus. In it we may recognise the following special bands—(*a*) the *lig. talotibiale anterius,* which extends from the front of the medial malleolus to the neck of the talus; (*b*) the *lig. talotibiale posterius,* stretching between the back of the medial malleolus and the postero-medial rough surface of the talus; (*c*) the *lig. tibionaviculare,* which extends from the tip of the medial malleolus to the medial side of the navicular bone; (*d*) the *lig. calcaneotibiale,* which extends between the tip of the medial malleolus and the medial side of the sustentaculum tali; (*e*) *lig. talotibiale profundum,* which consists of deeper fibres extending from the tip of the medial malleolus to the medial side of the talus.

A **synovial stratum** lines the fibrous stratum of the articular capsule and, as already described, the articular cavity extends into the interval between the tibia and fibula distal to the tibio-fibular interosseous ligament. Both at the front and back of the ankle-joint, as well as proximally in the angle formed by the three bones, the synovial membrane covers pads of fat.

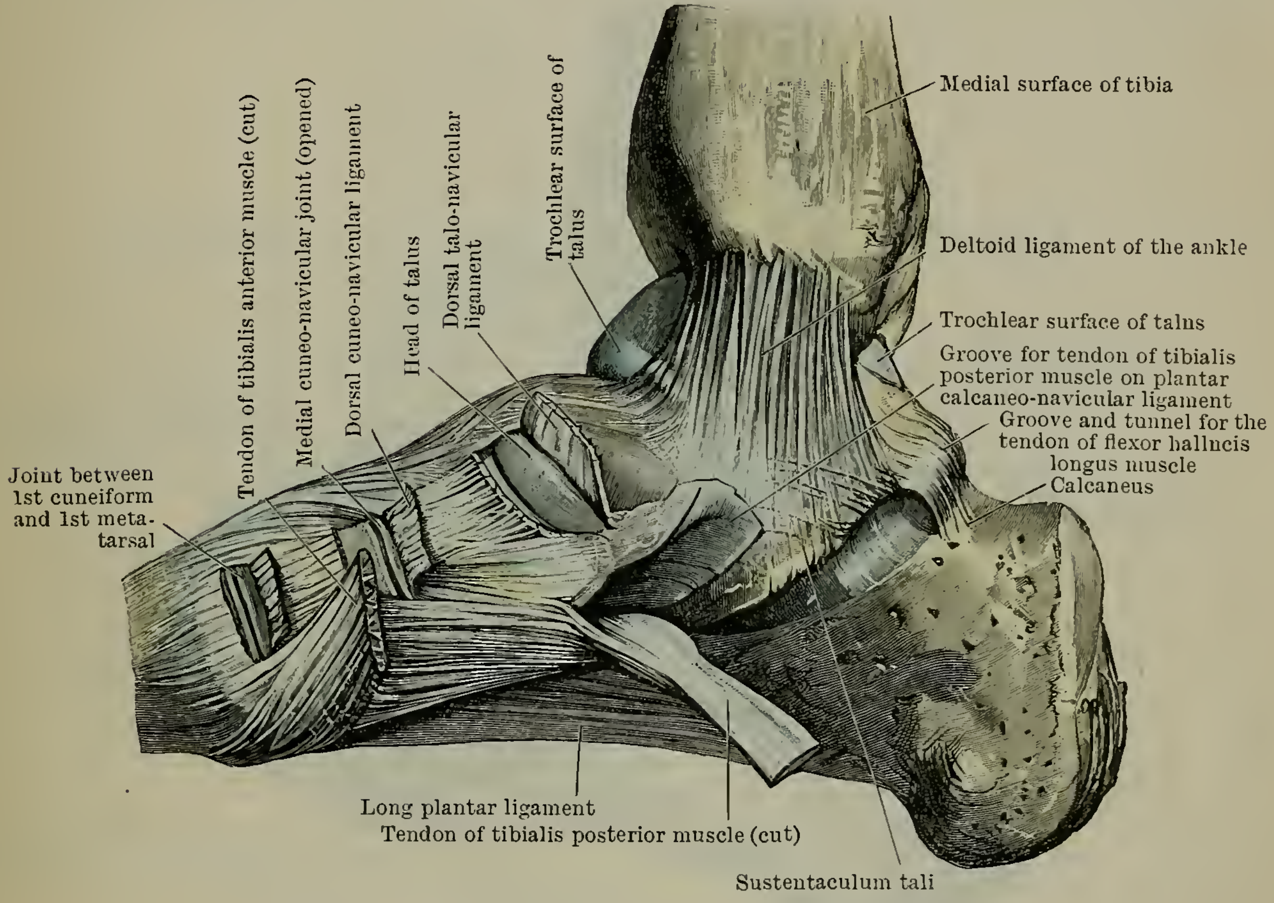
Tendon of tibialis anterior muscle (cut)
Medial cuneo-navicular joint (opened)
Dorsal cuneo-navicular ligament
Head of talus
Dorsal talo-navicular ligament
Trochlear surface of talus
Medial surface of tibia
Deltoid ligament of the ankle
Trochlear surface of talus
Groove for tendon of tibialis posterior muscle on plantar calcaneo-navicular ligament
Groove and tunnel for the tendon of flexor hallucis longus muscle
Calcaneus
Joint between 1st cuneiform and 1st metatarsal
Long plantar ligament
Tendon of tibialis posterior muscle (cut)
Sustentaculum tali

FIG. 296.—ANKLE AND TARSAL-JOINTS FROM THE TIBIAL ASPECT.

Movements at the Ankle-Joint.—In the erect attitude the foot is placed at right angles to the leg; in other words, the normal position of the ankle-joint is **flexion.** Those movements which tend to diminish the angle so formed by the dorsum of the foot and the front of the leg are called **dorsiflexion,** while those which tend to increase the angle, *i.e.* to straighten the foot upon the leg, are called **extension.** As a matter of fact neither dorsiflexion nor extension is ever completely carried out, and the range of movement of which the foot is capable is limited to about 90°. These movements occur about an obliquely transverse axis, as is indicated by the natural lateral pointing of the toes. The weight of the body falls slightly anterior to the ankle-joint, so that a certain amount of muscular action is necessitated in order to maintain the foot at right angles to the leg; but additional stability is obtained from the obliquity above mentioned.

When the foot is raised from the ground, muscular action tends naturally to produce a certain amount of extension. When the foot is extended, as in standing on the toes, the posterior narrow part of the talus moves forwards into the wider part of the interval between the tibia and fibula, whereas in dorsiflexion, as in raising the anterior part of the foot from the ground, the widest part of the talus is forced back between the tibia and fibula; but notwithstanding the difference between these two movements, the fibula remains in close contact with the talus by reason of the action of the distal ligament of the lateral malleolus and the posterior talo-fibular ligament, so that lateral movement is prevented.

It is doubtful whether lateral movement at the ankle-joint can be obtained by any natural movement of the foot, although it is generally believed that in the position of partial extension a small amount of side-to-side movement may be produced by the application of external force. "This apparent play" of the ankle-joint during extension "is really due to oscillation of the small bones of the foot on each other, largely of the navicular on the talus, but also of the cuboid on the calcaneus. Excessive mobility of these latter is restrained by an important function of the posterior tubercle of the cuboid which locks into a notch in the calcaneus" (Blake).

ARTICULATIONES INTERTARSEÆ.

The **intertarsal joints** are all diarthroses in which the gliding movement is characteristic, as in the carpus. With the view of obtaining a proper conception of the many beautiful mechanical principles involved in the construction of the foot, it is necessary to study these articulations with considerable attention to detail.

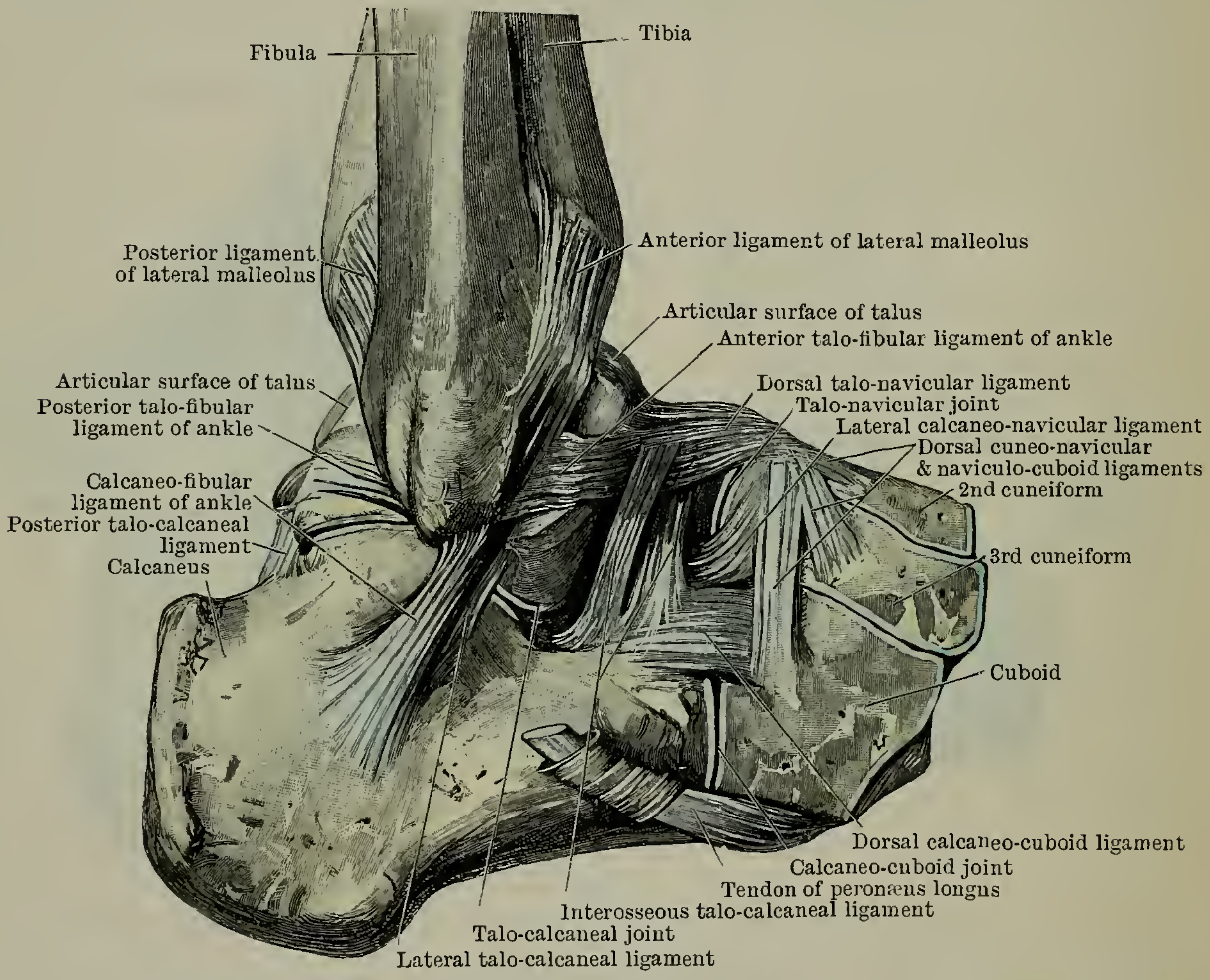
Fibula
Tibia
Posterior ligament of lateral malleolus
Anterior ligament of lateral malleolus
Articular surface of talus
Anterior talo-fibular ligament of ankle
Articular surface of talus
Posterior talo-fibular ligament of ankle
Dorsal talo-navicular ligament
Talo-navicular joint
Lateral calcaneo-navicular ligament
Dorsal cuneo-navicular & naviculo-cuboid ligaments
Calcaneo-fibular ligament of ankle
2nd cuneiform
Posterior talo-calcaneal ligament
Calcaneus
3rd cuneiform
Cuboid
Dorsal calcaneo-cuboid ligament
Calcaneo-cuboid joint
Tendon of peronæus longus
Interosseous talo-calcaneal ligament
Talo-calcaneal joint
Lateral talo-calcaneal ligament

FIG. 297.—LIGAMENTS ON THE LATERAL ASPECT OF THE ANKLE-JOINT AND ON THE DORSUM OF THE TARSUS.

Articulatio Talocalcanea.—The talus and calcaneus articulate with each other in the **talo-calcaneal joint.**

This joint is situated between the inferior facet on the body of the talus and a corresponding facet on the middle of the superior aspect of the calcaneus. On each bone the articulation is limited in front by a wide, deep groove which runs obliquely across each bone from the medial to the lateral side and forwards.

The supporting and investing ligaments form the fibrous stratum of an **articular capsule**, consisting for the most part of short fibres, but the joint derives additional strength from the calcaneo-fibular ligaments of the ankle-joint. The fibrous stratum of the capsule is subdivided into the following talo-calcaneal bands:—

The **ligamentum talocalcaneum anterius** consists of a band of short fibres placed immediately in relation to the anterior end of the deep groove which bounds the articular facets. They are attached to the antero-lateral aspect of the neck of the talus, from which they extend downwards to the adjacent superior surface of the calcaneus.

The **ligamentum talocalcaneum laterale** (Fig. 297) is in continuity with the posterior border of the preceding ligament, and it is placed parallel to, but on a deeper plane than, the calcaneo-fibular ligament of the ankle-joint. It consists of short fibres passing between the adjacent rough lateral margins of the two bones.

The **ligamentum talocalcaneum posterius** (Fig. 297) closes the joint-cavity on its posterior aspect. It consists of fibres which radiate from the posterior aspect of the posterior process of the talus to the superior surface of the calcaneus, immediately behind the articular facet.

The **ligamentum talocalcaneum mediale** lies obliquely on the medial side of the joint, and consists of fibres which extend from the medial posterior tubercle of the talus to the posterior roughened border of the sustentaculum tali. Some of its fibres become continuous with the plantar calcaneo-navicular ligament.

The **ligamentum talocalcaneum interosseum** (Fig. 298) closes the antero-medial aspect of the joint. It is the strongest of the series of ligaments entering into the capsule. Compared with it the other bands are, comparatively speaking, insignificant. Its attachments are to the bottom of each groove, so that it occupies the tarsal canal formed by these opposing grooves.

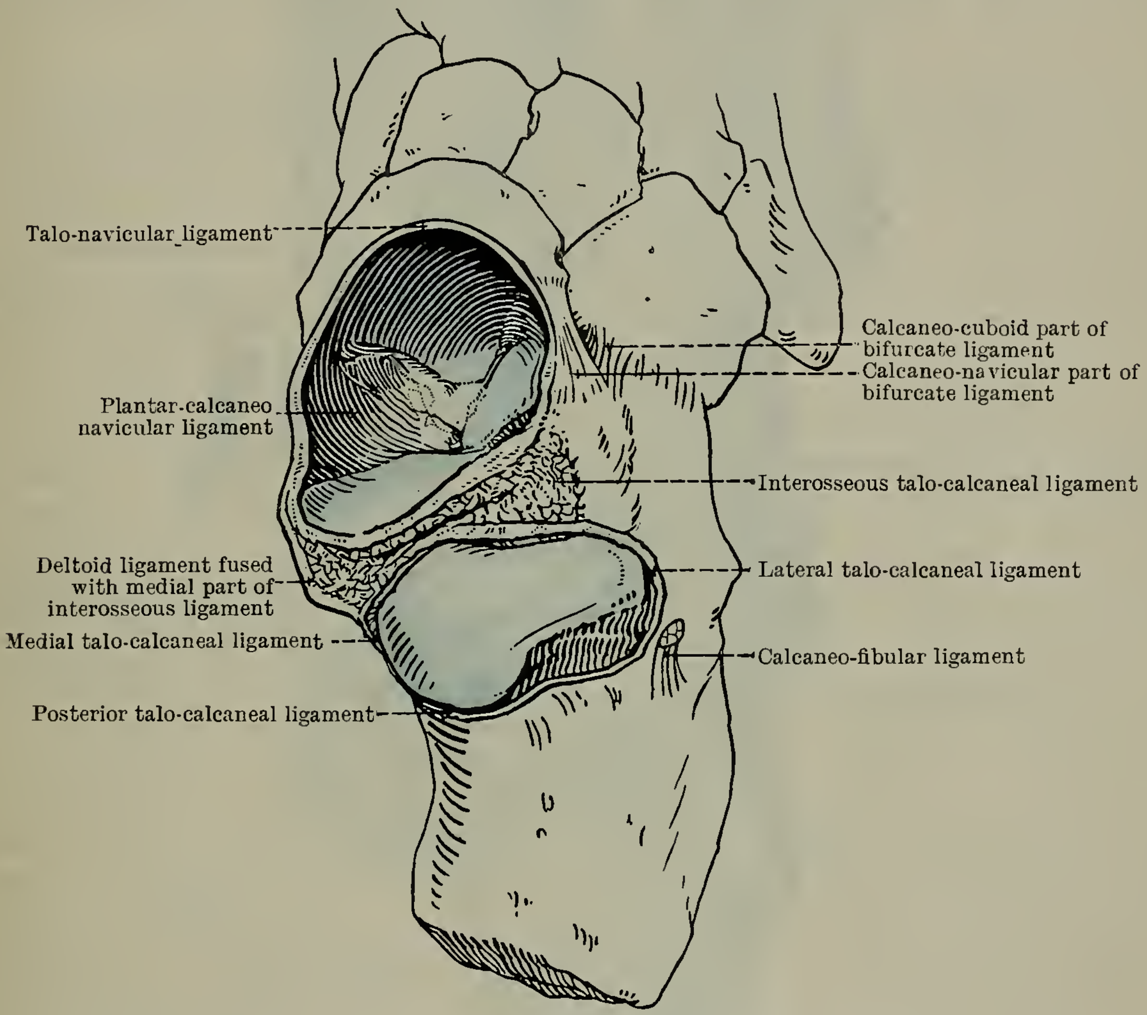
Talo-navicular ligament
Plantar-calcaneo-navicular ligament
Deltoid ligament fused with medial part of interosseous ligament
Medial talo-calcaneal ligament
Posterior talo-calcaneal ligament
Calcaneo-cuboid part of bifurcate ligament
Calcaneo-navicular part of bifurcate ligament
Interosseous talo-calcaneal ligament
Lateral talo-calcaneal ligament
Calcaneo-fibular ligament

FIG. 298.—THE LIGAMENTS OF THE POSTERIOR CALCANEO-TALOID AND THE CALCANEO-TALO-NAVICULAR JOINTS (seen from above after removal of the Talus).

A **synovial stratum** lines the fibrous stratum, and it is distinct from other tarsal synovial membranes.

Articulatio Talocalcaneonavicularis.—This is one of the most important of the joints of the foot, not only because the talus is here situated in relation to the summit of the antero-posterior arch of the foot, but because the head of the talus is received into a composite socket made up of the sustentaculum tali, the navicular, and the plantar calcaneo-navicular ligament.

The articular surface on the head of the talus presents anteriorly a convex rounded facet for articulation with the navicular, inferiorly a convex facet which rests upon the sustentaculum tali, and intermediate between these two there is a triangular facet which articulates with the plantar calcaneo-navicular ligament. All these facets are in continuity with each other, and are in front of the groove on the inferior surface of the talus. Occasionally a fourth narrow facet is found along the lateral and posterior part of the articular surface of the head of the talus, whereby it articulates with the calcaneo-navicular part of the bifurcate ligament.

The navicular bone presents a shallow, cup-shaped, articular cavity towards the head of the talus.

The articular surface of the sustentaculum tali is concave, and is usually marked off into two facets.

Two ligaments play an important part in binding together the calcaneus and the navicular, although these bones do not directly articulate; and further, these ligaments provide additional articular surfaces for the head of the talus. These are the two following:—

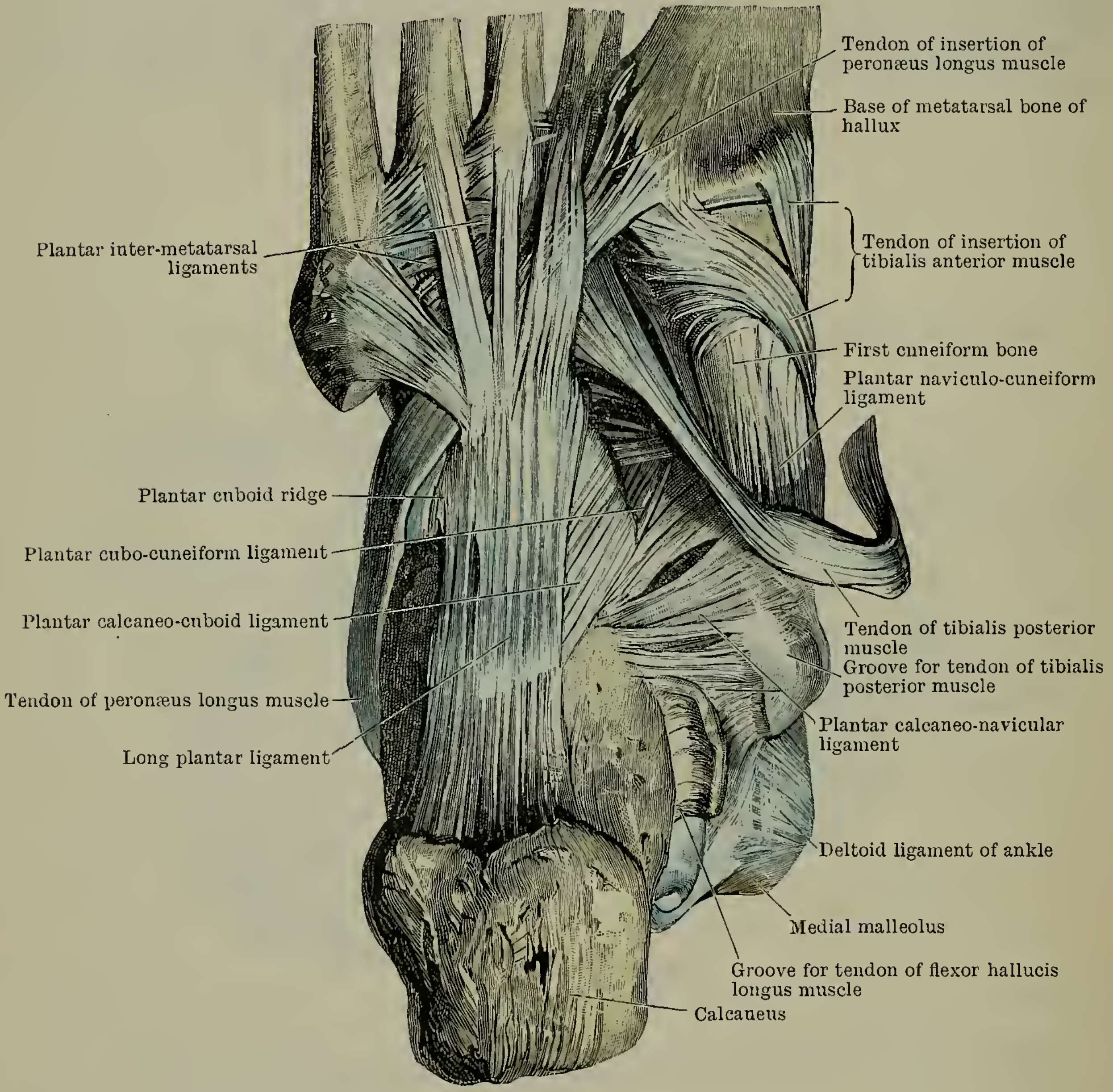
Tendon of insertion of peronæus longus muscle
Base of metatarsal bone of hallux
Plantar inter-metatarsal ligaments
Tendon of insertion of tibialis anterior muscle
First cuneiform bone
Plantar naviculo-cuneiform ligament
Plantar cuboid ridge
Plantar cubo-cuneiform ligament
Plantar calcaneo-cuboid ligament
Tendon of tibialis posterior muscle
Groove for tendon of tibialis posterior muscle
Tendon of peronæus longus muscle
Plantar calcaneo-navicular ligament
Long plantar ligament
Deltoid ligament of ankle
Medial malleolus
Groove for tendon of flexor hallucis longus muscle
Calcaneus

Fig. 299.—Plantar Aspect of Tarsal and Tarso-metatarsal Joints.

(*a*) The **ligamentum calcaneonaviculare plantare** (Figs. 298 and 299) is an extremely powerful fibro-cartilaginous band. It extends between the anterior margin of the sustentaculum tali and the plantar surface of the navicular. Certain of its upper fibres radiate upwards on the medial surface of the navicular, and become continuous with the tibio-navicular portion of the deltoid ligament of the ankle-joint. The plantar aspect of this ligament is in contact with the tendon of the tibialis posterior muscle, through which the head of the talus receives great support. Superiorly it contributes an articular surface which forms a triangular portion of the floor of the composite socket in which the head of the talus is received.

(*b*) The **calcaneo-navicular part of the bifurcate ligament** (Fig. 298) lies deeply in the front part of the sinus tarsi, *i.e.* the interval between the talus and calcaneus. Its fibres are short, and extend from the dorsal surface of the front part of the calcaneus, immediately to the lateral side of the sustentacular facet, forwards to the lateral side of the navicular bone. Frequently the ligament presents a surface which articulates with the head of the talus, and in these cases it forms a part of the composite socket.

The cavity of the talo-calcaneo-navicular joint is closed posteriorly by the interosseous talo-calcaneal ligament already described. On its medial and lateral inferior aspects it is closed by the calcaneo-navicular ligaments.

The superior and lateral aspects are covered by the **ligamentum talonaviculare dorsale.** This ligament is thin, and extends from the proximal non-articular area on the head of the talus to the dorsal surface of the navicular bone. It may be subdivided into *dorsal*, *lateral*, and *medial* **talo-navicular bands** (Fig. 297), which, with the calcaneo-navicular and interosseous talo-calcaneal ligaments, complete the capsular investment of the joint.

A distinct **synovial stratum** lines all parts of the capsule of the joint.

Articulatio Calcaneocuboidea.—This is situated between the anterior concavo-convex surface of the calcaneus and the posterior similar surface of the cuboid.

The **ligaments** which invest this joint constitute a **calcaneo-cuboid capsule,** whose parts are arranged in relation to the four non-articular sides of the cuboid bone, and are especially strong upon the plantar aspect, in relation to their great importance in resisting strains.

The **medial calcaneo-cuboid ligament** occupies part of the interval between the talus and calcaneus—the sinus tarsi. It is the *calcaneo-cuboid part* of the **lig. bifurcatum**, and is a V-shaped structure, of which the single end is attached to the calcaneus, and the double ends separate to reach contiguous areas on the navicular and cuboid respectively.

The **dorsal calcaneo-cuboid ligament** (Fig. 297) is a broad portion of the fibrous stratum of the capsule extending from the dorsal and lateral surfaces of the calcaneus to the dorsal surface of the cuboid.

The **lateral calcaneo-cuboid ligament** is another but narrower part of the capsule which extends from the lateral aspect of the calcaneus to the lateral side of the cuboid, immediately behind the facet on the tuberosity.

The **inferior calcaneo-cuboid ligament** consists of two parts—a superficial and a deep. The superficial series of fibres, the **long plantar ligament** (Fig. 299), is attached to the plantar surface of the calcaneus in front of the processes of the tuber calcanei. It forms a long powerful structure which runs forwards to be fixed to the plantar surface of the cuboid ridge, but many of its fibres pass superficial to the tendon of the peronæus longus, and extend to the bases of the third, fourth, and fifth metatarsal bones.

The deep series of fibres, the **plantar calcaneo-cuboid ligament** (Fig. 299), is distinctly separated from the long plantar ligament by a layer of areolar tissue. It forms a broad but short band of great strength, which is attached to the plantar surface of the distal end of the calcaneus, and extends to the plantar surface of the cuboid just behind the ridge. Both of these ligaments are of great importance in maintaining the longitudinal arch of the foot, and in this respect are only second to the plantar calcaneo-navicular ligament.

A **synovial stratum** lines the capsule.

Articulatio Tarsi Transversa (Choparti).—This is a term sometimes applied to the talo-navicular and calcaneo-cuboid joints. These articulations do not communicate with each other; and although there is an occasional direct articulation between the navicular and cuboid, it does not constitute an extension of the transverse tarsal joint, but is a prolongation from the series of cuneo-navicular and cuneo-cuboid articulations.

Nevertheless there is always a set of **ligaments** which bind the navicular and cuboid bones together, and these may be regarded as accessory to the various transverse tarsal joints.

The **dorsal cuboideo-navicular ligament** (Fig. 297) consists of short oblique fibres which attach the contiguous dorsal surfaces of the cuboid and navicular bones.

The **plantar cuboideo-navicular ligament** is transverse in direction, and extends between adjacent plantar areas of the cuboid and navicular bones.

The **interosseous cuboideo-navicular ligament** intervenes between contiguous surfaces of the same bones. When there is an extension of the cuneo-navicular joint backwards between the navicular and cuboid, it is situated in front of the last-mentioned ligament, and is called the **articulatio cuboideonavicularis.** Around this joint the preceding ligaments are grouped. Since, however, the joint is inconstant while the ligaments are always present, it is preferable to consider them as above indicated.

Articulatio Cuneonavicularis.—The **cuneo-navicular articulation** is situated between the navicular and the three cuneiform bones. The anterior surface of the navicular presents a facet for each of the cuneiform bones, but its articular sufrace is not interrupted. These facets form a somewhat convex anterior surface which fits into the shallow articular concavity presented by the proximal ends of the three cuneiform bones. This joint may be extended by the occasional cuboideo-navicular articulation already referred to.

The **fibrous stratum** of the **articular capsule** is composed of short strong bands which are distinctly visible on all sides except towards the cuboid bone, where the joint may communicate with the cuneo-cuboid and cuboideo-navicular joints. Anteriorly the joint communicates with the intercuneiform articulations. The dorsal parts of the capsule are short longitudinal bands termed **dorsal cuneo-navicular ligaments** (Figs. 296 and 297). These extend without interruption to the medial aspect of the joint. Inferiorly there are similar bands, known as **plantar cuneo-navicular ligaments**, also longitudinal in direction, but intimately associated with offsets from the tendon of the tibialis posterior muscle.

The **synovial stratum** which lines the fibrous stratum sends prolongations forwards on each side of the second cuneiform bone, and in addition it often communicates with the cuneo-cuboid joint cavity (Fig. 300). It always communicates with the cuboideo-navicular cavity when that joint exists.

Articulationes Intercuneiformeæ.—These are two in number, and exist between adjacent contiguous surfaces of the three cuneiform bones. These surfaces are partly articular and partly non-articular. The small size of the second cuneiform bone allows the first cuneiform as well as the third cuneiform to project forwards beyond it, one on each side, and therefore the articular surfaces turned towards the second cuneiform are not entirely occupied by that bone. They form a recess facing the metatarsus, into which the base of the second metatarsal bone is thrust (Fig. 300).

Ligamenta intercuneiformea dorsalia constitute fairly strong transverse bands which extend between adjacent dorsal surfaces and invest the joint cavities in this direction.

The **ligamenta intercuneiformea plantaria** are two strong bands which pass from the rough non-articular areas on opposite sides of the second cuneiform to the opposing surfaces of the first and third cuneiform bones. These ligaments shut in the joint cavities inferiorly, and also anteriorly in the case of the lateral of the two joints.

The **ligamenta intercuneiformea interossea** are bands which bind together adjacent cuneiform bones.

The **synovial stratum** is continuous with that which lines the cuneo-navicular joint, and it is prolonged through the medial inter-cuneiform joint into the tarso-metatarsal series of joints.

Articulatio Cuneocuboidea.—This occurs between the rounded or oval facets on the opposing surfaces of the cuboid and third cuneiform.

The **ligamentum cuneocuboideum dorsale** is a flat, somewhat transverse band which closes the joint on its dorsal aspect, and extends between the dorsal surfaces of the two bones.

The **ligamentum cuneocuboideum plantare** is difficult to determine. It is situated deep to the long plantar ligament, and extends between adjacent rough surfaces of the two bones.

The **ligamentum cuneocuboideum interosseum** is the strongest. It closes the joint cavity anteriorly, and is attached to the contiguous non-articular surfaces of the two bones.

The **synovial stratum** is frequently distinct, but at other times the joint cavity communicates with those of the cuneo-navicular and cuboideo-navicular articulations.

Synovial Strata of the Intertarsal Joints.—Four and sometimes five distinct and separate synovial strata may thus be enumerated in connexion with the tarsal articulations, viz.: (1) talo-calcaneal; (2) talo-calcaneo-navicular; (3) calcaneo-cuboid; (4) cuneo-navicular and its extensions (Fig. 300); (5) occasionally cuneo-cuboid.

ARTICULATIONES TARSOMETATARSEÆ.

The **tarso-metatarsal joints** are found between certain articular facets on the cuboid and three cuneiform bones on the one hand, and others on the bases of the five metatarsal bones. These articulations are associated with three distinct synovial cavities—namely, a medial, lateral, and intermediate.

(1) The **medial tarso-metatarsal articulation** occurs between the anterior convex reniform surface of the first cuneiform bone and the concavo-reniform surface on the posterior aspect of the base of the first metatarsal bone.

Ligaments which form the fibrous stratum of the **articular capsule** surround the articulation. In the capsule the **ligamenta tarsometatarsea dorsalia et plantaria** are its strongest parts, but it is not deficient either on the medial or on the lateral aspects.

A separate **synovial stratum** lines the fibrous stratum.

(2) The **intermediate tarso-metatarsal articulation** is an elaborate joint. It involves the three cuneiform bones and the bases of the second, third, and part of the fourth metatarsal bones.

The articulation presents the outline of an indented parapet both on its tarsal and its metatarsal aspects. Thus, on its tarsal side, the first and the third cuneiform bones project in front of the second cuneiform, so that the latter only presents a distal surface to the articulation; while the first cuneiform presents a portion of its lateral surface, and the third cuneiform presents both its distal and portions of its lateral and medial surfaces, since it projects in front of the cuboid bone. On its metatarsal side the base of the second metatarsal bone fits into the indentation between the third and first cuneiforms, to which it presents lateral and medial articular facets, but its posterior facet rests upon the anterior facet of the second cuneiform. The base of the third metatarsal bone rests its posterior facet upon the third cuneiform. The fourth metatarsal base presents part of its medial facet to the lateral side of the third cuneiform. In this way the indentations alternate on the two sides of the articulation, and an extremely powerful interlocking of parts is provided, which places any marked independent movement of these metatarsal bones entirely out of the question.

The **ligamenta tarsometatarsea dorsalia** are broad, flat bands which represent the most distinct part of the fibrous stratum of an investing **articular capsule**. They pass from behind forwards, and while the second metatarsal bone receives three, *i.e.* one from each cuneiform, the third metatarsal only receives one—from the third cuneiform.

The **ligamenta tarsometatarsea plantaria** correspond with the foregoing in their general arrangement, but they are weaker. That for the second metatarsal is the strongest. Oblique bands extend from the first cuneiform bone to the second and third metatarsals.

The **ligamenta cuneometatarsea interossea** are three in number. The *medial* connects the lateral side of the first cuneiform with the medial side of the base of the second metatarsal bone. The *middle* connects the medial side of the third cuneiform with the lateral side of the base of the second metatarsal. The *lateral* connects the adjacent lateral sides of the third cuneiform and fourth metatarsal.

The **stratum synoviale**, which lines this articulation, sends a prolongation backwards between the first and second cuneiform bones, where it opens into the cuneonavicular joint. It is likewise prolonged forwards upon both sides of each of the bases of the second and third metatarsal bones.

(3) The **lateral tarso-metatarsal articulation** is found between the proximal surfaces of the bases of the fourth and fifth metatarsal bones and the distal surface of the cuboid (Fig. 300).

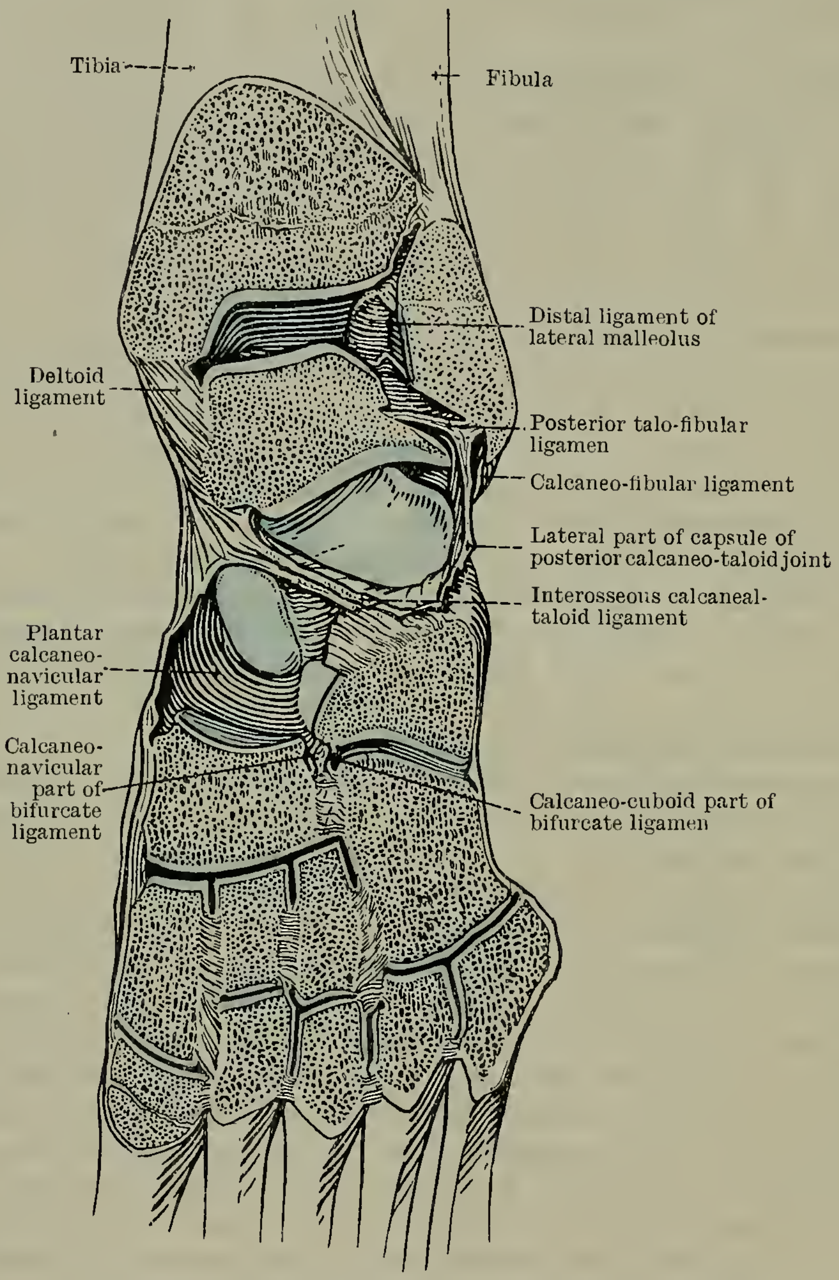
Tibia
Fibula
Distal ligament of lateral malleolus
Deltoid ligament
Posterior talo-fibular ligamen
Calcaneo-fibular ligament
Lateral part of capsule of posterior calcaneo-taloid joint
Interosseous calcaneal-taloid ligament
Plantar calcaneo-navicular ligament
Calcaneo-navicular part of bifurcate ligament
Calcaneo-cuboid part of bifurcate ligamen

Fig. 300.—Section showing the Joint Cavities of the Ankle and the Region of the Tarsus.

The communication between the medial inter-cuneiform joint and the tarso-metatarsal joint is not shown.

The fibrous stratum of the investing **articular capsule** may be resolved into the following ligaments:—

The **ligamenta tarsometatarsea dorsalia** resemble those already described. The base of the fourth metatarsal receives one from the third cuneiform and one from the cuboid. The base of the fifth metatarsal receives one from the cuboid.

The **ligamenta tarsometatarsea plantaria** are the weakest bands of the series, and consist of scattered fibres passing from the cuboid to the bases of the two metatarsals. Some fibres, which are almost transverse, extend from the third cuneiform to the fifth metatarsal, and additional fibres reach the fifth metatarsals from the long plantar ligament.

Occasionally the tarsal end of the ligamentum cuneometatarseum interosseum laterale is attached to the medial margin of the cuboid.

The **synovial stratum** is restricted to this articulation, and merely sends a prolongation forwards between the opposing articular surfaces of the fourth and fifth metatarsal bases.

ARTICULATIONES INTERMETATARSEÆ.

The **intermetatarsal articulations** are found between adjacent lateral aspects of the bases of the four lateral metatarsal bones. The articular facets are small, oval, or rounded surfaces which occupy only a limited portion of the flattened contiguous surfaces of the bones. Each joint is provided with an **articular capsule**, which, however, is not a complete investment, because the three joint cavities are in free communication on their proximal aspects with the tarso-metatarsal joint cavities —one with the lateral and two with the intermediate. The definite fibres of each fibrous stratum are situated chiefly in the transverse direction.

The **ligamenta basium dorsalia** are short bands which extend from one base to the other.

The **ligamenta basium plantaria** and the **ligamenta basium interossea** are similarly arranged, but the interosseous ligaments are the strongest and most important members of this series.

The **synovial stratum** of each capsule is an extension from the lateral and intermediate tarso-metatarsal joints (Fig. 300).

Frequently a bursa is found between the bases of the first and second metatarsal bones. It produces an appearance of indistinct facetting upon these bones, and it may communicate with the first cuneo-metatarsal joint.

The **ligamentum metatarsale transversum (transverse metatarsal ligament)** lies upon, and is attached to, the non-articular plantar aspects of the heads of all the metatarsal bones. It differs from the corresponding ligament in the palm in the fact that it binds all the metatarsal bones together, whereas in the palm the thumb is left free. It is closely associated with the plantar fibrous plates of the metatarso-phalangeal joints, to the plantar surfaces of which it contributes prolongations.

ARTICULATIONES METATARSOPHALANGEÆ.

Metatarso-phalangeal Joints.—Each of these joints is a modified ball-and-socket in which a shallow cup upon the bases of the first phalanges receives the somewhat globular head of a metatarsal bone.

Each joint retains a modified **articular capsule** which invests the joint. Its only distinct bands of the fibrous stratum are the **ligamenta collateralia**. These are strong cord-like bands which are situated on the medial and lateral sides of each joint, where they extend between adjacent rough surfaces.

On the dorsal aspect, ligaments distinct from the dorsal expansion of the extensor tendons can hardly be said to exist. The plantar aspect of the capsule consists of a thick **fibrous plate** strengthened by transverse fibres to form the **plantar accessory ligament**, which in the case of the great toe presents developed within it two large sesamoid bones. In the other toes this plate remains fibrous throughout, and is grooved on its plantar aspect for the accommodation of the long flexor tendons. It will thus be seen that the metatarso-phalangeal joints are constructed upon a plan very similar to that of the corresponding joints in the hand.

A **synovial stratum** lines the capsule of each articulation; and the epiphyseal lines of the metatarsals and phalanges are extra-capsular.

ARTICULATIONES DIGITORUM PEDIS.

Interphalangeal Joints.—Each toe possesses two interphalangeal joints except the great toe, which has only one. Not infrequently in the little toe the distal joint is obliterated through ankylosis. All the joints of this series are uniaxial or hinge joints. The nature of the articular surfaces closely resembles the corresponding joints in the fingers.

Each joint possesses an **articular capsule** which is either very thin or limited to the synovial stratum on the dorsal aspect. The plantar surface of the capsule is strengthened by a **fibrous plate.** The **ligamenta collateralia** are well-defined bands similar to those already described in connexion with the metatarso-phalangeal joints.

A **synovial stratum** lines each capsule in the series. The epiphyseal lines are extra-capsular.

Mechanism of the Foot.—The bones of the foot are arranged in the form of a longitudinal and a transverse arch. The longitudinal arch is built on a very remarkable plan. Posteriorly the mass of the calcaneus constitutes a rigid and stable pier of support, while anteriorly, by increasing the number of component parts, the anterior pier acquires great flexibility and elasticity without sacrificing strength or stability. The summit of the arch is formed by the talus, which receives the weight of the body from the tibia, and the resilience of the arch is assured by the calcaneo-navicular, calcaneo-cuboid, and long plantar ligaments, together with the plantar aponeurosis, which act as powerful braces or tie-bands, preventing undue separation of the piers of the arch, and consequent flattening of the foot. The weight of the body is distributed over all the five digits, owing to the arrangement of the bones of the foot in two parallel columns, a **medial** and a **lateral.** The former, consisting of the talus, navicular, and the three cuneiforms, with the three medial metatarsal bones, distributes weight through the talo-navicular joint, while the latter (*i.e.* the lateral column), comprising the calcaneus, cuboid, and the two lateral metatarsal bones, acts in a similar manner through the talo-calcaneal joint. The main line of immobility of this arch passes from the heel forwards through the middle toe, but its anterior section, which is slender, is supported on either side by two metatarsal bones, with their proximal tarsal associations, in all of which greater freedom of movement is found. The transverse arch is most marked at the level of the tarso-metatarsal articulations. The intersection of these two arches at right angles to each other introduces an architectural feature of great importance in connexion with the support of heavy weights. These longitudinal and transverse arches of the foot are in effect "vaults" intersecting each other at right angles, and in relation to the area which is common to both "vaults" the body weight is superposed exactly as the dome of a cathedral is carried upon two intersecting vaults.

Movements at the Joints of the Tarsus, Metatarsus, and Phalanges.—Considered in detail, the amount of movement which takes place between any two of these bones is extremely small, and, so far as the tarsus and metatarsus are concerned, it is mostly of the nature of a gliding motion.

At the metatarso-phalangeal and interphalangeal joints movement is much more free, and is of the nature of **flexion** (bending of the toes towards the sole of the foot, *i.e.* plantar flexion) and **extension.** The latter movement when continued so as to raise the toes from the ground, and bend or approximate them towards the front of the leg, is termed **dorsiflexion.** Coincident with dorsiflexion there is always associated a certain amount of spreading of the toes, which is called **abduction,** and similarly with prolonged flexion there follows a diminution or narrowing of the transverse diameter of the anterior part of the foot by drawing the toes together—a movement termed **adduction.** In the foot the movements of abduction and adduction take place in regard to a plane which bisects the foot antero-posteriorly through the second toe, for this toe carries the first and second dorsal interosseous muscles.

Notwithstanding the small amount of possible movement in connexion with individual tarsal and metatarsal joints, yet the sum total of these movements is considerable as regards the entire foot. In this way the movements of **inversion** and **eversion** of the foot result. By inversion we mean the raising of the medial border of the foot so that the sole looks medially, while the toes are depressed towards the ground, and the lateral border of the foot remains downwards. This takes place chiefly at the talo-calcanean joint, but the transverse tarsal joints also participate.

Eversion is chiefly the opposite of inversion, and the return of the foot to the normal position of the erect attitude; but under certain conditions it may be carried further, so that the lateral border of the foot is raised from the ground, while the medial border is depressed. In both of these movements there is **rotation** between the talus and calcaneus about an oblique axis which passes from the medial side of the neck of the talus to the lateral and inferior part of the calcaneus.

Of course, all the movements of the foot are subordinated to its primary functions as an organ of support and progression. For these purposes its longitudinal and transverse arches are of extreme importance. The longitudinal arch resting on the calcaneus behind and the heads of the metatarsal bones in front receives the weight of the body, as already explained, on the summit of the talus in the line of the third toe. Hence it is that the medial malleolus appears to be unduly prominent on the medial side of the ankle. The transverse arch buttresses the longitudinal one, and therefore, whether the body weight fall to the lateral or the medial side of the longitudinal arch, it is supported by a mechanism at once stable, flexible, and elastic, or resilient, and capable of reducing to a minimum all jars that may be received by the fore part of the foot. As the heel is raised in the act of walking, the weight is gradually transferred from the lateral to the medial side of the foot, until the foot finally leaves the ground with a propulsive movement, which results from flexion of the phalanges of the great toe. In this connexion it is worthy of note that the longitudinal line of greatest strength is on the medial side of the longitudinal arch, *i.e.* in relation to the great toe.

THE MUSCULAR SYSTEM.

MYOLOGY.

By A. M. Paterson.

Revised and partly rewritten by T. B. Johnston.

All muscle is derived from mesoderm, the cells of which become specialised to form muscle fibres and acquire the characteristic power of contractility. There are three varieties of muscle tissue, which can readily be distinguished from one another by their histological appearances, viz. :—(*a*) **striated** or **voluntary**; (*b*) **cardiac**; and (*c*) **unstriated, plain**, or **involuntary**. Group (*b*) is present only in the walls of the heart, and group (*c*) is found in the walls of viscera, blood-vessels, ducts of glands, etc. Both are entirely concerned with the internal economy of the body. Group (*a*), of which the skeletal muscles are formed, is concerned, for the most part, in the production of movements which result in some alteration of a part or parts of the body relative to the outside world.

It is with the skeletal muscles only that this section deals.

A **typical skeletal muscle** consists of a number of *fasciculi* or muscle bundles, enveloped in a connective tissue sheath termed *fascia*, and usually connected, at one or both extremities, with bundles of white fibrous tissue which constitute some variety of *tendon*.

Each fasciculus is surrounded and bound to its neighbours by a delicate connective tissue, the **perimysium externum**, and each consists of a number of elongated muscle fibres, held together in their turn by the **perimysium internum**. The perimysium internum is connected on the one hand to the **sarcolemma** (or cell-wall of the muscle fibre) and on the other to the perimysium externum, by which it is brought into connexion with some part of a tendon.

Attachments.—In order that a muscle may effectively exercise its power of contractility, it must possess (1) a relatively fixed point of attachment, which is termed the **origin**, and (2) a movable point of attachment, which is termed the **insertion**. These attachments are subject to a wide range of variation. Bones, cartilages, tendons, fibrous raphes, fasciæ, ligaments, and skin may serve this purpose, and the extent and character of the attachments show marked individual differences.

Muscular attachments may be (1) fleshy, (2) tendinous, or (3) a combination of the two. In the first case, *e.g.* vastus intermedius, the fleshy fibres appear to spring directly from the bone, although the actual union is perimysium to periosteum. In the second case, a varying extent of white fibrous tissue is interposed between the attachment and the fleshy belly. This intermediary is termed a **tendon**, and the shape and appearance of tendons show well-marked variations, the extremes being represented by the narrow ribbon-like tendon of the palmaris longus and the broad sheet-like tendon of the obliquus externus abdominis. The latter is usually referred to as an **aponeurosis**.

In some cases a muscle consists of two bellies connected by an *intermediate tendon*. Such muscles are termed digastric or biventral. The fleshy bellies may be set at an angle to one another (*e.g.* digastric and omohyoid), and in this event the intermediate tendon is anchored to some part of the skeletal system by a fascial sling. On the other hand, the two bellies may be placed in the same straight line.

The tendon, whether of origin or insertion, usually sends prolongations into the substance of the muscle, an arrangement which obviates the necessity for long fibres.

Muscular Form.—The amount of shortening which any muscle undergoes during contraction is directly proportional (nearly 1:2) to the length of its constituent fibres. (The longest muscle fibres are found in the sartorius and they do not exceed 15 cm.) The power which a muscle can exert varies directly with the number of its fibres. These two facts serve to explain the form of many skeletal muscles.

In some muscles the fibres run parallel (or nearly parallel) to the long axis. They are termed **fusiform**. When the points of attachment of a fusiform muscle are widely separated, a long tendon of insertion is provided, an arrangement which is economical of muscle tissue and does not interfere with efficiency.

When power is a prime consideration, a different arrangement of the fibres is adopted and the various **penniform** types result. In **unipenniform** muscles, the fibres are placed parallel to one another but not to the long axis. This arrangement provides the necessary increase in the number of fibres by increasing the length of the muscular belly (*e.g.* vastus medialis). There is a very slight loss of efficiency, it is true, but this loss is partly compensated for by economy in tendon, since the long broad tendon, which would have been required had the fibres been arranged in a fusiform manner, is replaced by a tendon, broad distally but tapering as it is continued proximally along one border of the muscle. In **bipenniform** (*e.g.* rectus femoris) and **multipenniform** muscles (*e.g.* deltoid) still greater power is obtained by a slight modification of the same arrangement.

Muscular Action.—Certain muscles, *e.g.* the diaphragm, the constrictors of the pharynx, etc., although included amongst the skeletal muscles and controlled, for the most part, by the will, exert their actions on viscera, but the great majority of skeletal muscles exercise their functions by producing movements at the joint or joints over which they pass on their way from origin to insertion.

When a muscle contracts, its insertion is, as a general rule, approximated to its origin, but, in cases where both attachments are movable, it frequently happens that the insertion may, for the time being, become relatively more fixed than the origin. The contraction of the muscle then results in the approximation of the origin to the insertion. For example, under ordinary conditions the serratus anterior acts on the scapula, but, when that bone is fixed by the action of synergic muscles, it can act as an accessory muscle of inspiration by elevating the ribs from which it arises.

Most of the skeletal muscles utilise the bones as levers and the particular action of any muscle is a simple problem in mechanics. It depends on the position of the two attachments and the relation of the muscle to the axes of the movements which are possible at the joint, or joints, over which it passes. Thus, in the case of the elbow joint where movements occur around a transverse axis only, all muscles which pass anterior to the joint can act as flexors, and all muscles which pass posterior to the joint can act as extensors. When the multi-axial joints are considered, the conditions are found to be much more complicated. Study the attachments of the pectoralis major and its relationship to the shoulder joint when the arm is by the side. Its action is obvious. It is a flexor, because it lies ventral to the transverse axis of the joint; it is an adductor, because it lies below the antero-posterior axis of the joint; and it is a medial rotator, because it passes in front of the vertical axis of the humerus. It must be noted, however, that an alteration in the position of the bone acted upon, may cause an alteration in the relation of a muscle to a particular axis and a consequent alteration in its action. Thus, when the arm is flexed to a right angle, the costo-sternal portion of the pectoralis major acts as an extensor (depressor), although these same fibres act as flexors of the extended arm.

All such mechanical problems are, to a large extent, of academic interest only, for it is movements and not individual muscles which are represented in the cerebral cortex. The movements at any given joint are never simple, and they almost invariably involve (1) active contraction of a group of **prime movers** to carry out the movement, (2) relaxation of the **antagonists** to enable the movement to be effected, and (3) active contractions of other groups which serve to steady adjoining parts and to obtain efficient working. This group includes two subdivisions. (*a*) **Fixation** muscles steady a movable point of origin, *e.g.* in the early stages of abduction at the shoulder-joint, the trapezius, the serratus anterior, etc., fix the scapula to enable the deltoid and the supraspinatus to act on the humerus. (*b*) **Synergic** muscles are called into play to prevent prime movers from wasting power by acting on such intermediate joints as they pass over, *e.g.* when the fist is clenched, the flexors of the digits are prevented from flexing the wrist by the synergic action of the extensors of that joint.

It becomes apparent, therefore, that the paralysis of any one muscle will not only result in a weakening of the movement, which it can, theoretically, bring about, but will also upset the balance of all movements in which it plays a part as a prime mover or as a synergic or fixation agent.

Topographically, muscles are usually arranged in groups, possessing common or related actions and common sources of nerve-supply. The groups are separated from one another by sheets of connective tissue of varying strength, known as *intermuscular septa.* Muscles of the same group may arise by independent heads of origin and possess a common insertion (*e.g.*, biceps brachii, triceps brachii, and quadriceps femoris).

Muscle Tone.—All living muscle possesses tone, and, by virtue of this property, many skeletal muscles effect an important influence when in the resting state. For example, the abdominal muscles control the position of the abdominal viscera by their tone alone, and, in the same way, the muscles which pass over the elbow joint retain the proximal ends of the radius and ulna in contact with the distal end of the humerus.

Nerve-Supply.—Each muscle is supplied by one or more nerves, which, in their course through it, separate into smaller and smaller branches. Ultimately their terminal filaments (axons) give off numerous collaterals, each of which forms a special end-organ in relation to a muscle cell.

It has been estimated that of the fibres contained in a nerve of supply to a muscle three-fifths are motor and two-fifths are sensory.

FASCIÆ.

Beneath the skin there are two (or in some regions three) layers of tissue which require consideration in relation to the muscular system: the superficial fascia (panniculus adiposus), the deep fascia, and, in animals, the panniculus carnosus (rudimentary in man, and represented chiefly by the *platysma* in the neck).

Fascia Superficialis (Superficial Fascia).—The superficial fascia is a continuous sheet of areolar tissue which underlies the skin of the whole body. It is closely adherent to the cutis vera, and is sometimes termed **panniculus adiposus**, from the fact that, except beneath the skin of the eyelids, penis, and scrotum it is usually more or less impregnated with fat. The cutaneous vessels and nerves ramify in this fascia; and its deep surface, membranous in character, is in loose connexion with the subjacent deep fascia. It is in this layer that dropsical effusions chiefly occur.

Fascia Profunda (Deep Fascia).—Underneath the skin and superficial fascia is a fibrous membrane, bluish white in colour, devoid of fat, and in closest relation to skeleton, ligaments, and muscles. This is the deep fascia. It covers, invests, and in some cases forms the means of attachment of the various muscles. It has a special tendency to become attached to all subcutaneous bony prominences, and to be continuous with the connecting ligaments. It forms septal laminæ, which separate groups of muscles and individual muscles; enclose glands and viscera; and form sheaths for vessels and nerves.

In the distal portions of the upper and lower extremities, where the various joints are close to one another, special thickenings of the deep fascia are present for the purpose of retaining the tendons in position when their muscles contract. These fascial bands act as pulleys round which the tendons work and they serve to prevent waste of power. This condition is further modified on the flexor aspects of the digits for the same purpose. The fibrous bands are connected to one another and to the phalanges in such a way as to form osteo-fascial tunnels in which the tendons lie.

Vaginæ Mucosæ.—In the situations just described where tendons are retained in place by localised thickening of the deep fascia, mucous sheaths are provided for them to facilitate their movements. Such sheaths may be related to one or more tendons. They are always closed sacs, with a parietal layer lining the space in which the tendon lies and a "visceral" layer closely applied to the tendon itself, so that the two mucous surfaces are in apposition with one another.

In the digital, mucous sheaths, continuity is established between the parietal and visceral layers by means of **vincula tendinum** (p. 391), as well as at the extremities of the sheaths. The vincula tendinum transmit small blood-vessels and may be regarded as incomplete "meso-tendons."

Bursæ Mucosæ.—Simple, closed, mucous sacs are placed between a tendon (or an aponeurosis) and a bony point or ligament over which it plays, or between the distal ends of two or more tendons, when they are inserted in close proximity to one another.

The **panniculus carnosus** is a thin muscular layer enveloping the trunk of animals with a hairy or furry coat. It is strongly developed in the hedgehog. In man it is represented mainly by the (rudimentary) platysma. It is placed between the superficial and the deep fascia.

Description of Muscles.—In studying the muscular system it is necessary to note the following characters in reference to each individual muscle: (1) The *shape* of the muscle—flat, cylindrical, triangular, rhomboidal, etc.; and the character of its extremities—membranous, tendinous, or fleshy. (2) The *attachments* of the muscle. (3) The *relations* of the surfaces and borders of the muscle to bones, joints, muscles, and other important structures. (4) Its *vascular* and *nervous supply*; and (5) *Its actions.*

DESCRIPTION OF THE MUSCLES.

The skeletal muscles may be divided into two series: axial and appendicular. The **axial** muscles comprise the muscles of the trunk, head, and face, including the **panniculus carnosus** (platysma). These muscles are more or less segmental in arrangement, and are grouped around the axial skeleton. The **appendicular muscles**, the muscles of the limbs, are grouped around the appendicular skeleton. They are not segmental in arrangement, they are morphologically separate from the axial muscles, and they are arranged in definite strata in relation to the bones of the limbs.

APPENDICULAR MUSCLES.

THE UPPER LIMB.

FASCIÆ AND SUPERFICIAL MUSCLES OF THE BACK.

Fasciæ.

The **superficial fascia** of the back presents no peculiarity. It is usually of considerable thickness, and contains a quantity of fat.

The **deep fascia** closely invests the muscles. It is attached in the median plane of the back to the ligamentum nuchæ, supraspinous ligaments, and vertebral spines; laterally it is attached to the spine of the scapula and to the clavicle, and is continued over the deltoid region to the arm. In the neck it is attached, above, to the superior nuchal line of the occipital bone, and is continuous, laterally, with the deep cervical fascia. Below the level of the shoulder it is continuous, round the border of the latissimus dorsi muscle, with the fascia of the axilla and of the abdominal wall. In the back and loin it blends with the **fascia lumbodorsalis** or aponeurosis of the latissimus dorsi. This layer conceals the sacrospinalis muscle, and is attached medially to the vertebral spines, and laterally to the angles of the ribs, and to the iliac crest.

The Superficial Muscles of the Back.

The muscles of the back are arranged in four series according to their attachments: (1) vertebro-scapular and vertebro-humeral; (2) vertebro-costal; (3) vertebro-cranial; and (4) vertebral. The first of this series consists of the posterior muscles connecting the superior extremity to the trunk, and comprises the first two layers of the muscles of the back—(1) trapezius and latissimus dorsi, and (2) levator scapulæ and rhomboidei (major and minor). The deeper (axial) muscles of the back are dealt with later (p. 438).

M. Trapezius.—The **trapezius** is a large triangular muscle which lies in the upper part of the back. It **arises** from the superior nuchal line of the occipital bone in its medial third, from the external occipital protuberance (Fig. 370, p. 445), from the ligamentum nuchæ, from the spines of the seventh cervical and all the thoracic vertebræ, and the intervening supraspinous ligaments. The origin is by direct fleshy attachment, except in relation to the occipital bone, the lower part of the neck, and the lower thoracic vertebræ, in which places the origins are tendinous.

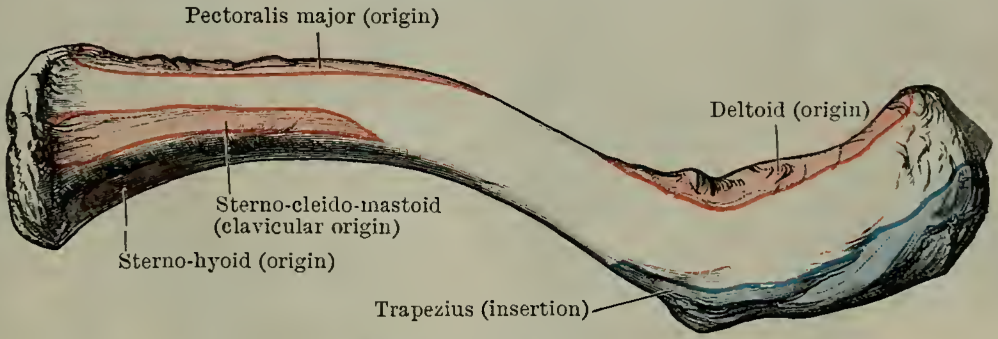
Pectoralis major (origin)
Deltoid (origin)
Sterno-cleido-mastoid (clavicular origin)
Sterno-hyoid (origin)
Trapezius (insertion)

FIG. 301.—MUSCLE-ATTACHMENTS TO THE RIGHT CLAVICLE (Upper Surface).

From their origins the muscular fibres converge towards the bones of the shoulder, to be **inserted** continuously from before backwards as follows: (1) The occipital and upper cervical fibres—into the posterior aspect of the clavicle in its lateral third (Figs. 301, p. 369, and 305, p. 375); (2) the lower cervical and upper thoracic fibres—into the medial border of the acromion, and the upper border of the spine of the scapula; and (3) the lower thoracic fibres, by a triangular flat tendon, beneath which a bursa is placed—into a rough tuberosity at the base of the spine of the scapula (Fig. 303, p. 371). The fibres inserted into the clavicle, acromion, and the upper border of the spine of the scapula spread over the adjacent subcutaneous surfaces of those bones for a variable distance. The occipital portion of the muscle may be in the form of a separate slip, or may be entirely absent.

The trapezius is superficial in its whole extent. Its upper lateral border forms the posterior limit of the posterior triangle of the neck. The inferior lateral border passes over the upper edge of the latissimus dorsi and the vertebral margin of the scapula, and forms a boundary of the so-called *triangle of auscultation*, which is completed, below, by the latissimus dorsi, and, laterally, by the vertebral margin of the scapula. This space is partly filled up by the rhomboideus major. The muscle overlaps the latissimus dorsi, and covers the rhomboidei, levator scapulæ, splenius capitis, semispinalis capitis, and the deeper axial muscles of the back, along with the ascending and the descending branch of the transverse artery of the neck, the accessory nerve, and muscular branches from the cervical plexus.

Nerve-Supply.—The trapezius has a double nerve-supply: (1) from the terminal fibres of the accessory nerve, and (2) from the cervical plexus (C. 3. and 4.). The cervical nerves communicate with the accessory nerve in the posterior triangle of the neck and beneath the trapezius.

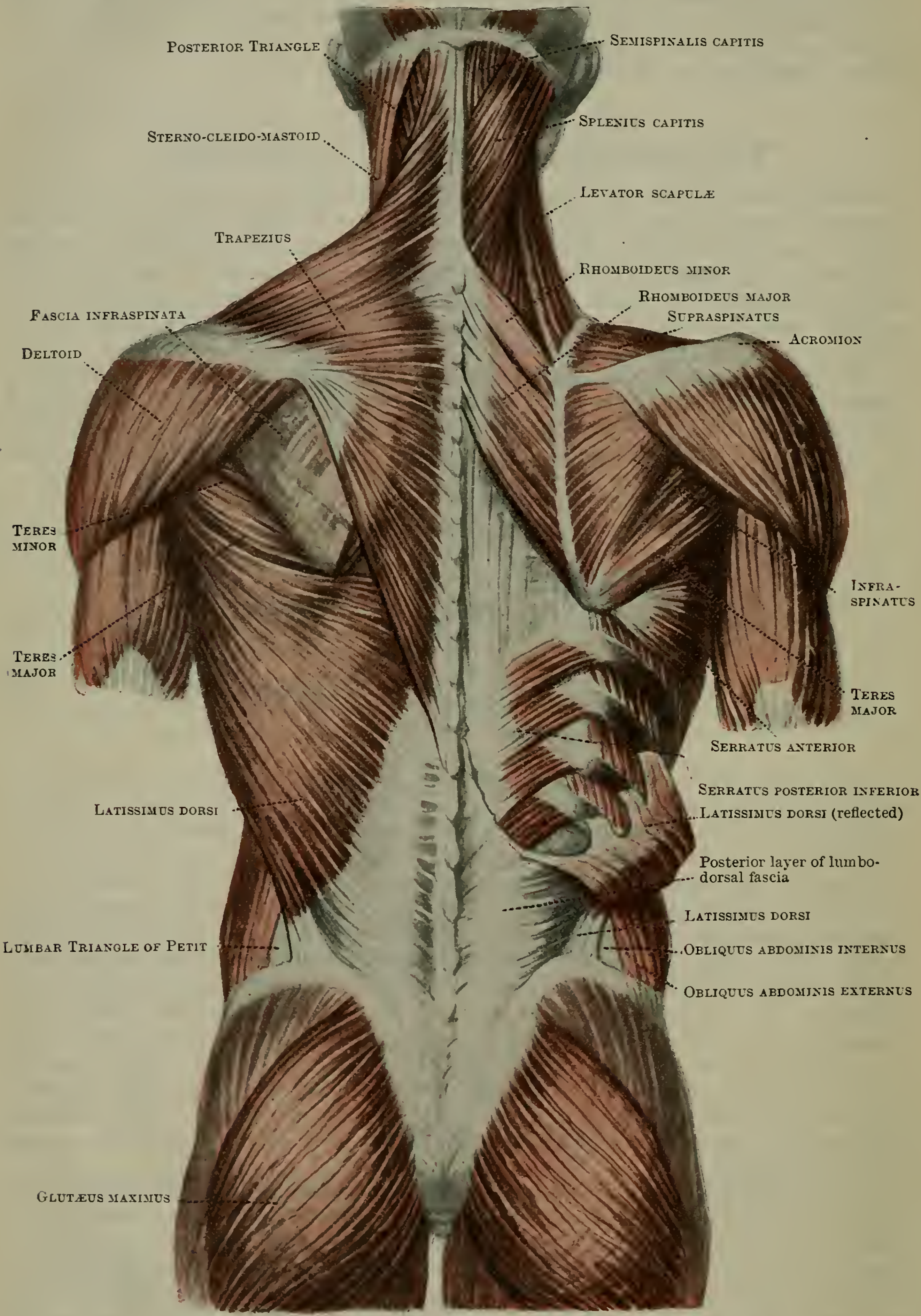

Fig. 302.—Superficial Muscles of the Back, and Vertebro-scapular Muscles.

Actions.—(1) In association with the serratus anterior the trapezius rotates the scapula so that the inferior angle passes laterally and forwards, and it elevates the lateral end of the clavicle. This rotation plays an important part in abduction of the humerus, after the bone has moved through an angle of about 30°. In the initial stage of this movement the trapezius and serratus anterior play the part of fixation muscles in order to prevent the deltoid and supraspinatus from exerting their action on the scapula instead of the humerus. (2) It assists the rhomboids to approximate the scapulæ, so bracing back the shoulders. (3) The upper fibres, in association with the levator scapulæ, elevate the lateral end of the clavicle and the scapula, as in shrugging movements. (4) The upper fibres, in association with the longissimus capitis, extend the head on the neck.

M. Latissimus Dorsi.—The **latissimus dorsi** is a large triangular muscle occupying the lower part of the back. The greater part of the muscle arises—(1) from the spines of the lower six thoracic vertebræ, and from the posterior layer of the lumbo-dorsal fascia (p. 437), so gaining attachment to the spines of the lumbar vertebræ, and the tendon of the sacrospinalis, with which the fascia blends below. It also arises laterally from the posterior part of the outer lip of the iliac crest.

From its origin the muscle is directed upwards and laterally, its fibres converging to the inferior angle of the scapula. In relation to its lateral and upper borders additional fibres arise. (2) *Along the lateral border* muscular slips arise from the lower three or four ribs, interdigitating with the slips of origin of the obliquus abdominis externus. (3) As *the superior border* of the muscle passes, horizontally, over the inferior angle of the scapula, an additional fleshy slip usually takes origin from that part of the bone and joins the muscle on its deep surface (Fig. 303).

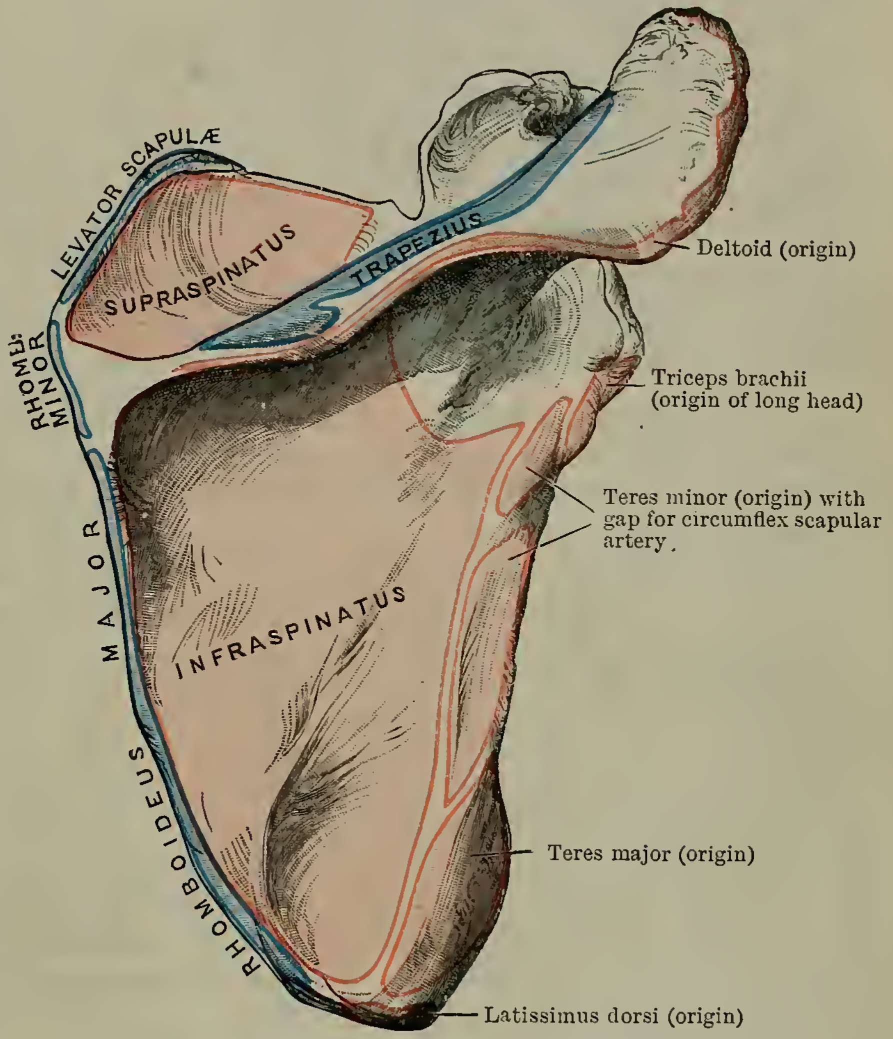
LEVATOR SCAPULÆ
SUPRASPINATUS
TRAPEZIUS
Deltoid (origin)
RHOMB. MINOR
Triceps brachii (origin of long head)
Teres minor (origin) with gap for circumflex scapular artery.
RHOMBOIDEUS MAJOR
INFRASPINATUS
Teres major (origin)
Latissimus dorsi (origin)

FIG. 303.—MUSCLE-ATTACHMENTS TO THE RIGHT SCAPULA (Dorsal Surface).

Beyond the inferior angle of the scapula the latissimus dorsi, greatly narrowed, curves spirally round the teres major muscle, and forms the prominence of the posterior axillary fold. It ends in a ribbon-like tendon, which is closely adherent, at first, to the teres major, and is inserted into the floor of the intertubercular sulcus of the humerus, extending for about three inches distal to the lesser tubercle (Fig. 314, p. 383). It is placed behind the axillary vessels and nerves, and in front of the insertion of the teres major, from which it is separated by a bursa.

In the back the latissimus dorsi is superficial, except in its upper part, which is concealed by the trapezius. It covers part of the lumbo-dorsal fascia, the serratus posterior inferior, the lower ribs, and the inferior angle of the scapula. At its upper border is the so-called *triangle of auscultation*; at its lateral border is the lumbar *triangle of Petit*, a small space bounded by the iliac crest, the latissimus dorsi, and the obliquus abdominis externus. This space is sometimes the site of a lumbar hernia.

[illegible]

Nerve-Supply.—The muscle has a single nerve—the thoraco-dorsal nerve—which supplies it on its deep surface. It is a branch from the posterior cord of the brachial plexus (C. (6.) 7. 8.).

Actions.—The latissimus dorsi is a powerful adductor and extensor of the humerus, so lowering the arm as in swimming. It also assists in medial rotation of the arm. Further, it acts from its insertion under three conditions: (1) It plays an important part in climbing, drawing the body upwards after the arms; (2) it assists the abdominal muscles (p. 486) in violent expiratory efforts; and (3) it is said to act as an accessory muscle of inspiration by elevating the lower ribs.

M. Levator Scapulæ.—The **levator scapulæ** is a strap-like muscle, **arising** by tendinous slips from the posterior tubercles of the transverse processes of the first three or four cervical vertebræ, between the attachments of the scalenus medius in front and the splenius cervicis behind.

It is directed downwards, to be **inserted** into the vertebral margin of the scapula, from the medial angle to the spine (Fig. 303).

It is concealed in its upper third by the sterno-mastoid muscle. Its middle third forms part of the floor of the posterior triangle and is related to the accessory nerve. In its lower third it is hidden by the trapezius, and conceals the dorsal scapular nerve and the descending branch of the transverse cervical artery.

Nerve-Supply.—The levator scapulæ has a double nerve-supply:—(1) from the dorsal scapular nerve from the brachial plexus (C. 5.), which either pierces or goes beneath the muscle, and (2) from the cervical plexus. Small branches from the anterior rami of the third and fourth cervical nerves enter the muscle on its superficial surface near its origin.

M. Rhomboideus Minor.—The **rhomboideus minor** may be regarded as a separated slip of the rhomboideus major, with which it is often continuous. It **arises** from the *ligamentum nuchæ* and the spines of the seventh cervical and first thoracic vertebræ.

Passing obliquely downwards and laterally it is **inserted** into the vertebral margin of the scapula below the levator scapulæ muscle, and opposite to the base of the spine (Fig. 303).

M. Rhomboideus Major.—The **rhomboideus major arises** from the spinous processes of the thoracic vertebræ from the second to the fifth inclusive, and from the corresponding supraspinous ligaments.

It also passes downwards and laterally and is **inserted**, below the rhomboideus minor, into the vertebral margin of the scapula, between the spine and the inferior angle (Fig. 303). The muscle is only inserted directly into the scapula by means of its inferior fibres. Its superior part is attached to a membranous band, which is connected to the vertebral margin of the scapula, for the most part by loose areolar tissue, but it is fixed to the bone at its extremities, above near the apex of the spine, and below at the inferior angle.

The rhomboid muscles are concealed to a large extent by the trapezius. The lower part of the rhomboideus major is superficial in the *triangle of auscultation.* The muscles cover the serratus posterior superior and vertebral aponeurosis.

Nerve-Supply.—The rhomboid muscles are supplied by the dorsal scapular nerve from the brachial plexus (C. 5.), which supplies branches to the deep surface of the muscles.

Actions.—The levator scapulæ and the rhomboids, which are the opponents of the trapezius and serratus anterior, rotate the scapula so that its inferior angle passes medially. Co-operating with the trapezius the levator scapulæ elevates the point of the shoulder, as in shrugging movements. The rhomboids, in association with the trapezius, approximate the two scapulæ, so bracing back the shoulders.

THE FASCIÆ AND MUSCLES OF THE PECTORAL REGION.

FASCIÆ.

The **superficial fascia** of the chest usually contains a quantity of fat, in which the mamma is embedded. The origin of the platysma muscle lies beneath its superior part.

The **deep fascia** is attached above to the clavicle, and, medially to the sternum. Below it is continuous with the fascia of the abdominal wall. It gives origin to the platysma and invests the pectoralis major. At the lateral border of the great pectoral muscle it is thickened, and forms the floor of the axillary space **(axillary fascia)**, continued posteriorly on to the posterior fold of the axilla and laterally into connexion with the deep fascia of the arm.

Costo-Coracoid Membrane.—Beneath the pectoralis major a deeper stratum of fascia invests the pectoralis minor muscle. At the superior border of this muscle it forms the costo-coracoid membrane, which passes upwards to the inferior border of the subclavius muscle, where it splits into two layers, attached in front of and behind that muscle to the borders of the inferior surface of the clavicle. The membrane traced medially, along the subclavius muscle, is attached to the first costal cartilage; passing laterally, along the upper border of the pectoralis minor, it reaches the coracoid process, and the coraco-clavicular ligament. The part of the membrane extending directly between the first costal cartilage and the coracoid process is thickened and forms the **costo-coracoid ligament.** The costo-coracoid membrane is pierced by the cephalic vein, thoraco-acromial artery, and branches of the lateral anterior thoracic nerve. By its deep surface it is connected to the sheath of the axillary vessels.

At the inferior border of the pectoralis minor there is a further extension of the deep fascia beneath the pectoralis major. It passes downwards to join the fascia forming the floor of the axilla, and is continued laterally into the fascia covering the biceps and coraco-brachialis muscles.

MUSCLES OF THE PECTORAL REGION.

The anterior muscles connecting the upper limb to the axial skeleton comprise the pectoralis major, pectoralis minor, subclavius, serratus anterior, and sterno-cleido-mastoid. The last is described in a later section (p. 459).

M. Pectoralis Major.—The **pectoralis major** is a large fan-shaped muscle arising in three parts: (1) *a pars clavicularis* arising from the anterior aspect of the clavicle in its medial half or two-thirds (Figs. 301, p. 369, and 305, p. 375); (2) *a pars sternocostalis*, the largest part of the muscle, arising from the anterior surface of the manubrium and body of the sternum by tendinous fibres decussating with those of the opposite muscle (Fig. 304, p. 374), and, more deeply, from the cartilages of the first six ribs; (3) *a pars abdominalis*, a small and separate slip, arising from the aponeurosis of the obliquus abdominis externus muscle. The abdominal slip, at first separate, soon merges with the sterno-costal portion, but a distinct interval usually remains between the two first-named parts of the muscle.

The fibres converge towards the proximal part of the arm, and are inseparably blended at a point half an inch from their insertion into the lateral border of the sulcus intertubercularis of the humerus.

The arrangement of the fibres of the muscle at its insertion is peculiar. The pars clavicularis is attached to the humerus in front of the pars sternocostalis and blends, inferiorly, with the tendinous insertion of the deltoid, the lateral fibres of origin being inserted proximal to the medial fibres. The upper sterno-costal fibres disappear under cover of the pars clavicularis near its insertion and are blended with the deep surface of its tendon. The lower sterno-costal fibres and the pars abdominalis curve upwards behind the superior sterno-costal fibres, and the latter have the highest attachment to the shaft of the humerus, helping to form a fascial expansion which extends upwards over the biceps tendon to the capsule of the shoulder-joint. In this way a bilaminar tendon is produced, united along its inferior border. The superficial lamina is formed by the superior sterno-costal fibres, blending for the most part with the tendon of the clavicular portion; and the deep lamina by the twisted lower sterno-costal and abdominal fibres.

Placed superficially, the pectoralis major forms the anterior wall and anterior fold of the axilla. Its superior border is separated from the edge of the deltoid muscle by an interval in which lie the cephalic vein and deltoid branches of the a. thoracoacromialis. Its deep surface is in relation with the ribs and intercostal muscles, the costo-coracoid membrane and the structures piercing it, the pectoralis minor, the biceps and coraco-brachialis, the axillary vessels, and the nerves of the brachial plexus.

Nerve-Supply.—The pectoralis major is supplied by both anterior thoracic nerves. The lateral anterior thoracic nerve, derived from the lateral cord of the brachial plexus (C. 5. 6. 7.), divides into two trunks. One pierces the costo-coracoid membrane, and supplies the clavicular part, and superior portion of the sterno-costal part of the muscle. The other branch communicates over the axillary artery with the medial anterior thoracic nerve, a derivative of the medial cord of the brachial plexus (C. 8. T. 1.). They then supply the pectoralis minor and, piercing that muscle, terminate in the lower part of the pectoralis major.

Actions.—The pectoralis major is a powerful adductor and medial rotator of the arm. The clavicular head (*portio attollens*) assists the anterior fibres of the deltoid to flex the humerus, a movement in which the limb is carried forwards and medially. The costo-sternal and abdominal fibres, although taking part in flexion from full extension until the arm reaches the side, are powerful extensors of the fully flexed humerus (*portio deprimens*). Like the latissimus dorsi (p. 371), the pectoralis major plays an important part in climbing and, when the shoulders are fixed, it can assist violent inspiratory efforts by raising the upper ribs.

Sternalis Muscle.—The sternalis is an occasional muscle lying parallel to the sternum upon the sterno-costal origin of the pectoralis major. It has attachments which are very variable both above and below, to the costal cartilages, sternum, rectus sheath, sterno-mastoid, and pectoralis major. Its **nerve-supply** is from one or both of the anterior thoracic nerves. In certain rare cases it has been said to be innervated by intercostal nerves. It is present in 4·4 cases out of 100. It has been regarded by different observers as (1) a vestige of the panniculus carnosus, (2) a homologue of the sterno-mastoid, or (3) a displaced slip of the pectoralis major.

Chondroepitrochlearis, Dorsoepitrochlearis, Axillary Arches, Costocoracoideus.—One or other of the above-named slips is occasionally present, crossing the floor of the axilla in the interval between the latissimus dorsi and the pectoralis major. They take **origin** from the costal cartilages, ribs, or borders of the pectoralis major (*chondroepitrochlearis*, *axillary arches*, *costocoracoideus*), or from the border of the latissimus dorsi (*dorsoepitrochlearis*, *axillary arches*, *costocoracoideus*). Their **insertion** is variable. The *chondroepitrochlearis* and *dorsoepitrochlearis* are inserted into the fascia of the arm, the medial intermuscular septum, or the medial epicondyle of the humerus. The *axillary arches* are inserted into the border of the pectoralis major, the fascia of the arm, or the coracobrachialis or biceps muscle. The *costocoracoideus*, arising from the ribs or the aponeurosis of the obliquus externus, or detaching itself from the border of the pectoralis major or latissimus dorsi, is attached to the coracoid process, alone or along with one of the muscles attached to that bone. These variable slips of muscle are supplied by the medial anterior thoracic nerve, the medial cutaneous nerve of the arm, or the intercostobrachial nerve.

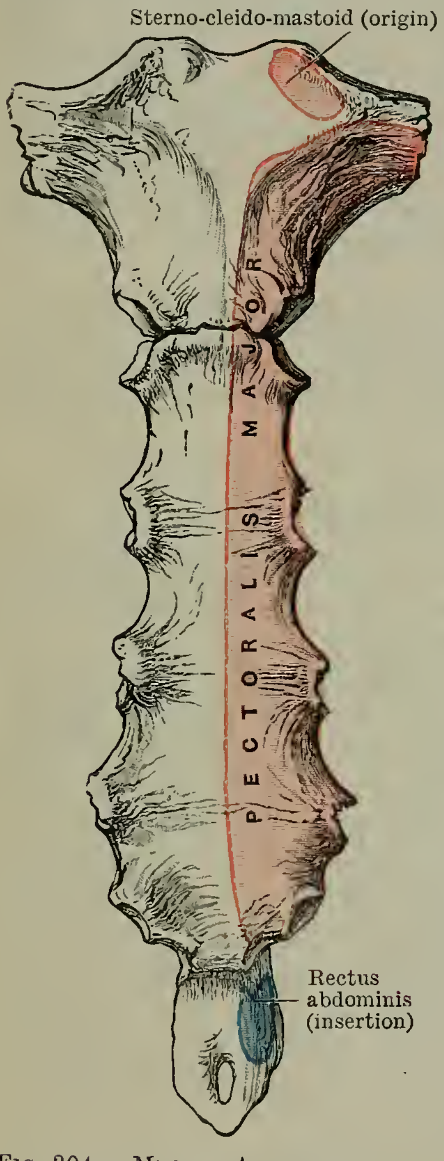

Fig. 304.—Muscle-Attachments to the Front of the Sternum.

M. Pectoralis Minor.—The **pectoralis minor** is a narrow, flat, triangular muscle. It **arises**, under cover of the pectoralis major, from (1) the surfaces and superior borders of the third, fourth, and fifth ribs near their anterior ends, and (2) from the fascia covering the third and fourth intercostal spaces between those ribs. It may have an additional origin from the second rib (Fig. 389, p. 468); and that from the fifth rib is often absent.

Directed obliquely upwards and laterally, it is **inserted** by a short, flat tendon into the lateral half of the medial border and upper surface of the coracoid process (Fig. 307, p. 376), and usually also into the conjoint origin of the biceps brachii and coracobrachialis.

It enters into the formation of the anterior wall of the axilla, lying under cover of the pectoralis major. It crosses the axillary vessels and the cords of the brachial plexus, and is pierced by the medial anterior thoracic nerve. Its fascial sheath is continuous above with the costo-coracoid membrane and below with the axillary fascia.

Either in part or wholly the pectoralis minor may pass over the coracoid process of the scapula, separated from it by a bursa, to pierce the coraco-acromial ligament, and be attached to the capsule of the shoulder-joint (coraco-humeral ligament).

Nerve-Supply.—The pectoralis minor is innervated like the pectoralis major by both anterior thoracic nerves. The lower division of the lateral nerve (C. 5. 6. 7.) communicates with the medial anterior thoracic nerve (C. 8. T. 1.), and the latter pierces and supplies the pectoralis minor, and ends in the pectoralis major.

Action.—The main use of the pectoralis minor is to draw the shoulder forwards. Since the muscle lies under cover of the pectoralis major and is never paralysed alone, it is very difficult to appreciate its action in the living subject.

M. Subclavius.—The **subclavius muscle** arises from the superior surface of the first costal cartilage in front of the costo-clavicular ligament, and from the upper surface of the sternal end of the first rib (Fig. 389, p. 468).

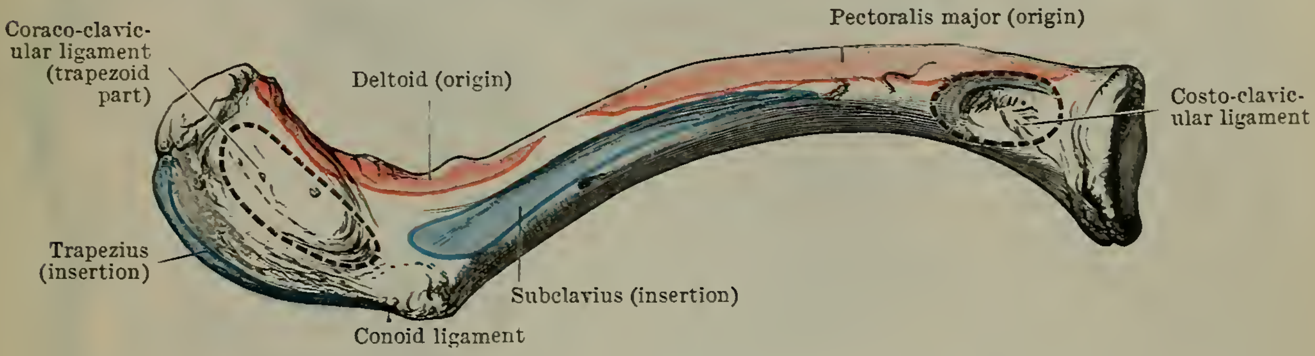
Coraco-clavicular ligament (trapezoid part)
Deltoid (origin)
Pectoralis major (origin)
Costo-clavicular ligament
Trapezius (insertion)
Subclavius (insertion)
Conoid ligament

Fig. 305.—Muscle-Attachments to the Right Clavicle (Inferior Surface).

It is **inserted** into a groove in the middle third of the inferior surface of the clavicle (Fig. 305).

The muscle is invested by the fascia which forms the costo-coracoid membrane, and is concealed by the clavicle and the clavicular origin of the pectoralis major. It lies in front of the subclavian vein.

Nerve-Supply.—**The nerve to the subclavius** is a fine branch of the brachial plexus (C. 5. 6.), which arises above the clavicle, and passes anterior to the subclavian artery to reach the muscle.

Action.—It acts as a depressor of the lateral end of the clavicle, and, by drawing the bone medially towards the sternum, steadies it in movements of the shoulder-girdle.

The **sternoclavicularis** is a small separate slip, rarely present, extending beneath the pectoralis major from the upper part of the sternum to the clavicle.

M. Serratus Anterior.—The **serratus anterior** is a large curved quadrilateral muscle occupying the side of the chest and medial wall of the axilla. It **arises** by fleshy slips from the lateral aspect of the upper eight and occasionally (as in the figure) from nine ribs. The first slip is a double one, arising from the first two ribs and the fascia covering the intervening space (Fig. 306).

The **insertion** of the muscle is threefold. (1) The first portion of the muscle (from the first and second ribs) is directed posteriorly to be inserted into the costal aspect of the medial angle of the scapula. (2) The next three slips of the muscle (from the second, third, and fourth ribs) are inserted into the vertebral margin of the scapula. (3) The last four slips (from the fifth, sixth, seventh, and eighth ribs) are directed obliquely upwards and posteriorly, to be inserted on the costal aspect of the inferior angle of the scapula (Fig. 307).

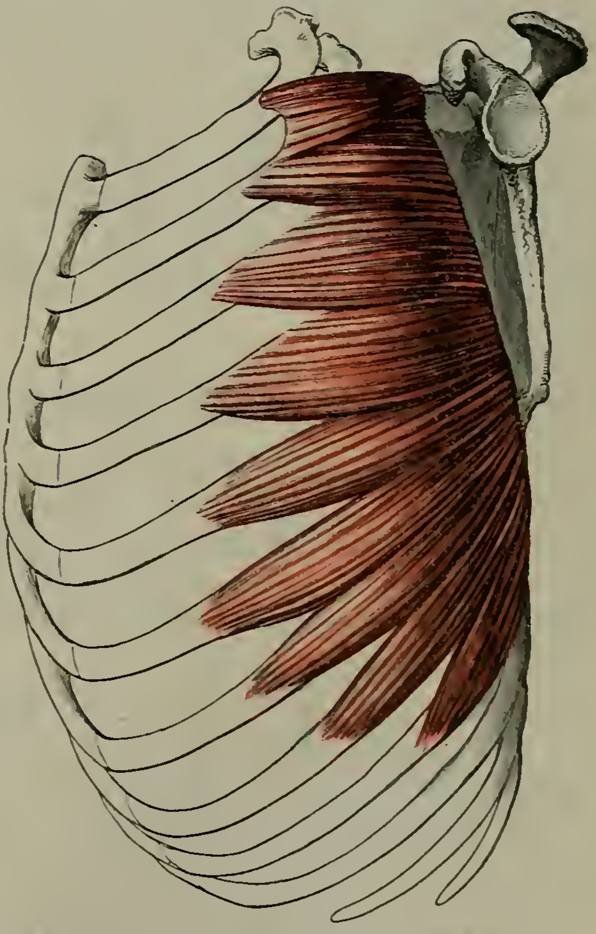

Fig. 306.—The Left Serratus Anterior Muscle.

The lateral surface of the muscle is partly superficial below the axillary space, on the side wall of the chest, where its slips of origin are seen inter-digitating with those of the obliquus externus abdominis. Higher up it forms the medial wall of the axilla and is covered by the infero-lateral part of the mammary gland. It is in contact with the pectoral muscles anteriorly and the subscapularis posteriorly. Its superior border appears in the floor of the posterior triangle, and over it the axillary artery and the cords of the brachial plexus pass in their course through the axilla. The inferior border is oblique, and is in contact with the latissimus dorsi muscle. The muscle may extend higher than usual, so as to be continuous, in the neck, with the levator scapulæ.

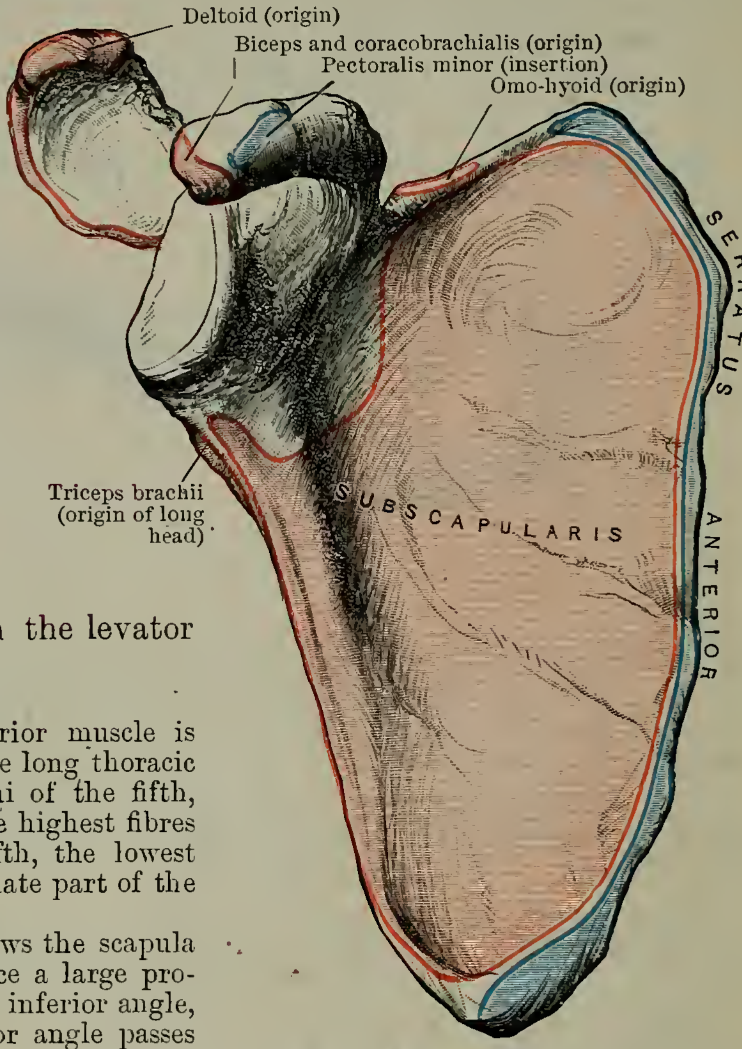
Deltoid (origin)
Biceps and coracobrachialis (origin)
Pectoralis minor (insertion)
Omo-hyoid (origin)
SERRATUS
ANTERIOR
SUBSCAPULARIS
Triceps brachii (origin of long head)

Fig. 307.—Muscle-Attachments to the Right Scapula (Anterior Aspect).

Nerve-Supply.—The serratus anterior muscle is supplied, on its superficial aspect, by the long thoracic nerve, a branch from the anterior rami of the fifth, sixth, and seventh cervical nerves. The highest fibres of the muscle are supplied by the fifth, the lowest fibres by the seventh, and the intermediate part of the muscle by the sixth cervical nerve.

Actions.—The serratus anterior draws the scapula forwards round the chest wall and, since a large proportion of its fibres are inserted into the inferior angle, it rotates the bone so that the inferior angle passes forwards and laterally. In association with the trapezius, it is a fixation muscle in the early stages of abduction of the humerus (p. 370) and an active agent in the later stages. By drawing the scapula forwards, it exercises a very important influence on forward pushing or thrusting movements with the hand, so much so that, when the serratus anterior is paralysed, these movements are impossible and attempts to produce them result in a backward projection ("*winging*") of the scapula. Like other muscles, when its insertion is fixed, it can act on its origin, thus coming into play as an accessory muscle of inspiration.

FASCIÆ AND MUSCLES OF THE SHOULDER.

The **deep fascia** of the shoulder region is especially strong where it covers the infraspinatus and teres minor muscles below the posterior border of the deltoid. In this situation it is tendinous in appearance and is firmly attached to the vertebral and axillary borders of the scapula. Above, it ensheathes the deltoid and is attached to the clavicle, the acromion, and the scapular spine.

Muscles.

The **muscles** proper to the shoulder comprise the deltoid, supraspinatus, infraspinatus, teres minor, teres major, and subscapularis.

M. Deltoideus.—The **deltoid**, a coarsely fasciculated multipennate muscle, has an extensive **origin** from (1) the front of the clavicle in its lateral third (Figs. 301, p. 369, and 305, p. 375); (2) the lateral border of the acromion; (3) the inferior edge of the free border of the spine of the scapula (Figs. 303, p. 371, and 302, p. 370); and (4) from the deep fascia covering the infraspinatus muscle. Its origin embraces the insertion of the trapezius.

The fibres of the muscle converge to the lateral aspect of the body of the humerus, to be **inserted** into a well-marked V-shaped impression above the radial groove (Fig. 310, p. 379). The insertion is partly united with the tendon of the pectoralis major.

The most anterior part of the deltoid muscle is formed of parallel fibres, not uncommonly separate from the rest of the muscle at their origin from the clavicle. These fibres may be continuous with the trapezius. The most posterior part arises by a fascial origin from the spine of the scapula and the fascia over the infraspinatus muscle. These portions are attached respectively to the front and back of the main tendon of insertion. The intermediate fibres are multipennate, attached above and below to three or four septal tendons, which extend for a variable distance downwards and upwards from the origin and insertion of the muscle. This arrangement increases the number of its constituent fibres and so increases the power of the deltoid. This increased power is necessary owing to the obvious mechanical disadvantage at which the muscle acts, and the fact that its action is usually exerted against the force of gravity.

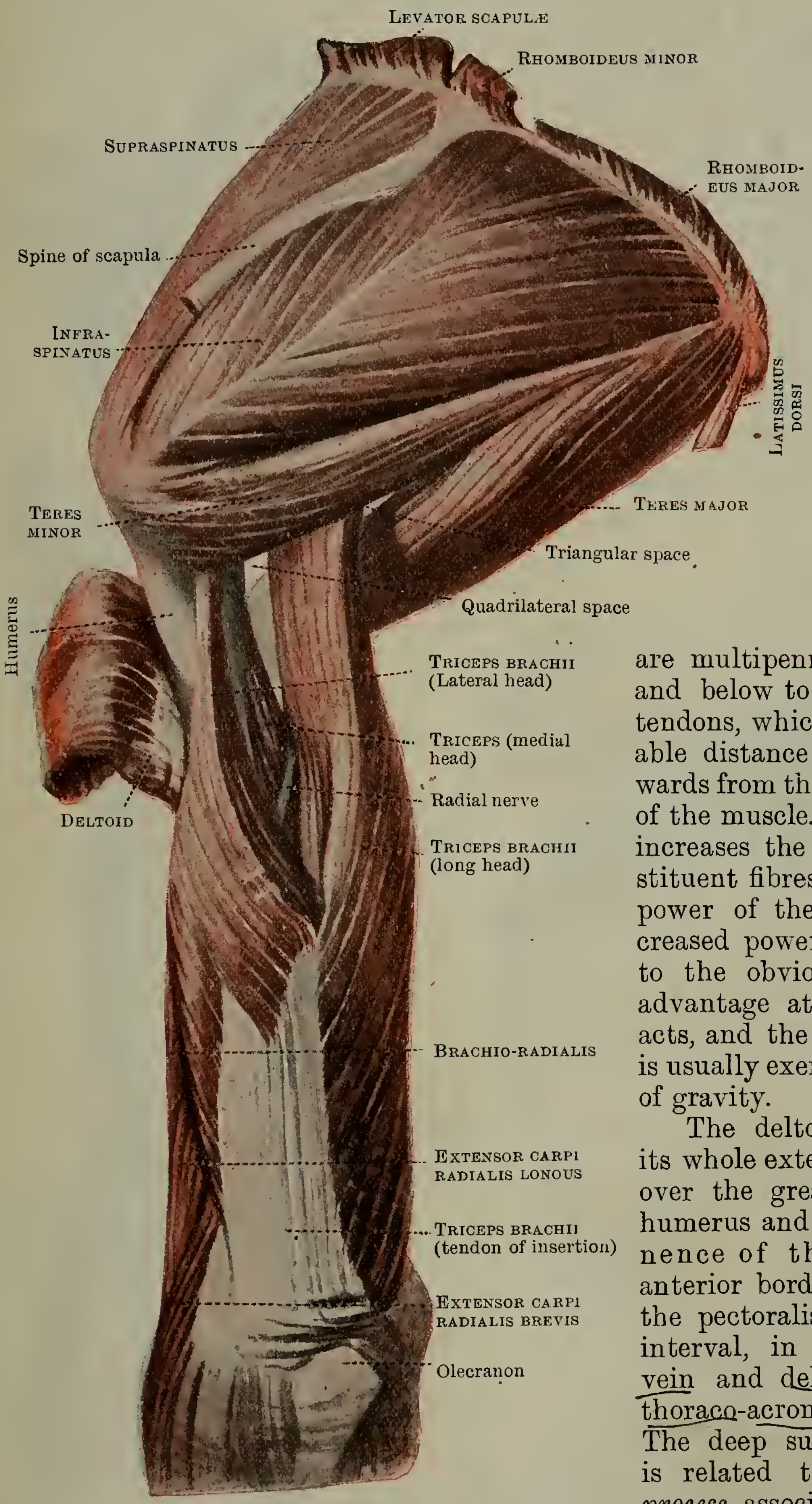

FIG. 308.—LEFT SCAPULAR MUSCLES AND TRICEPS.

The deltoid is superficial in its whole extent. It is spread out over the greater tubercle of the humerus and so forms the prominence of the shoulder. Its anterior border is separated from the pectoralis major by a narrow interval, in which the cephalic vein and deltoid branch of the thoraco-acromial artery are placed. The deep surface of the muscle is related to (1) the *coracoid process,* associated with which are the coraco-acromial ligament, and the attachments of the pectoralis minor, the coracobrachialis, and the short head of the biceps brachii; (2) the capsule of the *shoulder-joint* covering the *head of the humerus,* associated with which are the long head of the biceps, and the attachments of the subscapularis, supraspinatus, infraspinatus, and teres minor; and (3) the proximal part of the lateral surface of the *body of the humerus* associated with which are the posterior circumflex vessels of the humerus and the axillary nerve. The *subacromial bursa* intervenes between the middle fibres of the deltoid, the acromion, and the coraco-acromial ligament, on the one hand, and the supraspinatus, infraspinatus, and subscapularis tendons on the other.

Nerve-Supply.—The deltoid muscle is supplied by the terminal branches of the axillary (O.T. circumflex) nerve from the fifth and sixth cervical nerves.

Actions.—The deltoid is the principal abductor of the humerus. In this movement the arm is carried forwards and laterally (p. 366), and in the early stages the deltoid and supraspinatus are the active agents, the serratus anterior and trapezius playing the rôle of fixation muscles (p. 367). After the arm has been moved through an angle of 30°, further abduction is accompanied, *pari passu*, by rotation of the scapula.

The anterior fibres assist the clavicular head of the pectoralis major to produce flexion and medial rotation of the humerus; the posterior fibres act with the extensors and lateral rotators.

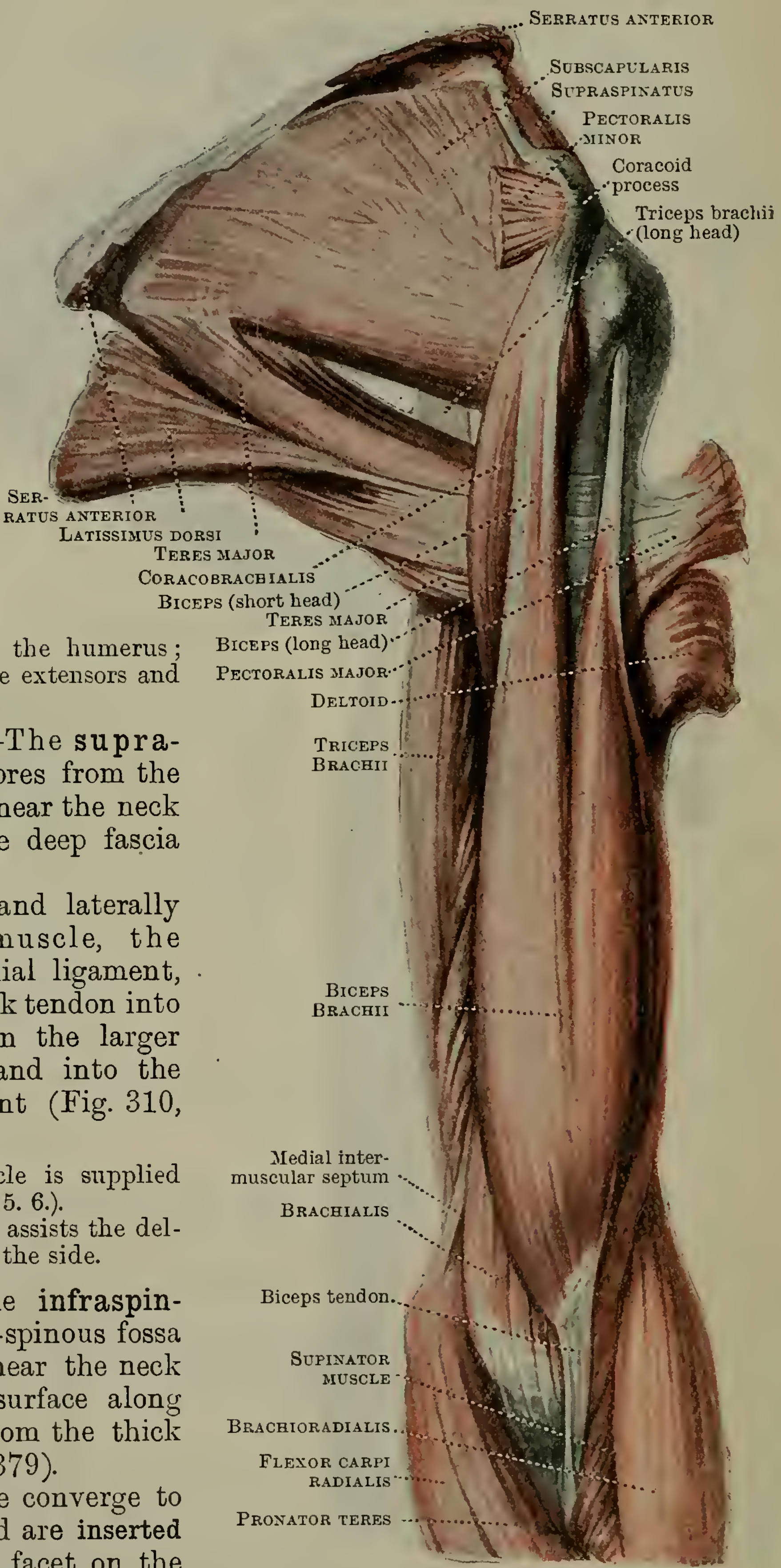

Fig. 309.—Muscles of Posterior Wall of Left Axilla and Front of Arm.

M. Supraspinatus.—The **supraspinatus arises** by fleshy fibres from the supra-spinous fossa (except near the neck of the bone) and from the deep fascia over it (Fig. 311, p. 379).

It is directed forwards and laterally under the trapezius muscle, the acromion and coraco-acromial ligament, to be **inserted** by a broad thick tendon into the most proximal facet on the larger tubercle of the humerus, and into the capsule of the shoulder-joint (Fig. 310, p. 379).

Nerve-Supply.—The muscle is supplied by the supra-scapular nerve (C. 5. 6.).

Action.—The supraspinatus assists the deltoid in abducting the arm from the side.

M. Infraspinatus.—The **infraspinatus arises** from the infra-spinous fossa of the scapula (excepting near the neck of the bone and the flat surface along the axillary margin) and from the thick fascia over it (Fig. 311, p. 379).

The fibres of the muscle converge to the neck of the scapula, and are **inserted** by tendon into the middle facet on the larger tubercle of the humerus, and into the capsule of the shoulder-joint (Fig. 315, p. 383). A bursa separates the muscle from the neck of the scapula, and, in a minority of cases, communicates with the synovial cavity of the shoulder-joint.

The supraspinatus and the upper part of the infraspinatus muscles are concealed by the trapezius, acromion, and deltoid. They cover the neck of the scapula, the transverse scapular artery and supra-scapular nerve, and the capsule of the shoulder-joint.

Nerve-Supply.—Supra-scapular nerve.

Action.—The infraspinatus is a powerful lateral rotator of the humerus.

M. Teres Minor.—The **teres minor** is a small muscle, **arising** by fleshy fibres from the proximal two-thirds of the flat surface on the dorsal aspect of the axillary margin of the scapula, and from fascial septa separating it from the infraspinatus and teres major muscles (Fig. 311, p. 379).

Lying alongside the lateral border of the infraspinatus, it is **inserted**, under cover of the deltoid, by a thick flat tendon, into the most distal of the three facets on the larger tubercle of the humerus and into the capsule of the shoulder-joint, and, by fleshy fibres, into the posterior aspect of the surgical neck and body of the humerus distal to the tubercle for about an inch (Fig. 315, p. 383).

It is separated from the teres major by the long or scapular head of the triceps brachii, and by the posterior circumflex vessels of the humerus and the axillary nerve. Its origin is pierced by the circumflex scapular artery. The muscle is invested by the deep fascia enclosing the infraspinatus, and is sometimes inseparable from that muscle.

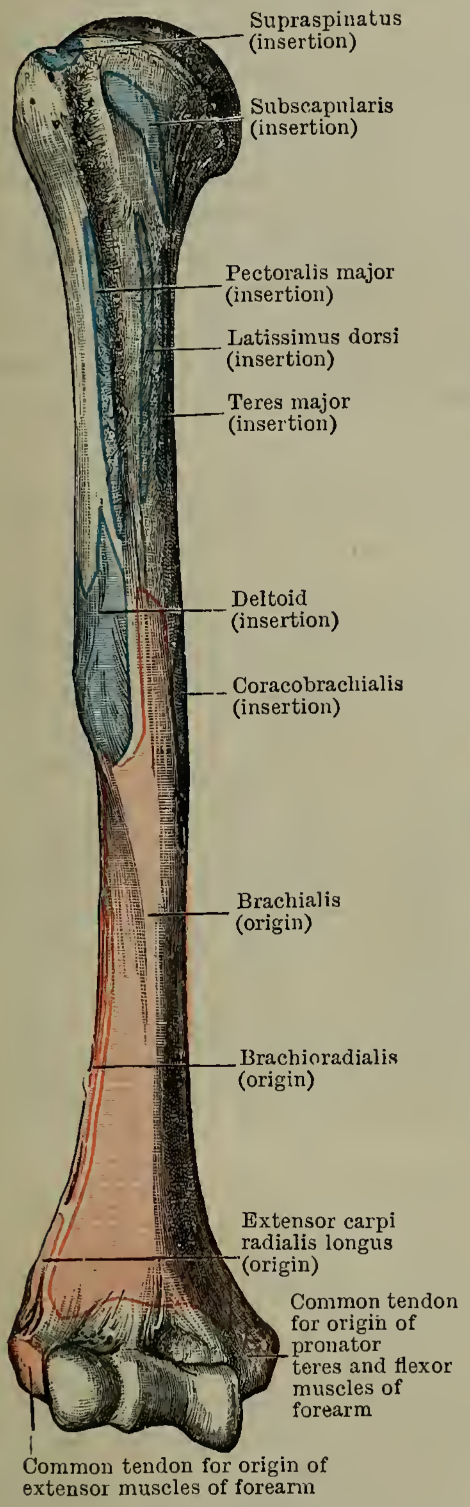
Supraspinatus (insertion)
Subscapularis (insertion)
Pectoralis major (insertion)
Latissimus dorsi (insertion)
Teres major (insertion)
Deltoid (insertion)
Coracobrachialis (insertion)
Brachialis (origin)
Brachioradialis (origin)
Extensor carpi radialis longus (origin)
Common tendon for origin of pronator teres and flexor muscles of forearm
Common tendon for origin of extensor muscles of forearm

FIG. 310.— MUSCLE - ATTACHMENTS TO THE ANTERIOR ASPECT OF THE RIGHT HUMERUS.

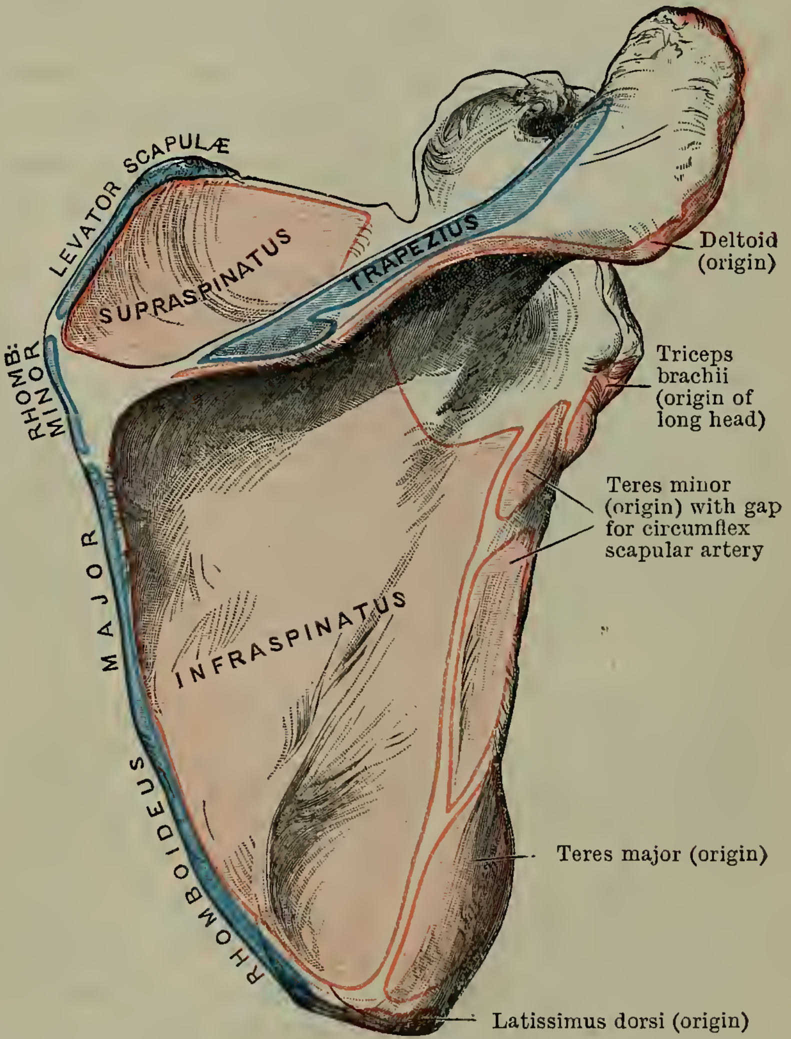
LEVATOR SCAPULÆ
SUPRASPINATUS
TRAPEZIUS
Deltoid (origin)
RHOMB. MINOR
Triceps brachii (origin of long head)
Teres minor (origin) with gap for circumflex scapular artery
RHOMBOIDEUS MAJOR
INFRASPINATUS
Teres major (origin)
Latissimus dorsi (origin)

FIG. 311.—MUSCLE-ATTACHMENTS TO THE RIGHT SCAPULA (Dorsal Surface).

Nerve-Supply.—The teres minor is supplied by a branch of the axillary nerve (C. 5. 6.). The nerve has a pseudo-ganglion, a fibrous swelling on it in its course to the muscle.

Action.—The muscle is a lateral rotator and adductor of the humerus.

M. Teres Major.—The **teres major** is much larger than the preceding muscle.

It **arises**, by fleshy fibres, from the lower third of the flat, dorsal surface of the axillary margin of the scapula (except for a small area at the inferior angle), and from fascial septa, which separate it on the one side from the subscapularis, and on the other from the infraspinatus and teres minor (Fig. 311).

The muscle is directed along the axillary margin of the scapula to the front of the body of the humerus, where it is **inserted**, by a broad flat tendon, into the medial border of the sulcus intertubercularis medial to the latissimus dorsi muscle (Fig. 314). Just before its insertion it is closely adherent to the tendon of the latissimus dorsi.

The teres major lies below the subscapularis muscle in the posterior wall of the axilla. The latissimus dorsi muscle, sweeping round from the back, covers its axillary surface on its way to its insertion. The muscle forms the inferior boundary of a **triangular space** in the posterior wall of the axilla, of which the other boundaries are, above, the borders of the subscapularis and teres minor muscles, and laterally the surgical neck of the humerus. This space is subdivided by the long head of the triceps brachii, which passes behind the teres major muscle, into (*a*) a **quadrilateral space** above, for the passage of the axillary nerve and posterior circumflex artery of the humerus; and (*b*) a **smaller triangular space** below, for the circumflex scapulæ artery.

Nerve-Supply.—The teres major is supplied, along with part of the subscapularis muscle, by the lower subscapular nerve (C. 5. 6.).

Action.—A medial rotator and adductor of the humerus.

M. Subscapularis.—The **subscapularis** is a large triangular muscle which covers the costal surface of the scapula. It **arises** by fleshy fibres from the whole of the subscapular fossa and the groove along the axillary margin, excepting the surfaces at the angles of the bone (Fig. 307, p. 376). Springing from several ridges in the fossa are fibrous septa projecting into the substance of the muscle, which increase the extent of its attachment.

Converging to the head of the humerus, the muscular fibres are **inserted** by a broad, thick tendon into the smaller tubercle of the humerus and into the capsule of the shoulder-joint, and by fleshy fibres into the surgical neck and the body of the humerus distal to the tubercle for about an inch, under cover of the coracobrachialis and short head of the biceps (Fig. 314, p. 383).

This muscle forms the greater part of the posterior wall of the axilla. Its medial or anterior surface is in contact with the serratus anterior and the axillary vessels and nerves. It is separated from the neck of the scapula by a bursa, which is in direct communication with the synovial cavity of the shoulder-joint.

Nerve-Supply.—There are two and often three nerves supplying the subscapularis, viz., the upper subscapular (C. 5. 6.), which is often double; and the lower subscapular (C. 5. 6.), which, after supplying its lateral (lower) portion, ends in the teres major.

Actions.—The subscapularis is a medial rotator of the humerus, but, when the arm is abducted through 90°, the relation of the muscle to the axes of movements becomes altered and it can then act with the pectoralis major to draw the arm forwards.

The principal action of the above group of muscles is on the shoulder-joint. They have also secondary actions in relation to movements of the trunk and limbs.

Movements of the Shoulder.—In all free movements of the arm the acromio- and sterno-clavicular joints are affected in addition to the shoulder-joint itself, and, in limited movements, the shoulder girdle must be steadied by the appropriate fixation muscles.

In considering these movements it must be observed that, in the erect posture, the anterior surface of the humerus is directed medially as well as forwards and that the line of the shoulder-joint passes backwards and laterally and is not parallel to the sagittal plane. It follows that the movement of flexion carries the humerus forwards and medially in front of the body and that the movement of abduction carries it forwards as well as laterally. Flexion occurs in a plane at right angles to the costal surface of the scapula and is limited to a range of 90°, since rotation of the scapula cannot effect any influence upon it. Abduction, on the other hand, occurs in the same plane as the scapula and, although the movement of the humerus on the glenoid fossa is limited to about 90°, rotation of the scapula gives the arm an additional range of just under 90°. Combinations of flexion and abduction give ranges varying between these two extremes, the range becoming greater as the degree of abduction is increased.

In relation to the trunk and limbs, the shoulder muscles, by fixing the humerus, have auxiliary power on the one hand in movements of the trunk, such as forced inspiration; on the other hand, acting along with muscles fixing the elbow-joint, they stiffen the limb so as to permit of the more refined movements of the wrist and fingers.

FASCIÆ AND MUSCLES OF THE ARM.

FASCIÆ.

The **superficial fascia** presents no features of importance. There is a bursa beneath it over the olecranon, and occasionally another over the medial epicondyle of the humerus.

The **deep fascia** forms a strong tubular investment for the muscles on the anterior and posterior aspects of the humerus. It is continuous above with the deep fascia of the shoulder and axilla, and is further strengthened by fibres derived from the insertions of the pectoralis major, latissimus dorsi, and deltoid muscles. At the elbow it becomes continuous with the deep fascia of the forearm, and gains attachment to the epicondyles of the humerus and the olecranon of the ulna; it is strengthened also by important bands associated with the insertions of the biceps anteriorly and the triceps posteriorly, to which reference will be made in the account of these muscles.

About the middle of the arm on the medial side, the deep fascia is perforated for the passage of the basilic vein and the medial cutaneous nerve of the forearm.

The **intermuscular septa** are processes of the deep fascia attached to the epicondylic ridges of the humerus. The **medial** and stronger **septum** is placed between the brachialis muscle anteriorly and the medial head of the triceps posteriorly, and gives origin to both. It extends proximally to the insertion of the coracobrachialis (which is often continued into it), and its proximal part is pierced by the ulnar nerve and superior ulnar collateral vessels. The **lateral septum** is thinner. It separates the brachialis muscle and brachioradialis in front from the medial and lateral heads of the triceps behind, and gives origin to those muscles. It extends proximally to the insertion of the deltoid, and is pierced by the radial nerve and profunda brachii vessels.

MUSCLES OF THE ARM.

The muscles of the arm comprise the biceps, coracobrachialis, and brachialis on the anterior aspect, and the triceps brachii on the posterior aspect of the humerus. Except at its extremities, the biceps brachii is superficial, and forms a rounded fleshy mass on the anterior aspect of the arm. The coracobrachialis is visible on its medial side in the proximal half of the arm, particularly when the arm is raised. The brachialis is concealed by the biceps. The triceps brachii forms the thick mass of muscle covering the posterior surface of the humerus.

M. Coracobrachialis.—The **coracobrachialis** is a rudimentary muscle. It **arises** under cover of the deltoid from the tip of the coracoid process, by fleshy fibres, in common with the short head of the biceps, and also frequently from the tendon of insertion of the pectoralis minor muscle.

The fleshy belly is pierced by the musculo-cutaneous nerve, and ends in a flat tendon which is **inserted** into a faint linear impression about an inch in length on the middle of the medial border of the body of the humerus (Fig. 314, p. 383). It is often continued into the medial intermuscular septum.

The **coracobrachialis** is the remains of a *threefold muscle*, of which only two elements are usually present in man, but of which in anomalous cases all the parts may be more or less fully developed. The passage of the musculo-cutaneous nerve through the muscle is an indication of its natural separation into two parts, which represent the persistent middle and distal elements.

The commonest variety is one in which the more superficial (distal) part of the muscle extends more distally than usual, so as to be inserted into the medial intermuscular septum, or even into the medial epicondyle of the humerus. A third slip (**coracobrachialis superior** or **brevis, rotator humeri**) may more rarely be present, forming a short muscle **arising** from the root of the coracoid process, and **inserted** into the medial side of the humerus just distal to the capsule of the shoulder-joint.

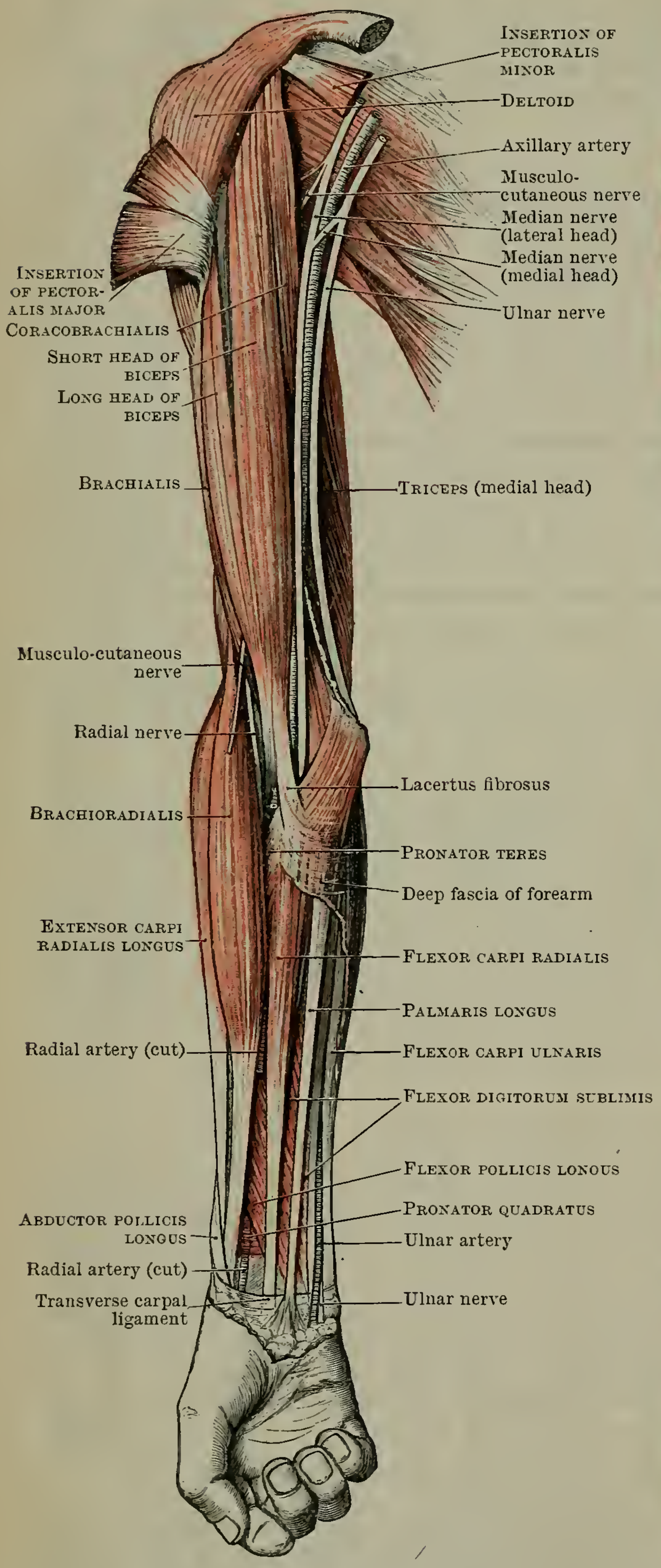

Fig. 312.—Superficial Muscles on the Anterior Aspect of the Right Arm and Forearm.

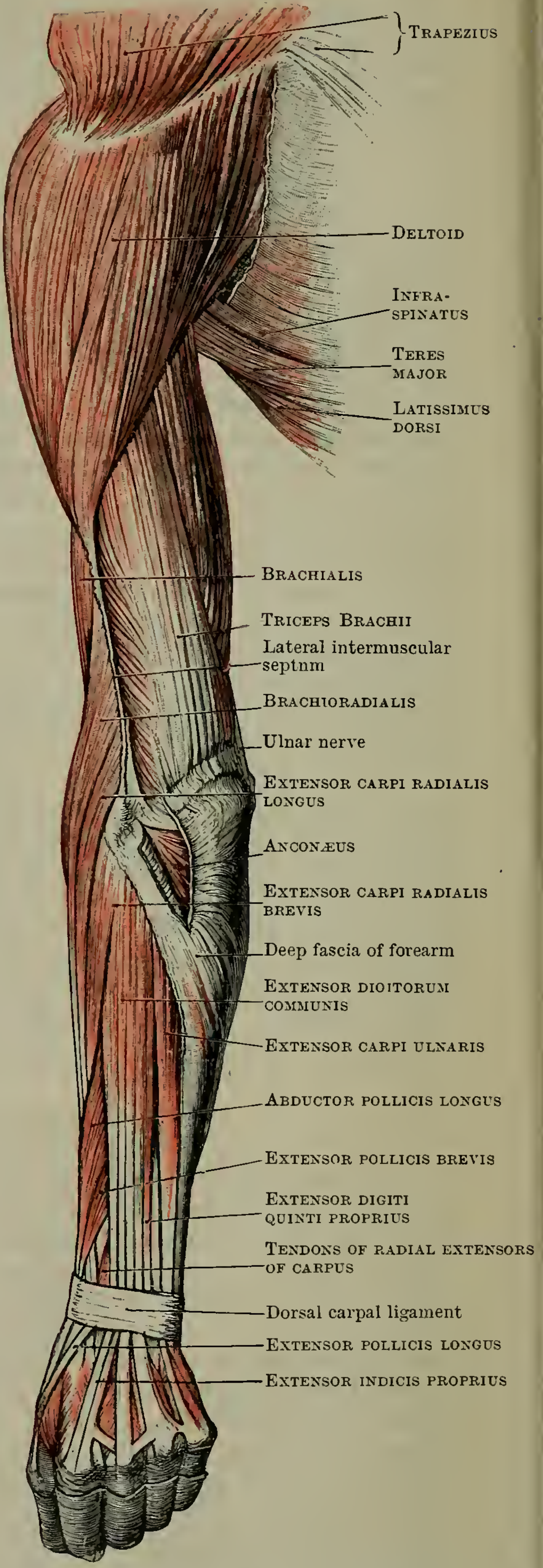

Fig. 313.—The Muscles on the Posterior Side of the Left Arm, Forearm, and Hand.

Nerve-Supply.—The nerve to the coracobrachialis comes from the 7th or 6th and 7th cervical nerves. Incorporated with the musculo-cutaneous, the nerve separates to supply the muscle before the latter nerve pierces it.

Action.—The muscle assists in flexion and adduction of the arm. In addition, when the humerus is rotated laterally, it can produce medial rotation until the position of rest is reached.

M. Biceps Brachii.—The **biceps brachii** arises by two tendinous *heads*. (1) The **short head (caput breve)** is attached in common with the coracobrachialis to the tip of the coracoid process of the scapula (Fig. 307, p. 376). Concealed by the deltoid and tendinous at first, this head forms a separate fleshy belly, which is united to the long head by an investment of the deep fascia. (2) The **long head (caput longum)** arises by a round tendon from the supraglenoidal tuberosity at the root of the coracoid process and from the labrum glenoidale on each side. Its tendon passes through the cavity of the shoulder-joint, and, emerging from the capsule beneath the transverse humeral ligament (invested by a prolongation of the synovial membrane), it occupies the intertubercular groove of the humerus where it is covered by a fascial prolongation of the tendon of the pectoralis major. In the arm it forms a fleshy belly which unites with the short head just distal to the middle of the arm.

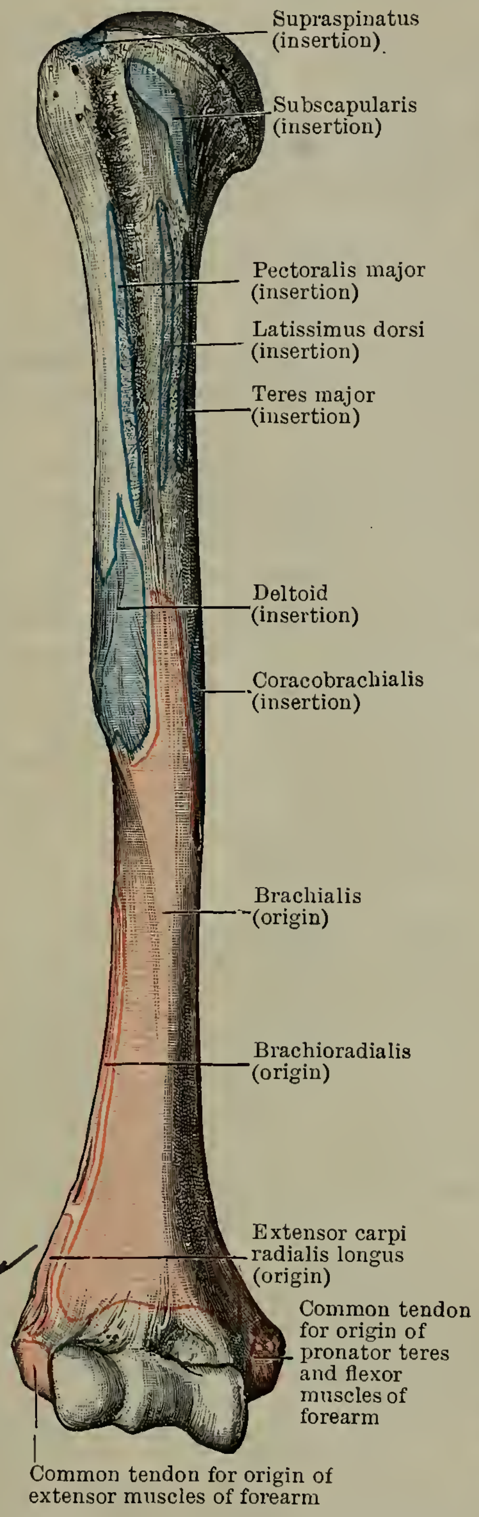
Supraspinatus (insertion)
Subscapularis (insertion)
Pectoralis major (insertion)
Latissimus dorsi (insertion)
Teres major (insertion)
Deltoid (insertion)
Coracobrachialis (insertion)
Brachialis (origin)
Brachioradialis (origin)
Extensor carpi radialis longus (origin)
Common tendon for origin of pronator teres and flexor muscles of forearm
Common tendon for origin of extensor muscles of forearm

Fig. 314.—Muscle-Attachments to the Anterior Aspect of the Right Humerus.

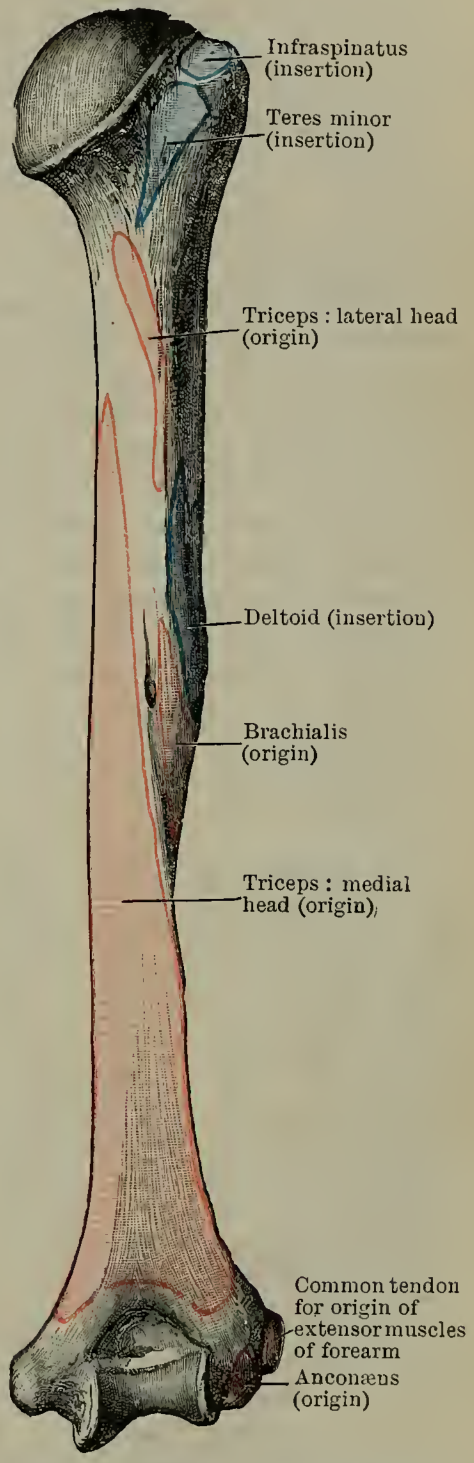
Infraspinatus (insertion)
Teres minor (insertion)
Triceps : lateral head (origin)
Deltoid (insertion)
Brachialis (origin)
Triceps : medial head (origin)
Common tendon for origin of extensor muscles of forearm
Anconæus (origin)

Fig. 315.—Muscle-Attachments to the Posterior Surface of the Right Humerus.

The **insertion** of the muscle is likewise twofold. (1) The two bellies become connected to a strong *tendon*, attached deeply in the hollow of the elbow to the rough dorsal portion of the tubercle of the radius (Figs. 322, p. 392, and 329, p. 400). A bursa separates the tendon from the volar portion of the tuberosity. (2) From the medial and anterior part of the tendon, and partly in continuity with the fleshy fibres of the muscle, a strong *membranous band* (**the lacertus fibrosus**) extends, distally and medially, over the hollow of the elbow to join the deep fascia covering the origins of the flexor and pronator muscles of the forearm. Its proximal part is thickened and can be felt subcutaneously as a crescentic border which crosses in front of the brachial artery and the median nerve.

In the arm the biceps conceals the brachialis muscle and the musculo-cutaneous nerve. Its medial border is the guide to the position of the brachial artery and median nerve.

A **third head of origin** is common (10 per cent), and usually arises from the humerus, between the insertions of the deltoid and coracobrachialis. Two or even three additional heads may be present at the same time. The long head of the muscle may be absent, or may take origin from the intertubercular groove. The muscle may have an additional insertion into the medial epicondyle of the humerus, or into the fascia of the forearm.

Nerve-Supply.—Each head receives a branch from the musculo-cutaneous nerve (C. 5. 6.).

Actions.—The principal actions of the biceps are exerted on the elbow and radio-ulnar joints. It is a strong flexor of the forearm and acts to best advantage as a supinator when the elbow-joint is flexed. The actions on the shoulder-joint are weak, the short head helping in flexion and adduction, and the long head in abduction.

M. Brachialis.—The **brachialis** is a large muscle **arising** from the distal two-thirds of the anterior aspect of the body of the humerus and from the intermuscular septum on each side (Fig. 314, p. 383).

Clasping the insertion of the deltoid proximally, it ends distally in a strong tendon, which is **inserted**, deep in the hollow of the elbow, into the anterior ligament of the elbow-joint, the distal surface of the coronoid process, and slightly into the immediately adjacent part of the volar surface of the body of the ulna (Fig. 322, p. 392). The lateral part of the muscle, arising from the lateral epicondylic ridge and lateral intermuscular septum, forms a slip more or less separate, which may be partially fused with the brachioradialis muscle.

It is concealed for the most part by the biceps muscle in the arm. It forms the floor of the cubital fossa, and covers the anterior aspect of the elbow-joint.

Nerve-Supply.—It is supplied by the musculo-cutaneous nerve (C. 5. 6.); and also (in most instances) at its lateral border by a fine branch of the radial nerve (C. (5.) 6.).

Action.—This muscle is a flexor of the elbow-joint.

M. Triceps Brachii.—The **triceps brachii** is the only muscle on the posterior aspect of the arm. It **arises** by three heads: a lateral and a medial head, from the humerus, and a long head from the scapula. (1) **The long head** (**caput longum**) begins as a strong tendon attached to the infra-glenoidal tuberosity (Figs. 307, p. 376, and 311, p. 379). This gives rise to a fleshy belly which, after passing between the teres major and teres minor muscles, occupies the middle of the back of the arm. (2) **The lateral head** is attached by fibres, partly tendinous and partly fleshy, to the curved lateral border of the humerus from the insertion of the teres minor proximally to the radial groove distally, and receives additional fibres from the posterior surface of the lateral intermuscular septum (Fig. 313, p. 382). Its fibres are directed distally and medially over the radial groove, concealing the radial (musculo-spiral) nerve, the profunda brachii artery, and the medial head of the muscle. (3) The **medial head** arises by fleshy fibres from an elongated triangular area on the posterior surface of the humerus, extending proximally to the level of the insertion of the teres major, and distally nearly to the margin of the olecranon fossa (Fig. 315, p. 383). It also arises, on each side, from the intermuscular septum,—from the whole length of the medial septum, and from the part of the lateral septum which is below the passage of the radial nerve.

The three heads of origin are **inserted**, by a broad and membranous common tendon, into an impression occupying the posterior part of the proximal end of the olecranon of the ulna (Fig. 329, p. 400), and into the deep fascia of the forearm on each side of it. The long and lateral heads join the borders of the tendon of insertion, and the medial head is attached to its deep surface. A small thick-walled bursa separates the tendon of the triceps from the posterior ligament of the elbow-joint and the proximal end of the olecranon.

The muscle is superficial in almost its whole extent. The long (scapular) head is concealed at its origin by its relation to the teres muscles, between which it passes.

The **subanconæus** is a small muscle occasionally present. It consists of scattered fibres **arising** from the distal end of the posterior surface of the humerus, deep to the triceps, and it is **inserted** into the posterior ligament of the elbow-joint.

Nerve-Supply.—The several heads of the muscle are supplied separately by branches of the radial nerve. The lateral head receives fibres from C. (6.) 7. 8.; the long and medial head from C. 7. 8. The medial head has a double supply. One nerve enters its proximal part, another (ulnar collateral nerve of Krause) enters the distal part of the muscle.

Actions.—The triceps is the extensor muscle of the elbow-joint. The long head also acts as an adductor of the humerus at the shoulder-joint.

FASCIÆ AND MUSCLES OF THE FOREARM AND HAND.

Fasciæ.

The **superficial fascia** in the forearm presents no exceptional features. On the dorsum of the hand it is loose and thin; in the palm it is generally well furnished with fat, forming pads for the protection of the vessels and nerves. Numerous fibrous septa penetrate its substance, passing between the palmar aponeurosis and the skin, especially along the lines of flexure. A band of transverse fibres (*superficial transverse metacarpal ligament*) crosses the distal part of the palm, being enclosed within the skin folds which form the webs of the fingers and connected to the volar aspects of the fibrous digital sheaths.

M. Palmaris Brevis.—The **palmaris brevis** is a quadrilateral subcutaneous muscle which lies in the medial side of the hand, under the superficial fascia. It **arises** from the medial border of the thick central portion of the palmar aponeurosis and from the volar surface of the transverse carpal ligament and is **inserted** into the skin of the medial border of the hand for a variable distance. It covers the ulnar artery and nerve, branches of which supply it. Its action is to wrinkle the skin of the medial border of the hand, and by raising up the skin and superficial fascia, to deepen the hollow of the hand.

The **deep fascia** of the forearm and hand is continuous above with the deep fascia of the arm. In the proximal part of the forearm it is strengthened in front, by fibres from the lacertus fibrosus (semilunar fascia) of the biceps; behind, by the fascial insertions of the triceps; and laterally, by fibres derived from the humeral epicondyles in relation to the common tendons of origin of the flexor and extensor muscles of the forearm which in part take their origin from them. It is attached to the dorsal margin of the ulna, and affords increased attachment to the flexor and extensor carpi ulnaris and the flexor digitorum profundus muscles. A second layer of fascia is closely associated with the volar surface of the flexor digitorum sublimis. Thin in the proximal part of the forearm, it becomes considerably thickened near the wrist, where it lies deep to the tendons of the flexor carpi radialis, palmaris longus, and flexor carpi ulnaris and the ulnar vessels and nerve. These two layers become partially blended on the volar aspect of the carpus to constitute the transverse carpal ligament. On the dorsal aspect of the wrist, the deep fascia is strengthened by a number of oblique fibres and forms the dorsal carpal ligament.

Ligamentum Carpi Transversum.—The **transverse carpal ligament** is a band about an inch and a half in depth, continuous, proximally and distally, with the deep fasciæ of the forearm and the palm of the hand. It is attached laterally to the navicular and large multangular bones; medially to the pisiform and os hamatum; and it forms a membranous arch binding down, in the hollow of the carpus, the flexor tendons of the digits, and the median nerve. It is divided into *two compartments*, the larger accommodating the tendons of the flexors of the digits and the median nerve, the smaller (placed laterally) containing the tendon of the flexor carpi radialis. There are *three synovial membranes* in these compartments: one for the flexor carpi radialis tendon, and two others, which often communicate together, enveloping the tendon of the flexor pollicis longus and the flexor tendons of the fingers respectively. The surface of the ligament is crossed by the palmar branches of the median and ulnar nerves; by the tendon of the palmaris longus muscle, which is attached to its surface; and by the ulnar artery and nerve, which are again bridged over and protected by a band of fibrous tissue continuous proximally with the investing layer of the deep fascia. This is called the *volar carpal ligament,* and it passes from the pisiform bone to the surface of the transverse carpal ligament. The distal border of the ligament is continuous with the palmar aponeurosis in the centre, and its sides give origin to the superficial muscles of the thumb and the muscles of the little finger.

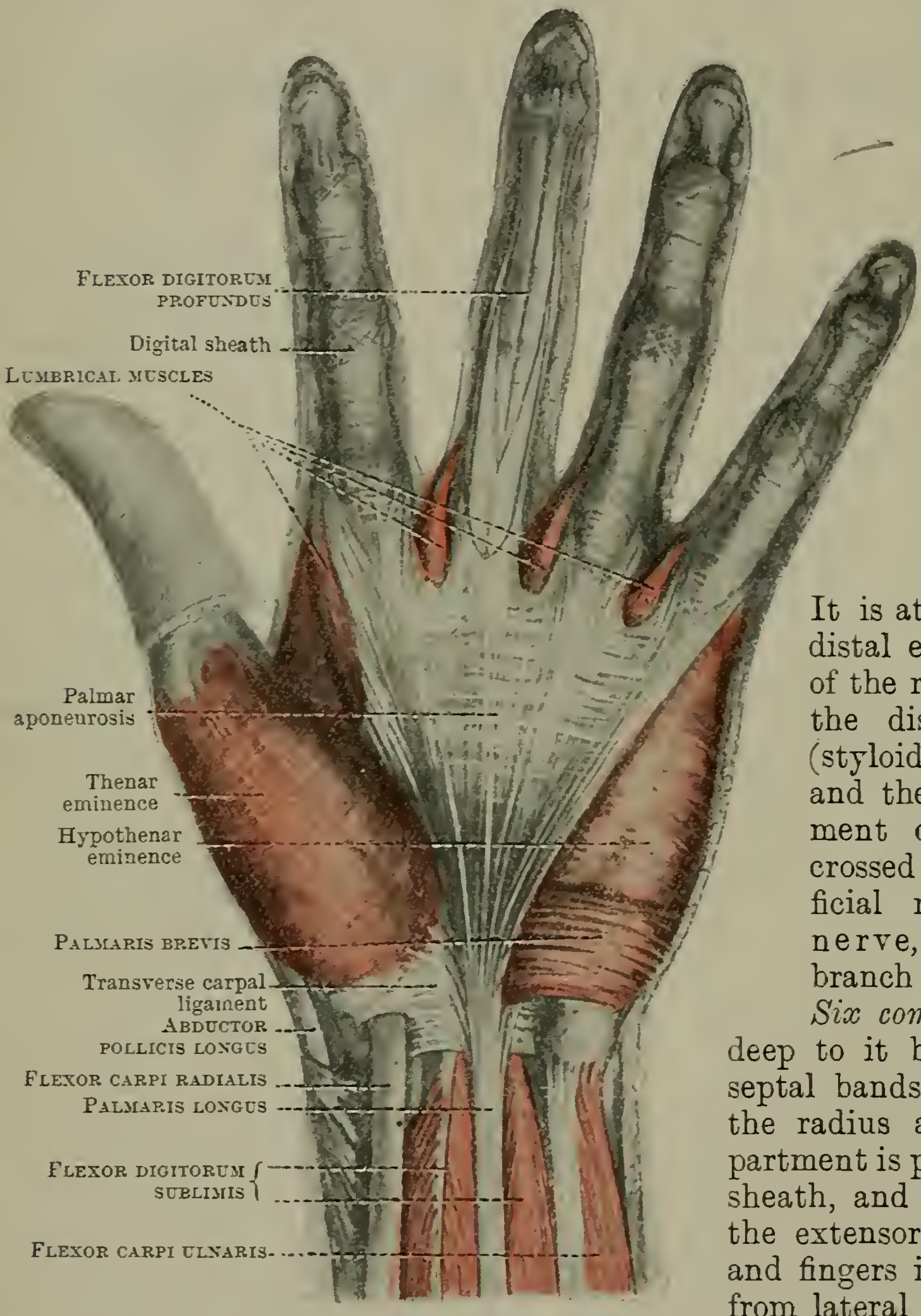

Fig. 316.—The Palmar Aponeurosis.

Ligamentum Carpi Dorsale.—The dorsal carpal ligament is placed at a more proximal level than the transverse carpal ligament. It consists of an oblique band of fibres about an inch broad, continuous proximally and distally with the deep fascia of the forearm and hand. It is attached laterally to the distal end of the volar border of the radius, and medially to the distal end of the ulna (styloid process), the carpus, and the ulnar collateral ligament of the wrist. It is crossed by veins, by the superficial ramus of the radial nerve, and by the dorsal branch of the ulnar nerve. *Six compartments* are formed deep to it by the attachment of septal bands to the distal ends of the radius and ulna. Each compartment is provided with a mucous sheath, and they serve to transmit the extensor tendons of the wrist and fingers in the following order from lateral to medial side:—(1) Abductor pollicis longus and extensor pollicis brevis, (2) Extensores carpi radiales, longus and brevis, (3) Extensor pollicis longus, (4) Extensor digitorum communis and extensor indicis proprius, (5) Extensor digiti quinti proprius, (6) Extensor carpi ulnaris.

The thin deep fascia of the dorsum of the hand is lost over the expansions of the extensor tendons on the fingers. Between the metacarpal bones a strong layer of fascia covers and gives attachment to the interossei muscles.

Aponeurosis Palmaris.—The palmar aponeurosis is of considerable importance. In the centre of the palm it forms a thick triangular membrane, the apex of which joins the distal edge of the transverse carpal ligament, and, more superficially, receives the insertion of the tendon of the palmaris longus muscle. The fascia separates below into four slips, one for each finger. The slips are connected together on their deep surfaces by transverse fibres, which cover the lumbricals and the digital vessels and nerves (**fasciculi transversi**). More distally each slip separates into two parts, to be connected to the sides of the metacarpo-phalangeal joints and the first phalanx of the medial four digits. In the cleft between the two halves of each slip the **digital fibrous sheath** is attached and extends distally on to the finger. The lateral borders of this triangular central portion of the palmar aponeurosis are continuous with thin layers of deep fascia, which cover and envelop the muscles of the thenar and hypothenar eminences. The medial border gives origin to the palmaris brevis muscle (p. 385).

The **digital fibrous sheaths (vaginæ fibrosæ)** are tubular envelopes extending along the palmar aspect of the digits and enclosing the flexor tendons. Each consists of a fibrous sheath attached to the lateral borders of the phalanges and inter-phalangeal joints, and continuous proximally with the palmar aponeurosis. Opposite each inter-phalangeal articulation the digital sheath is loose and thin; opposite the first two phalanges (the first only in the case of the thumb) it becomes extremely thick, and gives rise to the **ligamenta vaginalia,** which serve to keep the tendons closely applied to the bones during flexion of the fingers. Within each sheath are the flexor tendons, enveloped in a **mucous sheath (vagina mucosa)** which surrounds the tendons and lines the interior of the fibrous sheath. The mucous linings of the digital sheaths extend a short distance proximally in the palm, and in some cases communicate with the large mucous sheaths enclosing the flexor tendons beneath the transverse carpal ligament. There may be a separate distinct mucous sheath for each digit; but most commonly only the sheaths for the three middle digits are separate; those of the flexor pollicis longus and the flexor tendons of the little finger usually communicate with the mucous sheaths placed beneath the transverse carpal ligament.

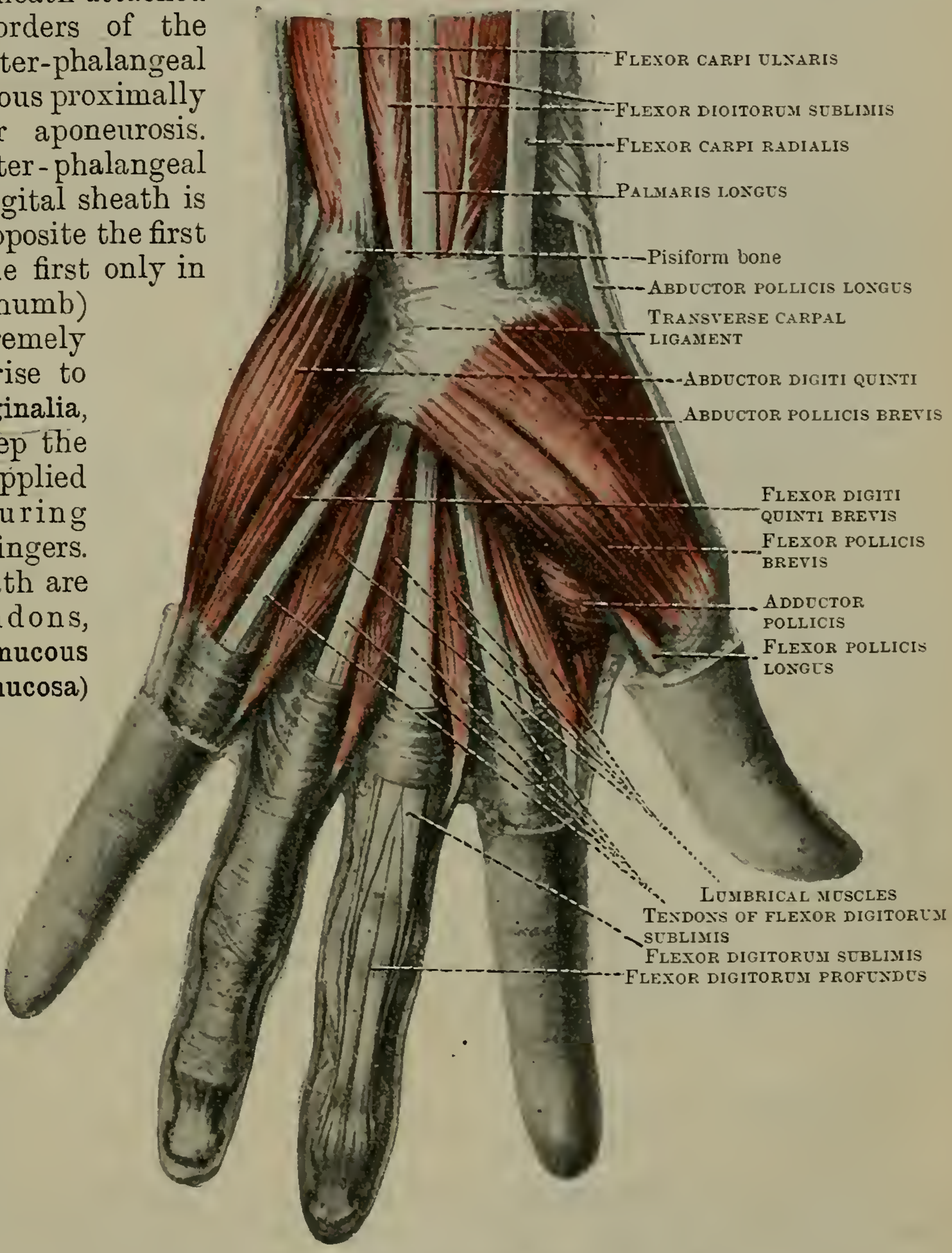

Fig. 317.—Superficial Muscles and Tendons in the Palm of the Left Hand.

Regarded as a whole, the transverse carpal ligament, the palmar aponeurosis, and the fibrous digital sheaths form a continuous sheet, which serves to increase the efficiency of the flexor muscles of the digits and wrist and to increase the power of prehension. The fascial thickenings retain the tendons in position and provide pulleys over which they act. When the flexor muscles of the digits contract, their tendons do not raise ridges under the skin, which would interfere with the efficiency of the hand as a gripping instrument, and, as a result, the extent of the movements of the phalanges is directly proportional to the amount of shortening of the muscles concerned.

THE MUSCLES ON THE ANTERIOR AND MEDIAL ASPECTS OF THE FOREARM.

The muscles on the anterior and medial aspects of the forearm comprise the pronators and the flexors of the wrist and fingers. In the forearm they are arranged in three strata: (1) a superficial layer consisting of four muscles which radiate from the medial epicondyle of the humerus, from which they take origin by a common tendon. They are named, from radial to ulnar side, pronator teres, flexor carpi radialis, palmaris longus, and flexor carpi ulnaris. These muscles conceal the muscle which by itself constitutes (2) the intermediate stratum—the flexor digitorum sublimis, and this again conceals, for the most part, (3) the deep layer of muscles, including the flexor digitorum profundus covering the ulna, the flexor pollicis longus on the radius, and the pronator quadratus, which is more deeply placed than the previous muscles, and stretches across the forearm between the distal portions of the radius and ulna.

I. Superficial Muscles.

M. Pronator Teres.—The **pronator teres** is the shortest muscle of this group. It has a double **origin**: (1) a *superficial head* (**caput humerale**), the main origin, partly fleshy, partly tendinous, from the most distal part of the medial epicondylic ridge of the humerus and from the medial intermuscular septum, from the medial epicondyle of the humerus, from the fascia over it, and from an intermuscular septum between it and the flexor carpi radialis (Fig. 310, p. 379); (2) a *deep head* (**caput ulnare**), a slender tendinous slip from the medial side of the coronoid process of the ulna, which joins the superficial origin of the muscle on its deep surface (Fig. 322, p. 392). The median nerve separates the two heads from one another.

The muscle passes distally and laterally to be **inserted** by tendon into an oval impression on the middle of the lateral surface of the body of the radius (Figs. 322, p. 392, and 329, p. 400). The fibres of the muscle are twisted on themselves, so that the most proximal humeral fibres form the most distal fibres of the tendon of insertion, and the most distal humeral fibres and those arising from the coronoid process are most proximal at the insertion.

The pronator teres forms the medial boundary of the hollow of the elbow. It is superficially placed, except near its insertion, where it is covered by the brachioradialis muscle and by the radial vessels and superficial branch of the radial nerve.

Nerve-Supply.—Median nerve (C. 6.).
Action.—The muscle is a pronator of the forearm and assists in flexion of the elbow joint.

M. Flexor Carpi Radialis.—The **flexor carpi radialis** muscle takes its **origin** from the common tendon from the medial epicondyle of the humerus, from the fascia over it, and from the intermuscular septa on either side.

About the middle of the forearm, the fleshy belly gives place to a flattened tendon, which becomes more cord-like as it approaches the wrist. Entering the hand, the tendon splits the transverse carpal ligament into its two constituent layers and occupies the groove on the greater multangular bone, where it is surrounded by a mucous sheath. Finally it is inserted into the base of the second and usually into the adjoining part of the base of the third metacarpal bone (Fig. 325, p. 395).

The muscle is superficial except near its insertion. Its tendon, in the distal half of the forearm, is an important guide to the radial vessels, which are placed to its radial side. After passing beneath the transverse carpal ligament the tendon is concealed by the origins of the short muscles of the thumb, and is crossed, from medial to lateral side, by the tendon of the flexor pollicis longus. Besides the mucous sheath enveloping the tendon beneath the ligament, a mucous bursa is placed beneath the insertion of the tendon.

Nerve-Supply.—Median nerve (C. 6.).

Actions.—This muscle acts primarily with the flexor carpi ulnaris to flex the wrist, but an important function is to steady the wrist during extension of the fingers; *i.e.* in association with the ulnar flexor of the wrist, it is a synergic muscle for the extensors of the digits. In addition, it may co-operate with the radial extensors of the wrist to produce abduction of the hand, and with the pronators or flexors of the elbow to produce pronation or flexion of the forearm, as the case may be.

M. Palmaris Longus.—The **palmaris longus** arises also from the common flexor tendon from the medial epicondyle of the humerus, from the fascia over it, and from intermuscular septa on each side.

It forms a short fusiform muscle, which ends, in the middle of the forearm, in a long flat tendon. This passes superficial to the transverse carpal ligament, and is **inserted** (1) into the surface of the transverse carpal ligament, and (2) into the apex of the thick central portion of the palmar aponeurosis. A tendinous slip is frequently sent to the short muscles of the thumb and the fascia covering them.

The palmaris longus is the smallest muscle of the forearm. In the distal third of the forearm its tendon is placed directly over the median nerve, along the radial border of the tendons of the flexor digitorum sublimis.

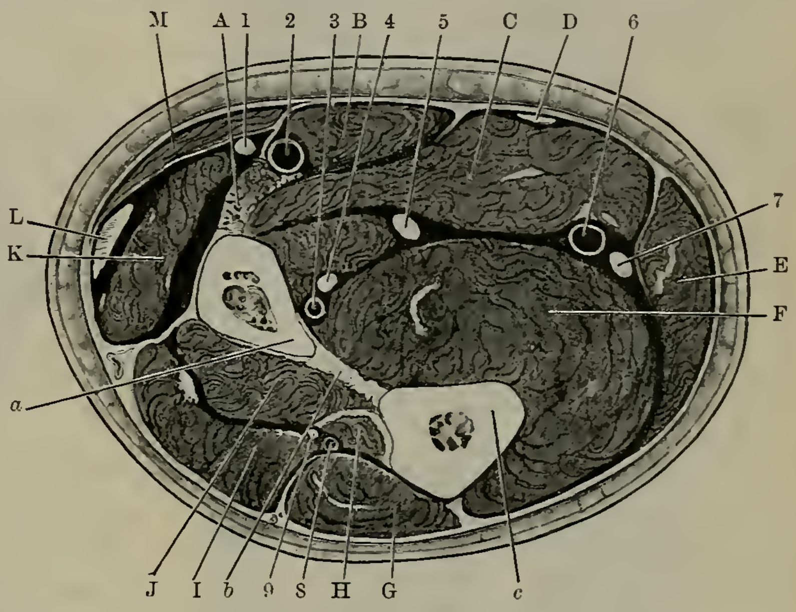

FIG. 318.—DISTAL SURFACE OF A SECTION ACROSS THE RIGHT FOREARM IN THE MIDDLE THIRD.

A, PRONATOR TERES (insertion); B, FLEXOR CARPI RADIALIS; C, FLEXOR DIGITORUM SUBLIMIS; D, PALMARIS LONGUS; E, FLEXOR CARPI ULNARIS; F, FLEXOR DIGITORUM PROFUNDUS; G, EXTENSOR CARPI ULNARIS; H, EXTENSOR POLLICIS LONGUS; I, EXTENSOR DIGITORUM COMMUNIS AND EXTENSOR DIGITI QUINTI PROPRIUS; J, ABDUCTOR POLLICIS LONGUS; K, EXTENSOR CARPI RADIALIS BREVIS; L, EXTENSOR CARPI RADIALIS LONGUS; M, BRACHIORADIALIS. *a*, Radius; *b*, Interosseous membrane; *c*, Ulna. 1, Superficial ramus of radial nerve; 2, Radial artery; 3, Volar interosseous artery; 4, Volar interosseous nerve (underneath flexor pollicis longus); 5, Median nerve; 6, Ulnar artery; 7, Ulnar nerve; 8, Dorsal interosseous artery; 9, Dorsal interosseous nerve.

The palmaris longus is the most variable muscle in the body, and is often absent (10 per cent). It represents a flexor of the first phalanges, but in man it has become very much reduced, owing to differentiation of the other digital flexors and to finer control of the lumbricals and interossei.

Nerve-Supply.—Median nerve (C. 6.).

Actions.—The muscle assists in flexion of the elbow and wrist. It also acts as a tensor of the palmar aponeurosis.

M. Flexor Carpi Ulnaris.—The **flexor carpi ulnaris** muscle has a double **origin**, from the humerus and from the ulna. (1) It arises from the common tendon attached to the medial epicondyle of the humerus, from the fascia over it, and from a lateral intermuscular septum. (2) By means of the deep fascia of the forearm it obtains an attachment to the medial border of the olecranon and the dorsal margin of the ulna in its proximal three-fifths.

The fleshy fibres join a tendon which lies on the anterior border of the muscle and is **inserted** into the pisiform bone, and in the form of two ligamentous bands (piso-hamate and piso-metacarpal) into the hamulus of the os hamatum, and the proximal end of the fifth metacarpal bone (Fig. 325, p. 395).

The muscle is superficially placed along the medial border of the forearm. It conceals the flexor digitorum profundus muscle, the ulnar nerve (which enters the forearm between the two heads of origin of the muscle), and the ulnar artery. The tendon serves as a guide to the artery in the distal half of the forearm.

Nerve-Supply.—Ulnar nerve (C. 8. T. 1.).

Actions.—The flexor carpi ulnaris is a flexor and adductor of the wrist, and an accessory flexor of the elbow-joint. It steadies the pisiform bone during contractions of the abductor digiti quinti and, like the flexor carpi radialis, acts as a synergic muscle during extension of the fingers.

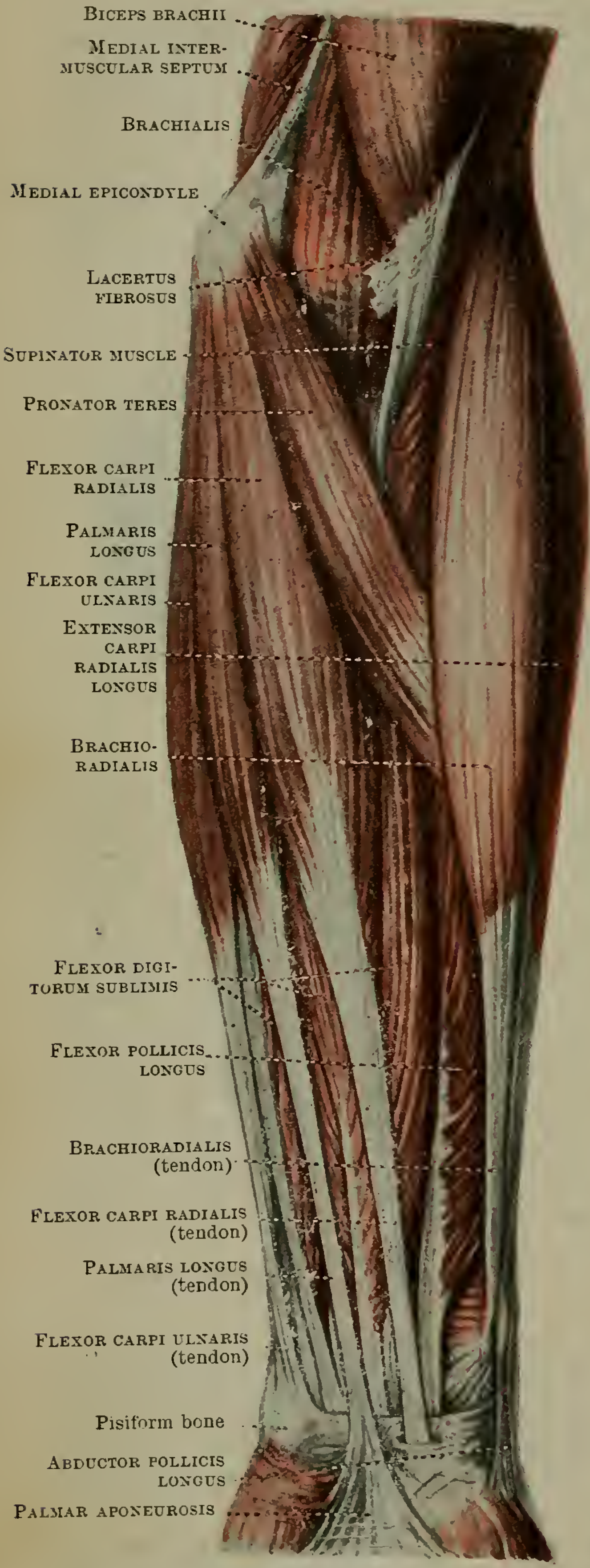

Fig. 319.—The Superficial Muscles of the Left Forearm.

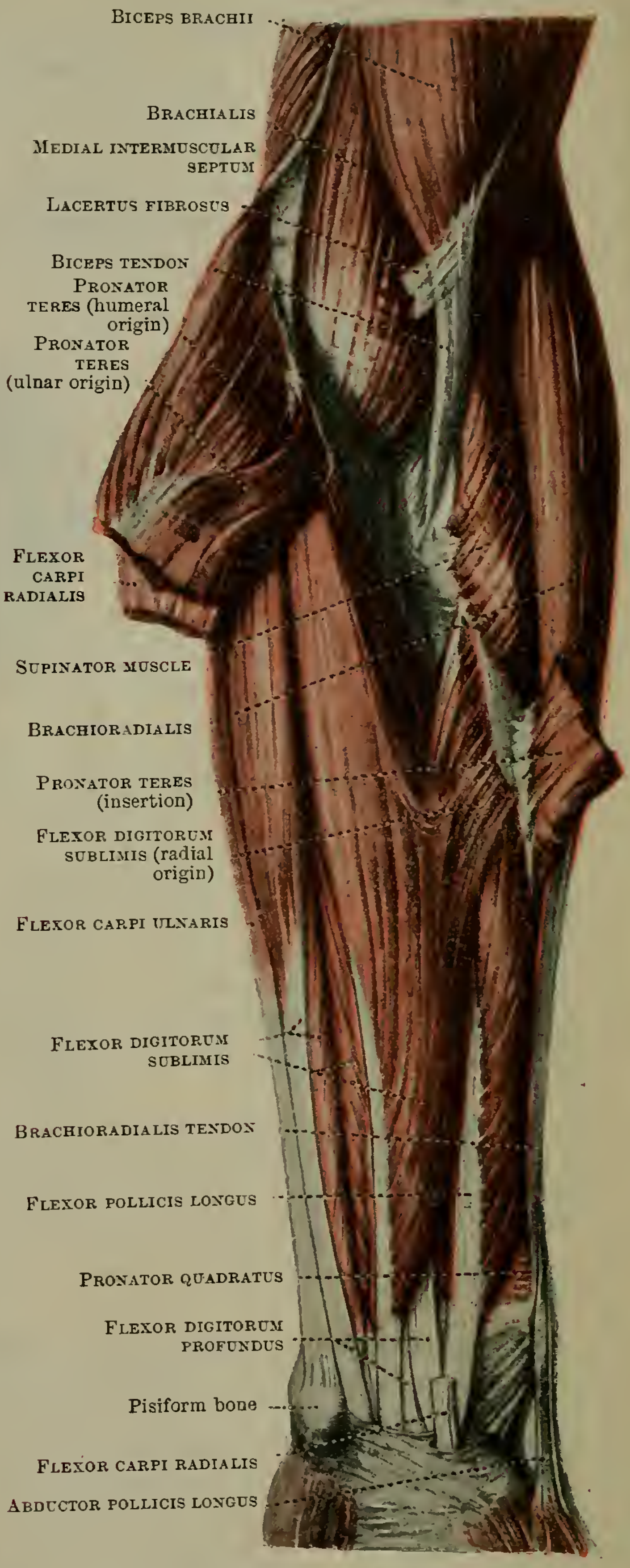

Fig. 320.—Deeper Muscles of the Left Forearm.

2. Intermediate Layer.

M. Flexor Digitorum Sublimis.—The **flexor digitorum sublimis** occupies a deeper plane than the four previous muscles. It has a wide **origin**, from the humerus, radius, and ulna. (1) The chief or humero-ulnar head of origin is from the medial epicondyle of the humerus by the common tendon, from adjacent intermuscular septa, and from the *ulnar collateral* ligament of the elbow, by a slender fasciculus, from the medial border of the coronoid process of the ulna, proximal and medial to the origin of the pronator teres (Fig. 322, p. 392). (2) The *radial* head of origin is from the proximal two-thirds of the volar margin of the radius by a thin fibro-muscular attachment (Fig. 322, p. 392).

In the distal third of the forearm the muscle gives rise to four tendons, one for each of the four medial digits. Those for the middle and ring fingers lie side by side and are placed superficial to the tendons for the index and the little finger. The proximal part of the muscle is similarly subdivisible into two strata, of which the more superficial comprises the radial and part of the humeral head. The whole of the radial head is destined for the middle finger. The same arrangement holds at the wrist, where the tendons pass under cover of the transverse carpal ligament and are enclosed in a large mucous sheath together with the tendons of the flexor digitorum profundus.

Under cover of the palmar aponeurosis the tendons diverge and, in company with the corresponding tendon of the deep flexor, each enters the digital sheath of its own digit. Opposite the first phalanx, the tendon is split into two parts by the tendon of the flexor digitorum profundus; after surrounding that tendon the two parts are partially reunited on its deep surface, and are **inserted**, after partial decussation, in two portions into the sides of the second phalanx.

The **vincula tendinum** form additional insertions of the muscle. They consist of delicate bands of connective tissue enveloped in folds of the mucous sheath, and are known as the **vincula longa** and **brevia**. The vinculum breve is a triangular band of fibres containing yellow elastic tissue (ligamentum subflavum), occupying the interval between the tendon and the digit for a short distance close to the insertion. It is attached to the front of the interphalangeal articulation and the head of the first phalanx. The vinculum longum is a long narrow band extending from the back of the tendon to the proximal part of the palmar surface of the ~~first~~ phalanx. [illegible]

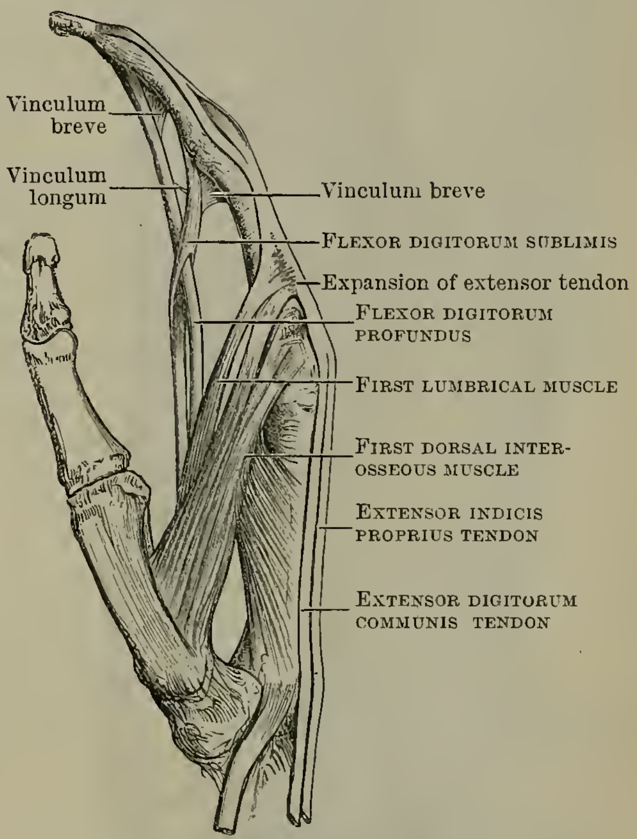
Vinculum breve
Vinculum longum
Vinculum breve
FLEXOR DIGITORUM SUBLIMIS
Expansion of extensor tendon
FLEXOR DIGITORUM PROFUNDUS
FIRST LUMBRICAL MUSCLE
FIRST DORSAL INTEROSSEOUS MUSCLE
EXTENSOR INDICIS PROPRIUS TENDON
EXTENSOR DIGITORUM COMMUNIS TENDON

FIG. 321.—THE TENDONS ATTACHED TO THE INDEX FINGER.

Nerve-Supply.—Median nerve (C. 6.).

Actions.—The muscle is a flexor of the proximal interphalangeal and metacarpo-phalangeal joints. When this action is strongly opposed, the muscle assists in flexing the wrist joint.

3. Deep Layer.

M. Flexor Digitorum Profundus.—The **flexor digitorum profundus** is a large muscle **arising** from the ulna, the interosseous membrane, and the deep fascia of the forearm, under cover of the flexor digitorum sublimis and the flexor carpi ulnaris. Its ulnar origin is from the volar and medial surfaces of the bone in its proximal two-thirds, extending proximally so as to include the medial side of the olecranon, and to embrace the insertion of the brachialis muscle into the coronoid process. It arises laterally from the medial half of the interosseous membrane in its middle third (Figs. 322, p. 392, and 323, p. 393), and medially from the deep fascia of the forearm dorsal to the origin of the flexor carpi ulnaris.

The muscle forms a broad thick tendon which passes beneath the transverse carpal ligament, covered by the tendons of the flexor digitorum sublimis, and enveloped in the same mucous sheath, and divides, in the palm, into four tendons for **insertion** into the terminal phalanges of the fingers. The tendon associated with the forefinger is usually separate in its whole length, and is mainly derived from those fibres which arise from the interosseous membrane.

Each tendon enters the digital sheath of the finger deep to the tendon of the flexor digitorum sublimis, which it pierces opposite the first phalanx, and is finally inserted into the base of the terminal phalanx. Like the tendons of the flexor sublimis, those of the deep flexor are provided with vincula, viz., **vincula brevia** attached to the capsule of the second interphalangeal articulation, and **vincula longa**, which are in this case connected to the tendons of the subjacent flexor digitorum sublimis.

Mm. Lumbricales. — The lumbricales are four small cylindrical muscles associated with the tendons of the flexor digitorum profundus in the palm of the hand. *The two lateral muscles* **arise**, each by a single head, from the radial sides of the tendons of the flexor digitorum profundus destined respectively for the fore and middle fingers. *The two medial muscles* **arise**, each by two heads, from the adjacent sides of the second and third, and third and fourth tendons.

From their origins the muscles are directed distally to the lateral side of each of the metacarpo-phalangeal joints, to be **inserted** into the capsules of these articulations, the lateral border of the first phalanx, and chiefly into the lateral side of the extensor tendon on the dorsum of the phalanx. The lumbricales vary considerably in number, and may be increased to six or diminished to two.

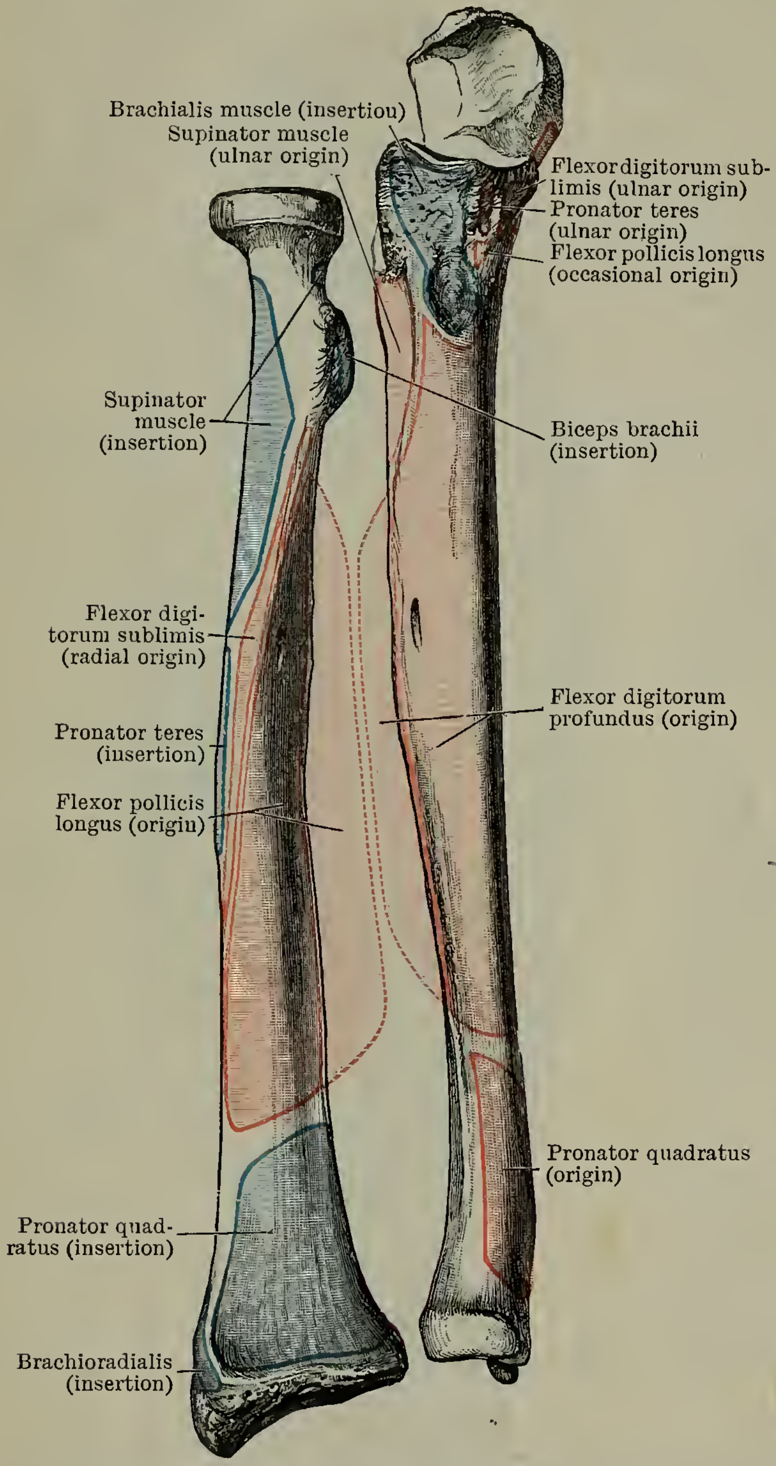
Brachialis muscle (insertion)
Supinator muscle (ulnar origin)
Flexor digitorum sublimis (ulnar origin)
Pronator teres (ulnar origin)
Flexor pollicis longus (occasional origin)
Supinator muscle (insertion)
Biceps brachii (insertion)
Flexor digitorum sublimis (radial origin)
Flexor digitorum profundus (origin)
Pronator teres (insertion)
Flexor pollicis longus (origin)
Pronator quadratus (origin)
Pronator quadratus (insertion)
Brachioradialis (insertion)

FIG. 322.—MUSCLE-ATTACHMENTS TO THE RIGHT RADIUS AND ULNA (Volar Aspects).

Nerve-Supply.—The flexor digitorum profundus is supplied in its lateral part by the volar interosseous branch of the median nerve (C. 7. 8. T. 1.); and in its medial part by the ulnar nerve (C. 8. T. 1.). The lateral two lumbricales are supplied by the median nerve (C. 8. T. 1.), and the medial two muscles by the ulnar nerve (C. 8. T. 1.).

Actions.—Primarily the flexor digitorum profundus is a flexor of the distal phalanges, and it helps to produce flexion of the second and first phalanges. Secondarily, it is a flexor of the wrist joint, this action being brought out when the movement is effected against strong resistance.

The lumbrical muscles act as flexors of the fingers at the metacarpo-phalangeal joints, and, at the same time (by their attachment to the extensor tendons), they act as extensors of the fingers, acting on both inter-phalangeal joints. In this fine movement, which is utilised in making the upward stroke in writing, the interossei participate as well as the lumbricals.

M. Flexor Pollicis Longus.—The **flexor pollicis longus** arises, beneath the flexor digitorum sublimis, by fleshy fibres, from the volar surface of the body of the radius in its middle two-fourths, and from a corresponding portion of the interosseous membrane. It has an additional origin, occasionally, from the medial border of the coronoid process of the ulna (Fig. 322, p. 392). Its radial origin is limited proximally by the oblique origin of the radial head of the flexor digitorum sublimis, and distally by the insertion of the pronator quadratus muscle.

The muscle ends, proximal to the wrist, in a tendon, which passes over the pronator quadratus into the hand beneath the transverse carpal ligament, and is enveloped in a special mucous sheath.

In the palm the tendon is directed distally along the medial side of the thenar eminence, between the flexor brevis and adductor muscles of the thumb, to be **inserted** into the base of the terminal phalanx of the thumb on its volar surface.

The muscle is placed deeply in the forearm, being concealed by the superficial layer of muscles and by the flexor digitorum sublimis.

Nerve-Supply.—Volar interosseous branch of the median (C. 7. 8. T. 1.).

Actions.—The muscle is a flexor of the thumb, acting on the metacarpal bone and both phalanges.

M. Pronator Quadratus.—The **pronator quadratus** is a quadrilateral fleshy muscle, occupying the distal fourth of the forearm. It is placed beneath the deep flexor tendons, and **arises** from the distal fourth of the volar margin and surface of the ulna (Fig. 322, p. 392).

Its fibres run transversely to be **inserted** into the distal fourth of the volar surface of the radius, and into the narrow triangular area on its medial side, in front of the attachment of the interosseous membrane (Fig. 322, p. 392).

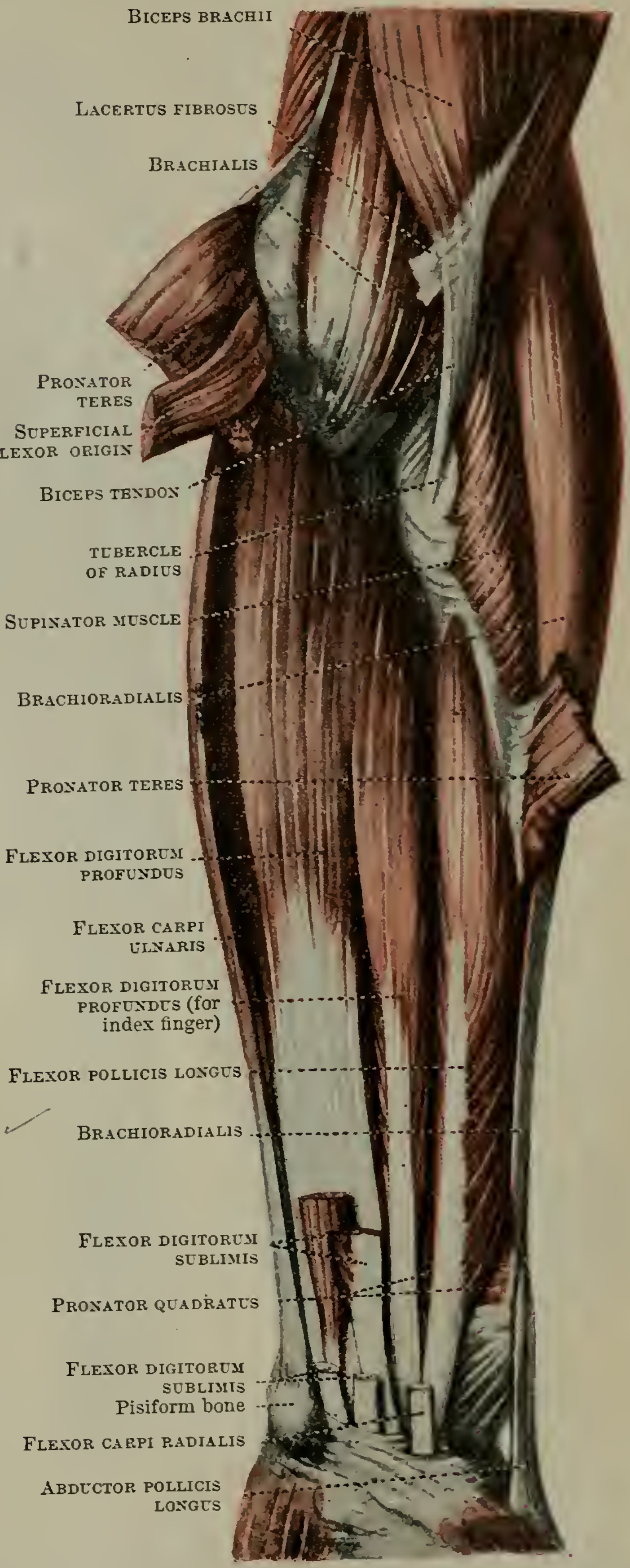

Fig. 323.—The Deepest Muscles on the Volar Aspect of the Left Forearm.

The pronator quadratus is subject to considerable variations. It frequently consists of two strata, separated by the terminal part of the volar interosseous nerve; it may be increased in size, having an additional origin from radius or ulna, or from both bones, and an insertion into the carpus; it may even be absent.

The muscle is placed deeply in the distal part of the forearm, and is wholly concealed by the tendons of the muscles which descend, under cover of the transverse carpal ligament, to the wrist and fingers. The radial artery and its accompanying veins pass over it at its insertion into the radius.

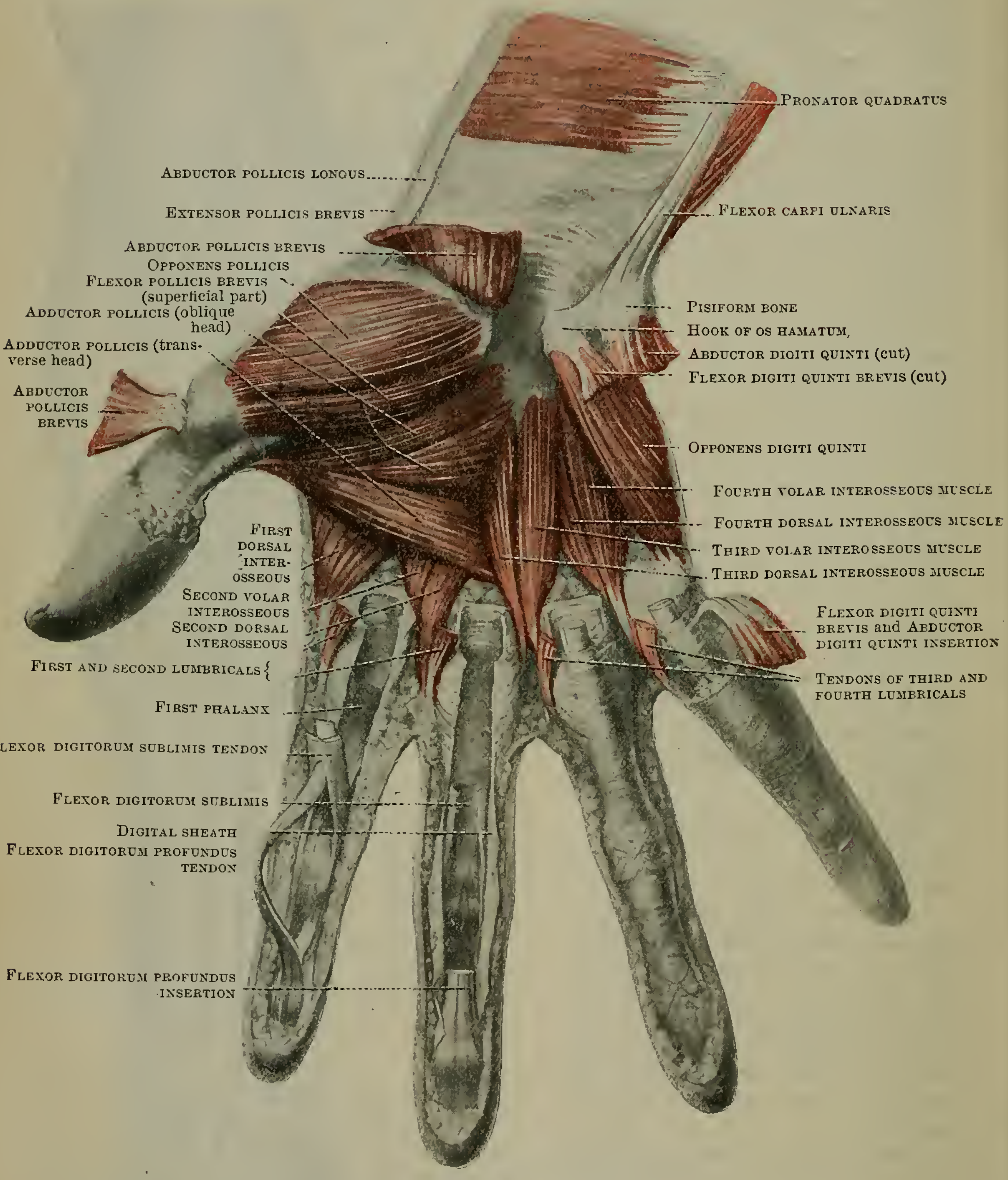
Pronator quadratus
Abductor pollicis longus
Extensor pollicis brevis
Flexor carpi ulnaris
Abductor pollicis brevis
Opponens pollicis
Flexor pollicis brevis (superficial part)
Adductor pollicis (oblique head)
Adductor pollicis (transverse head)
Abductor pollicis brevis
Pisiform bone
Hook of os hamatum,
Abductor digiti quinti (cut)
Flexor digiti quinti brevis (cut)
Opponens digiti quinti
Fourth volar interosseous muscle
Fourth dorsal interosseous muscle
Third volar interosseous muscle
Third dorsal interosseous muscle
First dorsal interosseous
Second volar interosseous
Second dorsal interosseous
Flexor digiti quinti brevis and Abductor digiti quinti insertion
First and second lumbricals
Tendons of third and fourth lumbricals
First phalanx
Flexor digitorum sublimis tendon
Flexor digitorum sublimis
Digital sheath
Flexor digitorum profundus tendon
Flexor digitorum profundus insertion

Fig. 324.—The Palmar Muscles (Right Side)

Nerve-Supply.—Volar interosseous branch of the median nerve (C. 7. 8. T. 1.).

Action.—The muscle acts along with the pronator teres in producing pronation of the forearm.

SHORT MUSCLES OF THE HAND.

The short muscles belonging to the hand, in addition to the palmaris brevis and the lumbrical muscles, already described, include the four muscles of the thumb which produce the thenar eminence, the three muscles of the little finger, which form the hypothenar eminence, and the interossei muscles, which are deeply placed between the metacarpal bones.

Muscles of the Thumb.

The abductor pollicis brevis, the opponens pollicis, the flexor pollicis brevis, and the adductor pollicis constitute the muscles of the thumb.

M. Abductor Pollicis Brevis.—The **abductor pollicis brevis** (O.T. **abductor pollicis**) **arises** by fleshy fibres from the tubercle of the navicular bone, the ridge of the greater multangular bone, the volar surface of the transverse carpal ligament, and from tendinous slips derived from the insertions of the palmaris longus and abductor pollicis longus muscles (Fig. 325, p. 395). Strap-like in form, and superficial in position, it is **inserted** by a short tendon into the radial side of the first phalanx of the thumb at its proximal end, and into the lateral border of the tendon of the extensor pollicis longus muscle.

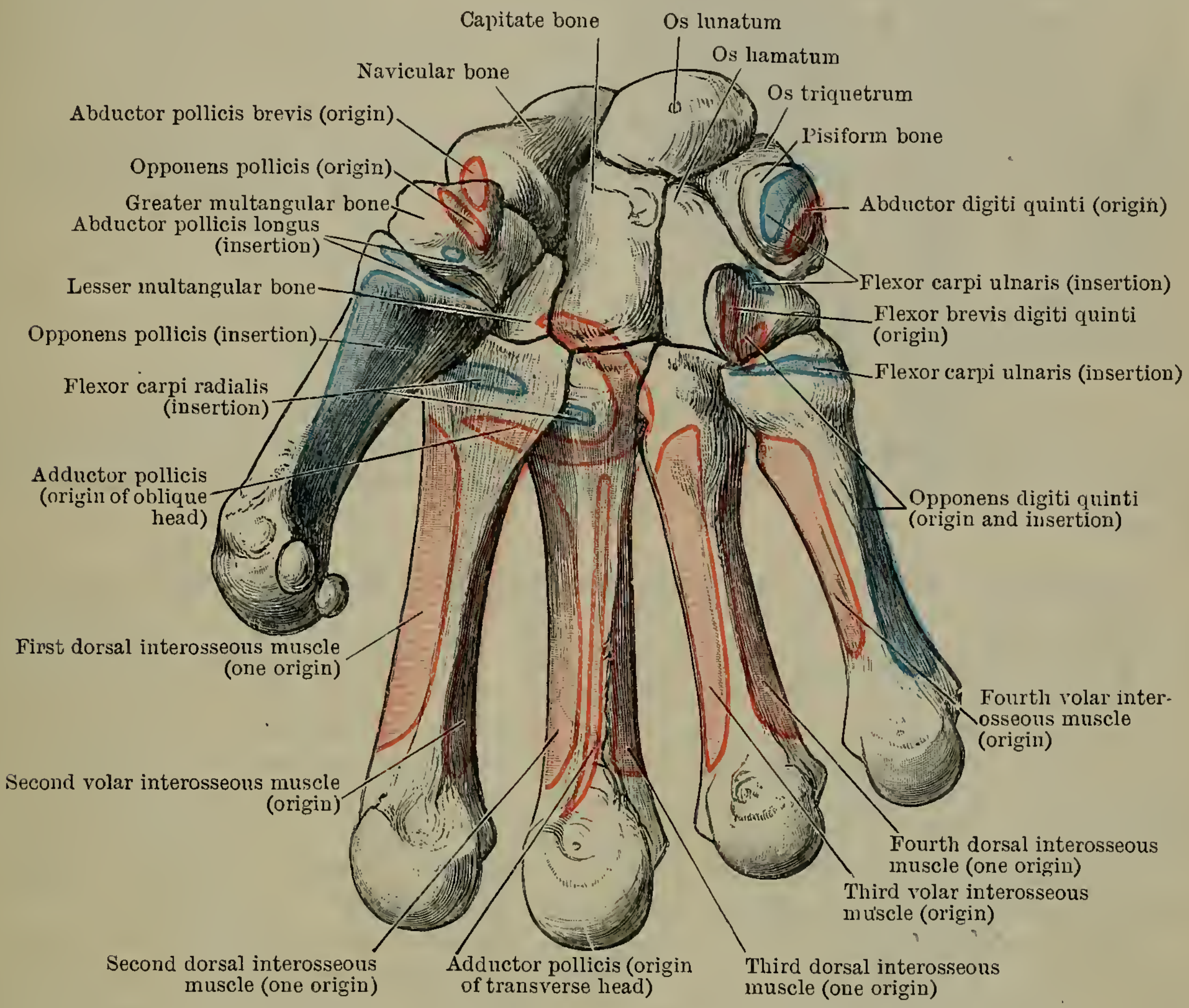
Capitate bone
Os lunatum
Os hamatum
Navicular bone
Os triquetrum
Abductor pollicis brevis (origin)
Pisiform bone
Opponens pollicis (origin)
Greater multangular bone
Abductor digiti quinti (origin)
Abductor pollicis longus (insertion)
Lesser multangular bone
Flexor carpi ulnaris (insertion)
Flexor brevis digiti quinti (origin)
Opponens pollicis (insertion)
Flexor carpi ulnaris (insertion)
Flexor carpi radialis (insertion)
Adductor pollicis (origin of oblique head)
Opponens digiti quinti (origin and insertion)
First dorsal interosseous muscle (one origin)
Fourth volar interosseous muscle (origin)
Second volar interosseous muscle (origin)
Fourth dorsal interosseous muscle (one origin)
Third volar interosseous muscle (origin)
Second dorsal interosseous muscle (one origin)
Adductor pollicis (origin of transverse head)
Third dorsal interosseous muscle (one origin)

FIG. 325.—MUSCLE-ATTACHMENTS TO THE VOLAR ASPECT OF THE CARPUS AND METACARPUS.

Nerve-Supply.—Median nerve (C. 6. 7.).

Actions.—The muscle acts on all the joints of the thumb. The movement of abduction, which it produces, occurs at the carpo-metacarpal joint, and the thumb moves in the direction of its radial border. Owing to the fact that the first metacarpal bone is placed with its volar surface directed medially, abduction of the thumb carries it forwards away from the palm. In addition, the abductor pollicis brevis assists in flexion of the metacarpo-phalangeal and in extension of the interphalangeal joint.

M. Opponens Pollicis.—The **opponens pollicis arises** by fleshy and tendinous fibres from the volar surface of the transverse carpal ligament and from the ridge on the greater multangular bone. It is partially concealed by the preceding muscle.

Extending distally and laterally it is **inserted** into the whole length of the radial border and the radial half of the volar surface of the first metacarpal bone (Fig. 325).

Nerve-Supply.—Median nerve (C. 6. 7.).

Action.—It acts solely on the first metacarpal bone, which is drawn medially and forwards, at the same time being rotated medially. As a result of these combined movements, in which the flexores and the adductor pollicis participate, the thumb can be opposed to each of the other digits.

M. Flexor Pollicis Brevis.—The **flexor pollicis brevis** consists of two parts. (*a*) *The superficial part of the muscle*, partly concealed by the abductor pollicis brevis, **arises**, by fleshy and tendinous fibres, from the distal border of the transverse carpal ligament, and sometimes from the ridge of the greater multangular bone.

It is **inserted** into the radial side of the base of the first phalanx of the thumb, a sesamoid bone being present in the tendon of insertion.

(*b*) *The deep part of the muscle* is blended at its origin with the lateral part of the oblique head of the adductor pollicis, but, separating from that muscle, it passes distally and laterally, deep to the flexor pollicis longus tendon, to be inserted in common with the superficial head.

Nerve-Supply.—Median nerve (C. 6. 7.).
Actions.—It is a flexor of the thumb and assists also in the movement of opposition of the thumb to the fingers.

N.B.—Many English anatomists regard the deep head, above described, as a part of the oblique adductor. They look on the first volar interosseous muscle (p. 397) as the deep head of the flexor pollicis brevis and therefore describe only three volar interossei.

M. Adductor Pollicis.—The **adductor pollicis** is separated into two parts by the radial artery.

(1) The **oblique head** lies deeply in the palm, covered by the tendons of the long flexors of the thumb and fingers. It **arises** by fleshy fibres from the volar surfaces of the greater and lesser multangular and capitate bones, from the sheath of the tendon of the flexor carpi radialis, from the volar surfaces of the bases of the second, third, and fourth metacarpal bones, and from the volar ligaments connecting these bones together (Fig. 325, p. 395).

It is **inserted** by a tendon, in which a sesamoid bone is developed, into the medial side of the base of the first phalanx of the thumb.

(2) The **transverse head**, lying deeply in the palm beneath the flexor tendons, **arises** by fleshy fibres from the medial ridge on the volar aspect of the body of the third metacarpal bone, in its distal two-thirds (Fig. 325, p. 395), and from the fascia covering the interosseous muscles in the second and third spaces.

Triangular in form, it is directed laterally, over the interossei muscles of the first two spaces, to be **inserted** by tendon into the medial side of the base of the first phalanx of the thumb along with the oblique head.

Nerve-Supply.—Deep branch of the ulnar nerve (C. 8. (T. 1.)).
Actions.—Adduction and opposition of the thumb.

Muscles of the Little Finger.

The short muscles of the little finger are the abductor, opponens, and flexor brevis digiti quinti.

M. Abductor Digiti Quinti.—The **abductor digiti quinti** is most superficial. It **arises** from the pisiform bone and from the tendon of the flexor carpi ulnaris and its ligamentous continuations (Fig. 325, p. 395).

It is **inserted** by tendon into the medial side of the base of the first phalanx of the little finger.

Nerve-Supply.—Deep branch of the ulnar nerve (C. 8. (T. 1.)).
Actions.—The muscle separates the little finger from the ring finger, and assists in flexion of the finger at the metacarpo-phalangeal joint.

M. Opponens Digiti Quinti.—The **opponens digiti quinti** arises under cover of the preceding muscle, by tendinous fibres, from the transverse carpal ligament and from the hamulus of the os hamatum.

It is **inserted** into the medial margin and medial half of the volar surface of the fifth metacarpal bone in its distal three-fourths (Fig. 325, p. 395).

Nerve-Supply.—Deep branch of the ulnar nerve (C. 8. (T. 1.)).

Action.—The muscle acts only on the metacarpal bone, drawing it forward, so as to deepen the hollow of the hand.

M. Flexor Digiti Quinti Brevis.—The **flexor digiti quinti brevis** may be absent or incorporated with either the opponens or abductor digiti quinti. It **arises**, by tendinous fibres, from the transverse carpal ligament and from the hamulus of the os hamatum (Fig. 325, p. 395).

It is **inserted** along with the abductor into the medial side of the first phalanx of the little finger.

Nerve-Supply.—The deep branch of the ulnar nerve (C. 8. (T. 1.)).

Actions.—Flexion of the little finger at the metacarpo-phalangeal joint.

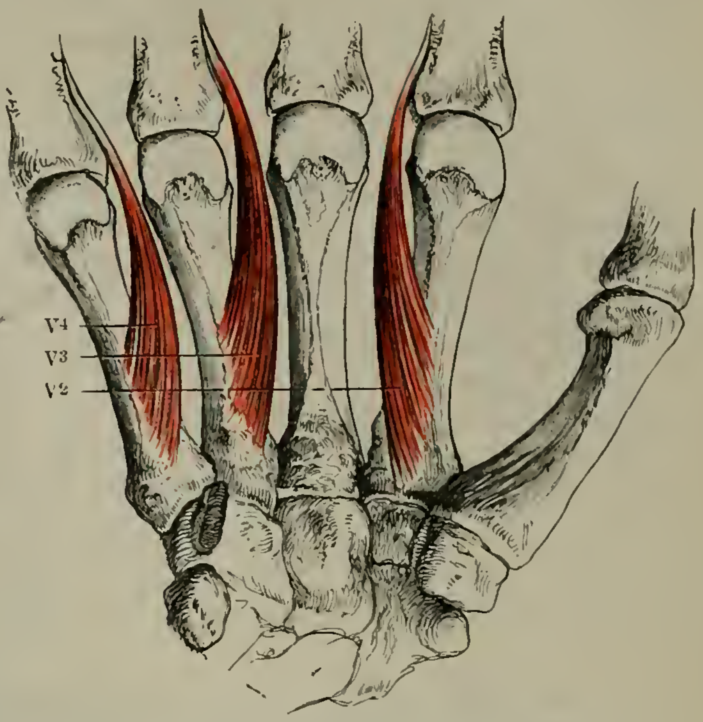

Fig. 326.—The Volar Interosseous Muscles (Right Side).

V^2, second ; V^3, third, and V^4, fourth volar interosseous muscles. The first volar interosseous muscle is shown in Fig. 328.

The Interosseous Muscles.

The interosseous muscles of the hand occupy the spaces between the metacarpal bones. They are arranged in two sets, volar and dorsal.

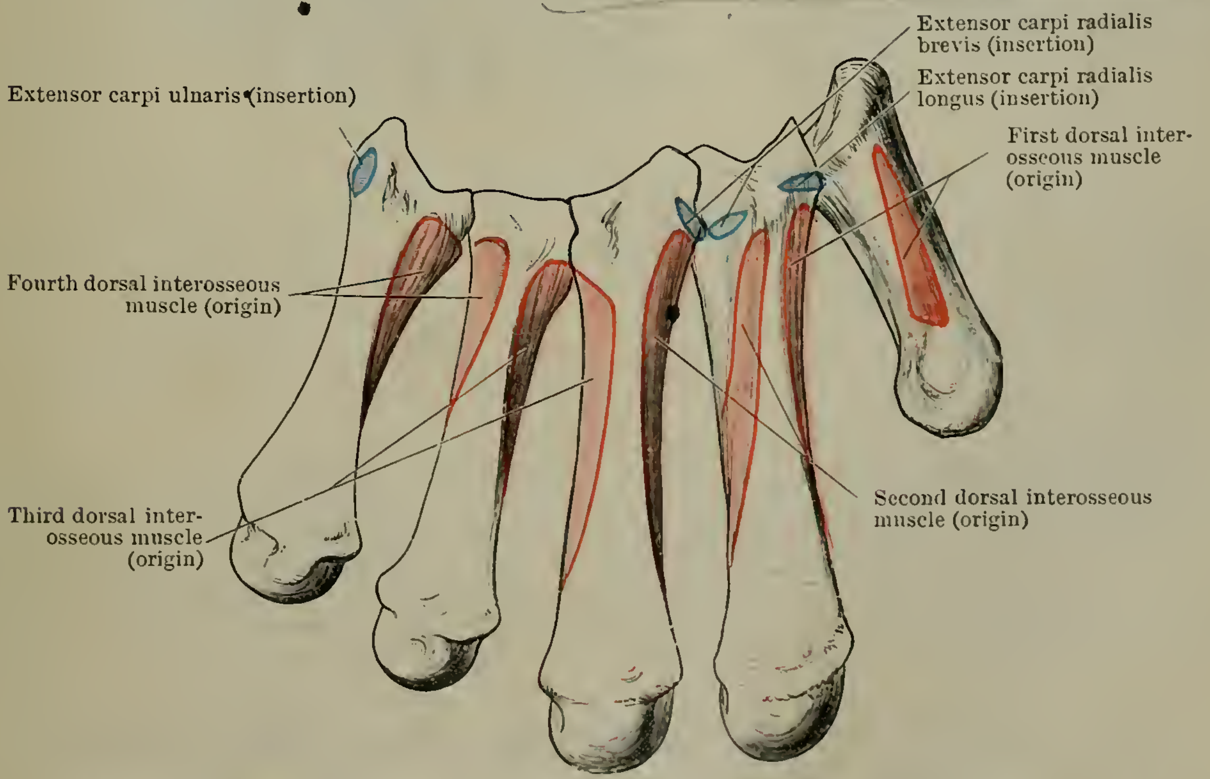
Extensor carpi ulnaris (insertion)
Extensor carpi radialis brevis (insertion)
Extensor carpi radialis longus (insertion)
First dorsal interosseous muscle (origin)
Fourth dorsal interosseous muscle (origin)
Third dorsal interosseous muscle (origin)
Second dorsal interosseous muscle (origin)

Fig. 327.—Muscle-Attachments to the Dorsal Aspect of the Right Metacarpus.

Mm. Interossei Volares.—The **volar** (O.T. **palmar**) **interossei** are four in number. Each **arises** by a single head; the *first* from the medial side of the base of the first metacarpal bone; the *second* from the medial side of the body of the second metacarpal bone; the *third* and *fourth* from the lateral sides of the bodies of the fourth and fifth metacarpal bones respectively (Fig. 327, p. 397). The first volar interosseous muscle lies deeply between the lateral head of the first dorsal interosseous muscle and the oblique head of the adductor pollicis, and is inserted, in common with the latter muscle, into the ulnar side of the base of the first phalanx of the thumb (see note on p. 396). Each of the remaining three ends in a tendon which is directed distally behind the deep transverse metacarpal ligament, to be **inserted** into the dorsal expansion of the extensor tendon, the capsule of the metacarpo-phalangeal articulation, and the side of the first phalanx of the finger; the *second* is **inserted** into the medial side of the second finger; the *third* and *fourth* into the lateral sides of the fourth and fifth fingers.

Mm. Interossei Dorsales.—The **dorsal interossei** are four in number. Each **arises** by two heads from the sides of the metacarpal bones bounding each interosseous space (Figs. 327, p. 397, and 328, p. 398).

Each forms a fleshy mass, ending in a membranous tendon which, passing distally, behind the deep transverse metacarpal ligament, is **inserted**, exactly like the volar muscles, into the dorsal aspect of each of the four fingers. The insertion of the *first* dorsal interosseous muscle is into the lateral side of the index finger; the *second* muscle is attached to the lateral side of the middle finger; the *third* muscle to the medial side of the same finger; and the *fourth* muscle to the medial side of the ring finger.

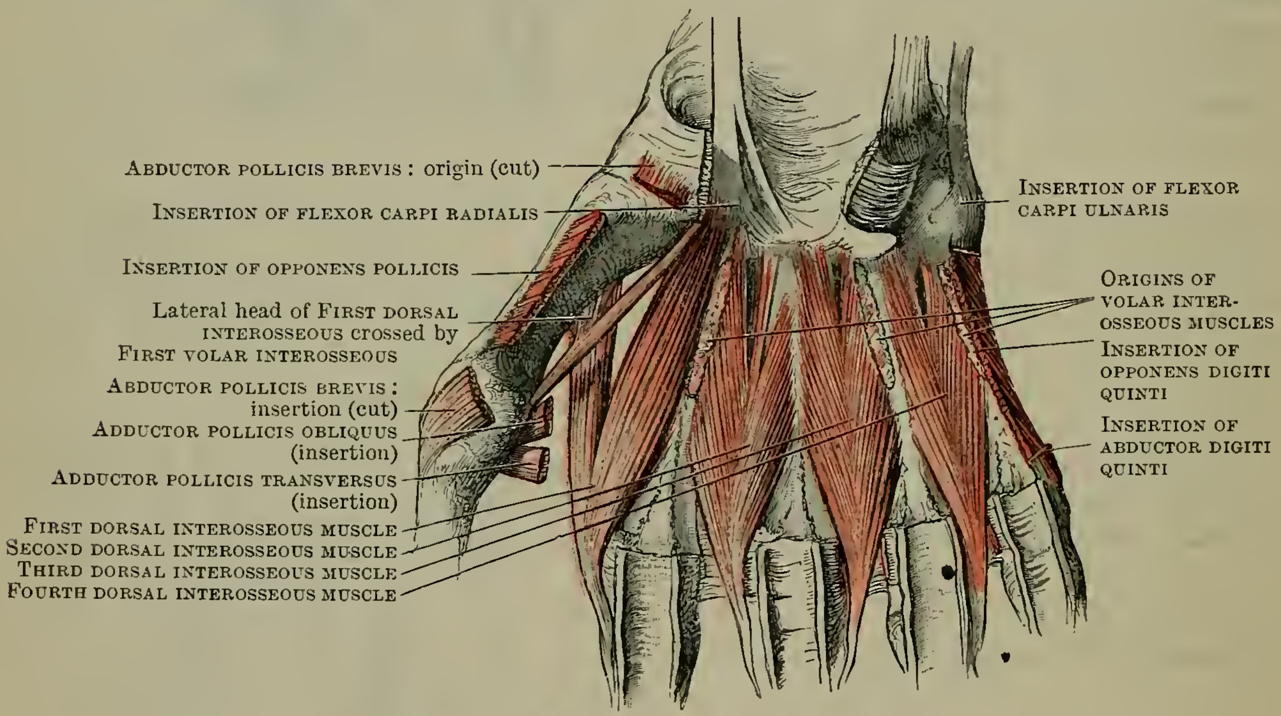
Abductor pollicis brevis: origin (cut)
Insertion of flexor carpi radialis
Insertion of opponens pollicis
Lateral head of First dorsal interosseous crossed by First volar interosseous
Abductor pollicis brevis: insertion (cut)
Adductor pollicis obliquus (insertion)
Adductor pollicis transversus (insertion)
First dorsal interosseous muscle
Second dorsal interosseous muscle
Third dorsal interosseous muscle
Fourth dorsal interosseous muscle
Insertion of flexor carpi ulnaris
Origins of volar interosseous muscles
Insertion of opponens digiti quinti
Insertion of abductor digiti quinti

FIG. 328.—DORSAL INTEROSSEOUS MUSCLES OF THE HAND (seen from the Volar Aspect).

The interosseous muscles of the hand in some cases have a disposition similar to that of the corresponding muscles of the foot (p. 437).

Nerve-Supply.—The deep branch of the ulnar nerve (C. 8. (T. 1.)).

Actions.—The interossei muscles act in a similar way to, and along with, the lumbricales, flexing the fingers at the metacarpo-phalangeal joints, and extending them at the interphalangeal joints. In addition, the **dorsal** interossei serve to **abduct** the fingers into which they are inserted (fore, middle, and ring fingers) from the middle line of the middle finger; the **volar** muscles on the other hand, with the exception of the first, **adduct** the fingers into which they are inserted (fore, ring, and little finger) towards the middle line of the middle finger. The first volar interosseous muscle helps in flexion of the thumb at the metacarpo-phalangeal joint.

THE MUSCLES ON THE DORSAL SURFACE OF THE FOREARM.

The group of muscles occupying the lateral side of the elbow and the dorsal surface of the forearm and hand include the supinator muscles of the forearm and the extensors of the wrist and digits. They are divisible into a **superficial** and a **deep layer.**

The **superficial layer** comprises seven muscles, which are in order, from the radial to the ulnar side of the forearm, the brachioradialis, the two radial extensors of the carpus, the extensor digitorum communis and extensor digiti quinti proprius, the extensor carpi ulnaris, and the anconæus. With the exception of the brachioradialis and the anconæus, these muscles share a common tendon of origin, which is attached to the anterior and distal aspects of the lateral epicondyle of the humerus (Fig. 315, p. 383).

The **deep muscles** are five in number: one, the supinator, extends between the proximal parts of the ulna and radius; the others are the special extensors of the thumb and forefinger, viz., the abductor pollicis longus, extensor pollicis longus and extensor pollicis brevis, and extensor indicis proprius. They cover the dorsal surface of the bones of the forearm and the interosseous membrane, and are almost wholly concealed by the superficial muscles. Only the abductor pollicis longus and the extensor pollicis brevis become superficial in the distal part of the forearm, where they emerge between the radial extensors of the carpus and the extensor digitorum communis.

Superficial Muscles.

M. Brachioradialis.—The **brachioradialis** arises, by fleshy fibres, from the anterior aspect of the proximal two-thirds of the lateral epicondylic ridge of the humerus, and from the anterior surface of the lateral intermuscular septum (Fig. 314, p. 383).

The muscle lies in the lateral side of the hollow of the elbow, passes distally along the lateral border of the forearm, and ends about the middle of the forearm in a narrow, flat tendon. It is **inserted**, under cover of the tendons of the abductor pollicis longus and extensor pollicis brevis, into the lateral side of the distal extremity of the radius, proximal to the styloid process (Figs. 322, p. 392, and 329, p. 400).

Nerve-Supply.—The muscle is supplied by a branch of the radial nerve (C. 5. 6.) in the hollow of the elbow.

Actions.—The muscle is primarily, and, according to Beevor, solely, a flexor of the elbow-joint. It may also act as a semi-pronator and semi-supinator of the forearm, bringing the limb from the supine or prone position, into a position in which the radius lies volar to the ulna.

M. Extensor Carpi Radialis Longus.—The **extensor carpi radialis longus arises**, by fleshy fibres, from the anterior aspect of the distal third of the lateral epicondylic ridge of the humerus, from the anterior surface of the lateral intermuscular septum, and from the common tendon of origin of the extensor muscles (Figs. 314 and 315, p. 383).

In the distal half of the forearm, it ends in a tendon which passes beneath the dorsal carpal ligament, to be **inserted** into the dorsal surface of the base of the second metacarpal bone on its radial side (Fig. 327, p. 397).

The muscle is concealed in its proximal part by the brachioradialis, and its tendon, in the distal half of the forearm, is crossed, obliquely, by the abductor pollicis longus and by the extensor pollicis brevis.

Nerve-Supply.—The muscle is supplied by a branch of the radial nerve in the hollow of the elbow (C. (5.) 6. 7. 8.).

M. Extensor Carpi Radialis Brevis.—The **extensor carpi radialis brevis arises** from the common tendon, from the *radial collateral* ligament of the elbow, from the fascia over it, and from intermuscular septa on either side.

It passes distally, in the dorsal surface of the forearm and under the dorsal carpal ligament, in close relation to the previous muscle, to be **inserted**, by a tendon, into the bases of the second and third metacarpal bones (Fig. 327, p. 397). A bursa is placed beneath the two radial extensor tendons close to their insertion.

It is practically concealed, in the forearm, by the extensor carpi radialis longus, and in the distal half is crossed obliquely by the abductor pollicis longus and the extensor pollicis brevis. The tendons of the two muscles are crossed, on the dorsum of the wrist, by the tendon of the extensor pollicis longus.

Nerve-Supply.—The deep branch of the radial nerve (C. (5.) 6. 7. (8.)).

Actions.—Both muscles are extensors of the wrist and they assist the flexor carpi radialis to produce abduction of the hand. In association with the extensor carpi ulnaris, they are synergic muscles for flexion of the fingers, as they counteract the effect which the digital flexors would otherwise produce on the wrist.

M. Extensor Digitorum Communis.—The **extensor digitorum communis** arises from the common tendon, from the fascia over it, and from intermuscular septa on either side. Extending along the dorsum of the forearm it ends, proximal to the wrist, in four tendons, of which the most lateral often has a separate fleshy belly. After passing under the dorsal carpal ligament, in a compartment along with the extensor indicis proprius, the tendons separate on the dorsum of the hand, where the three most medial tendons are joined together by two obliquely placed bands. One passes distally and laterally, and connects together the third and second tendons; the other is a broader and shorter band, which passes also distally and laterally, and joins the fourth to the third tendon. In some cases a third band is present which passes distally and medially from the first to the second tendon; and, frequently, the tendon for the little finger is joined to the tendon for the ring finger, and separates from it only a short distance above the distal end of the metacarpal bone.

The tendons are **inserted** in the following manner:—On the finger each tendon spreads out so as to form a membranous expansion over the knuckle and on the dorsum of the first phalanx. The border of the tendon is indefinite over the metacarpo-phalangeal articulation, of which it replaces the dorsal ligament. On the dorsum of the first phalanx the tendon receives at its sides the insertions of the interosseous and lumbrical muscles. At the distal end of the first phalanx it splits into ill-defined median and collateral slips, which pass over the dorsum of the first interphalangeal articulation, where they replace the dorsal ligament. The median slip is inserted into the dorsum of the base of the second phalanx, while the two lateral pieces become united to form a membranous tendon on the dorsum of the second phalanx, which, after passing over the second interphalangeal articulation, is inserted into the base of the terminal phalanx.

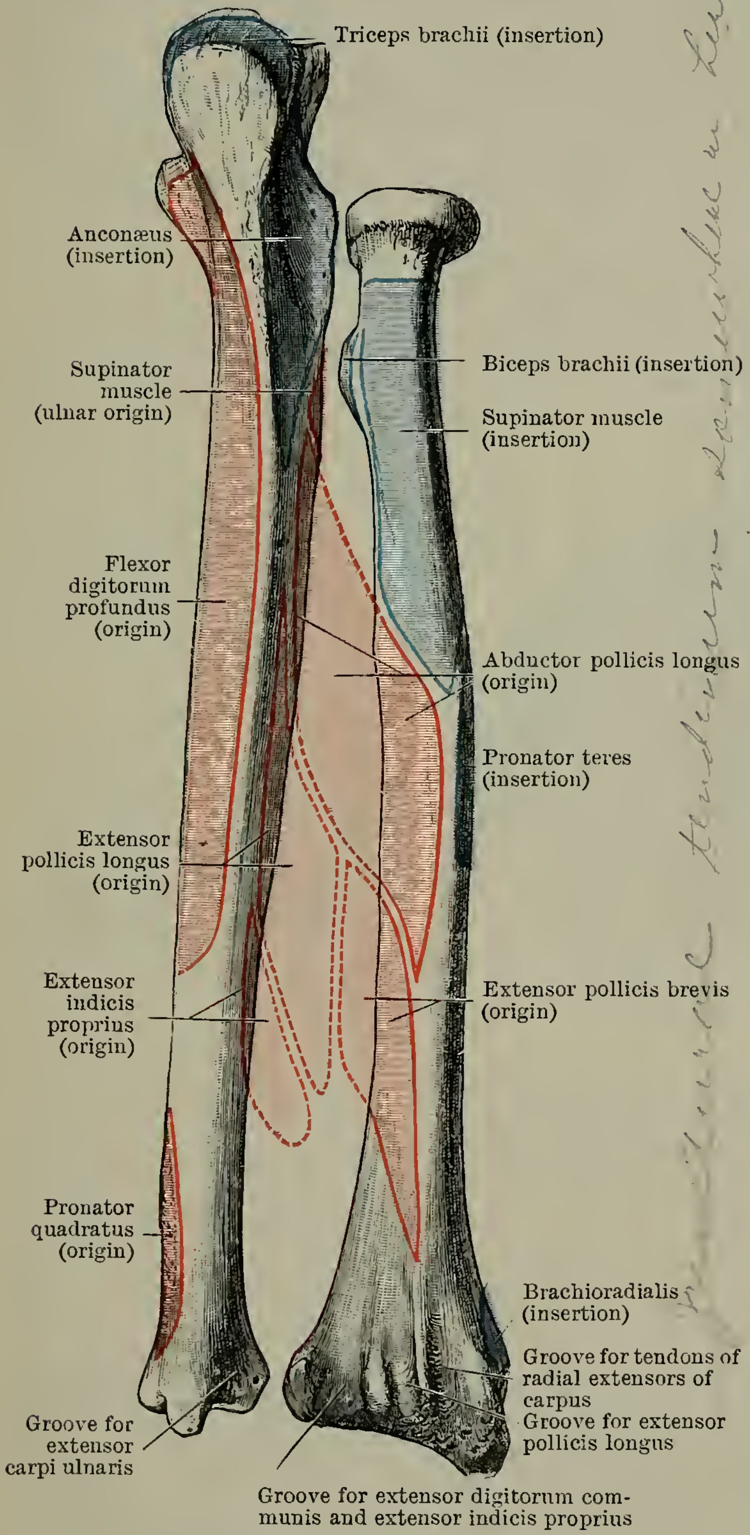
Triceps brachii (insertion)
Anconæus (insertion)
Supinator muscle (ulnar origin)
Biceps brachii (insertion)
Supinator muscle (insertion)
Flexor digitorum profundus (origin)
Abductor pollicis longus (origin)
Pronator teres (insertion)
Extensor pollicis longus (origin)
Extensor indicis proprius (origin)
Extensor pollicis brevis (origin)
Pronator quadratus (origin)
Brachioradialis (insertion)
Groove for tendons of radial extensors of carpus
Groove for extensor pollicis longus
Groove for extensor carpi ulnaris
Groove for extensor digitorum communis and extensor indicis proprius

FIG. 329.—MUSCLE-ATTACHMENTS TO THE RIGHT RADIUS AND ULNA (Dorsal Aspect).

The muscle is placed superficially in the forearm, between the extensors of the carpus and the proper extensor of the little finger (Fig. 330, p. 402).

Nerve-Supply.—The dorsal interosseous nerve (C. (5.) 6. 7. 8.).

Actions.—The muscle extends the fingers and wrist. On account of the attachment together of the tendons to the third, fourth, and fifth fingers by accessory bands on the dorsum of the hand, these three fingers can only be fully extended together, while extension of the index finger can take place separately. In extension of the interphalangeal joints the muscle is aided by the interossei and lumbrical muscles. When the dorsal interossei are paralysed, the fingers can be abducted by the extensor digitorum communis, but this movement is always associated with hyperextension at the metacarpo-phalangeal joints.

M. Extensor Digiti Quinti Proprius.—The **extensor digiti quinti proprius** has an **origin**, similar to and closely connected with that of the preceding muscle, from the common tendon, the fascia over it, and from intermuscular septa.

It passes along the dorsum of the forearm, as a narrow fleshy slip, between the extensor digitorum communis and the extensor carpi ulnaris, and ends in a tendon, which occupies a groove between the radius and ulna in a special compartment of the dorsal carpal ligament. On the dorsum of the hand the tendon is split into two parts, of which the more lateral is joined by the most medial tendon of the extensor digitorum communis, and both are finally **inserted** into the expansion of the extensor tendon on the dorsum of the first phalanx of the little finger.

Nerve-Supply.—The dorsal interosseous nerve (C. (5.) 6. 7. 8.).
Actions.—The muscle extends the little finger and wrist.

M. Extensor Carpi Ulnaris.—The **extensor carpi ulnaris** has a double **origin**: (1) from the common tendon from the lateral epicondyle of the humerus, from the fascia over it, and from the intermuscular septa; and (2), through the medium of the deep fascia, from the dorsal margin of the ulna in its middle two-fourths.

Lying in the forearm upon the medial part of the dorsal surface of the ulna, it ends in a tendon which occupies a groove on the dorsal surface of the ulna in a special compartment of the dorsal carpal ligament, and is **inserted** into the medial side of the base of the fifth metacarpal bone (Fig. 327, p. 397).

Nerve-Supply.—The dorsal interosseous nerve (C. (5.) 6. 7. 8.).
Actions.—The muscle is an extensor of the wrist, and at the same time, acting with the flexor carpi ulnaris, it is a powerful adductor of the wrist. Together with the radial extensors of the wrist, it is a synergic muscle for flexion of the fingers (p. 399).

M. Anconæus.—The **anconæus** is a small triangular muscle. It **arises**, by a separate tendon, from the distal part of the dorsal surface of the lateral epicondyle of the humerus (Fig. 315, p. 383) and from the dorsal part of the capsule of the elbow-joint.

It partially conceals the posterior ligament of the elbow-joint, the annular ligament of the radius, and the proximal part of the ulna, and is **inserted**, by fleshy fibres, into a triangular surface on the lateral aspect of the olecranon and dorsal surface of the ulna, as far distally as the oblique line (Fig. 329, p. 400). It is also inserted into the fascia which covers it.

Nerve-Supply.—The muscle is supplied by the terminal branch of the nerve to the medial head of the triceps muscle from the radial (C. 7. 8.).
Actions.—The anconæus is an extensor of the elbow.

Deep Muscles.

M. Supinator.—The **supinator muscle** is the most proximal of the deeper muscles. It is almost wholly concealed by the superficial muscles, and has a complex **origin**—(1) from the lateral epicondyle of the humerus; (2) from the radial collateral ligament of the elbow-joint and the annular ligament of the radius; and (3) from the dorsal part of the triangular surface on the shaft of the ulna just distal to the radial notch.

From this origin the muscle spreads laterally and distally dorsal to the proximal part of the radius, which it envelops almost completely, and is **inserted** into the volar and lateral surfaces of the bone. This attachment extends as far forwards as the tubercle of the radius, as far proximally as the neck, and as far distally as the oblique line and the insertion of the pronator teres (Figs. 322, p. 392, and 328, p. 400).

The muscle is divisible into *superficial* and *deep parts* with humeral and ulnar origins, between which the deep branch of the radial nerve passes in its course to the dorsal aspect of the forearm.

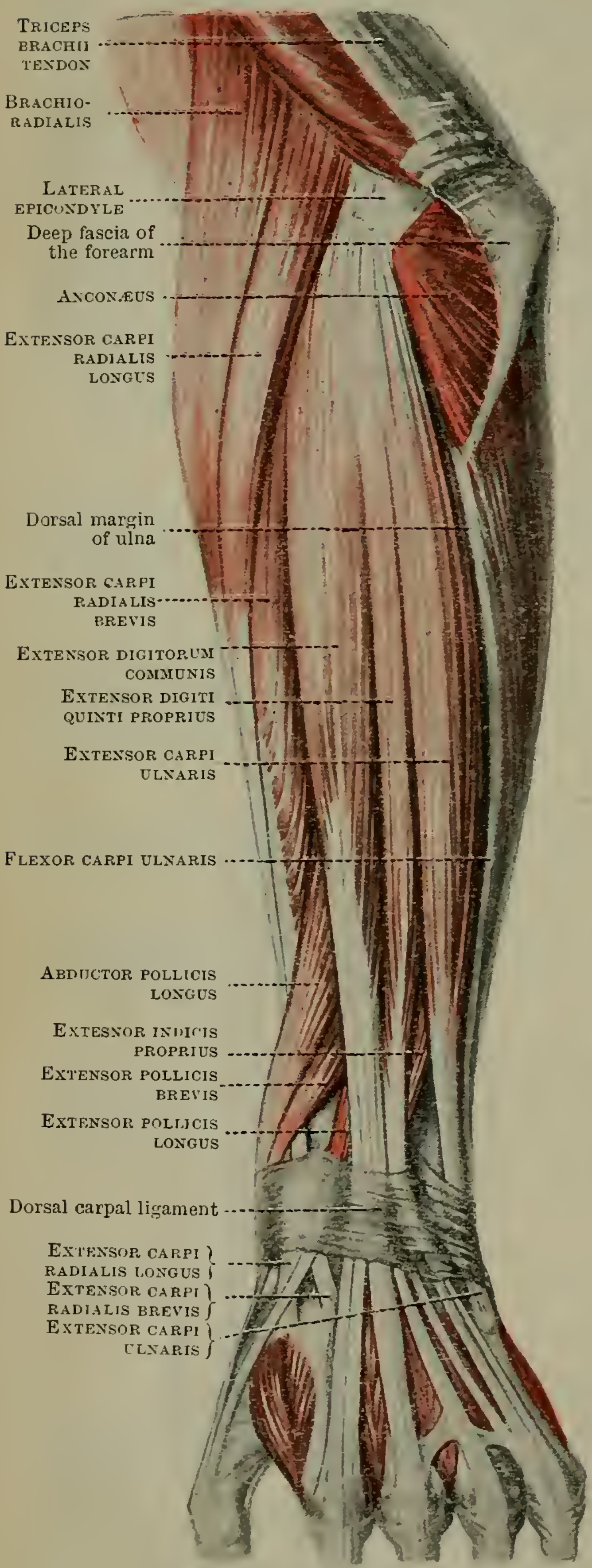

Fig. 330.—Superficial Muscles on the Dorsum of the Left Forearm.

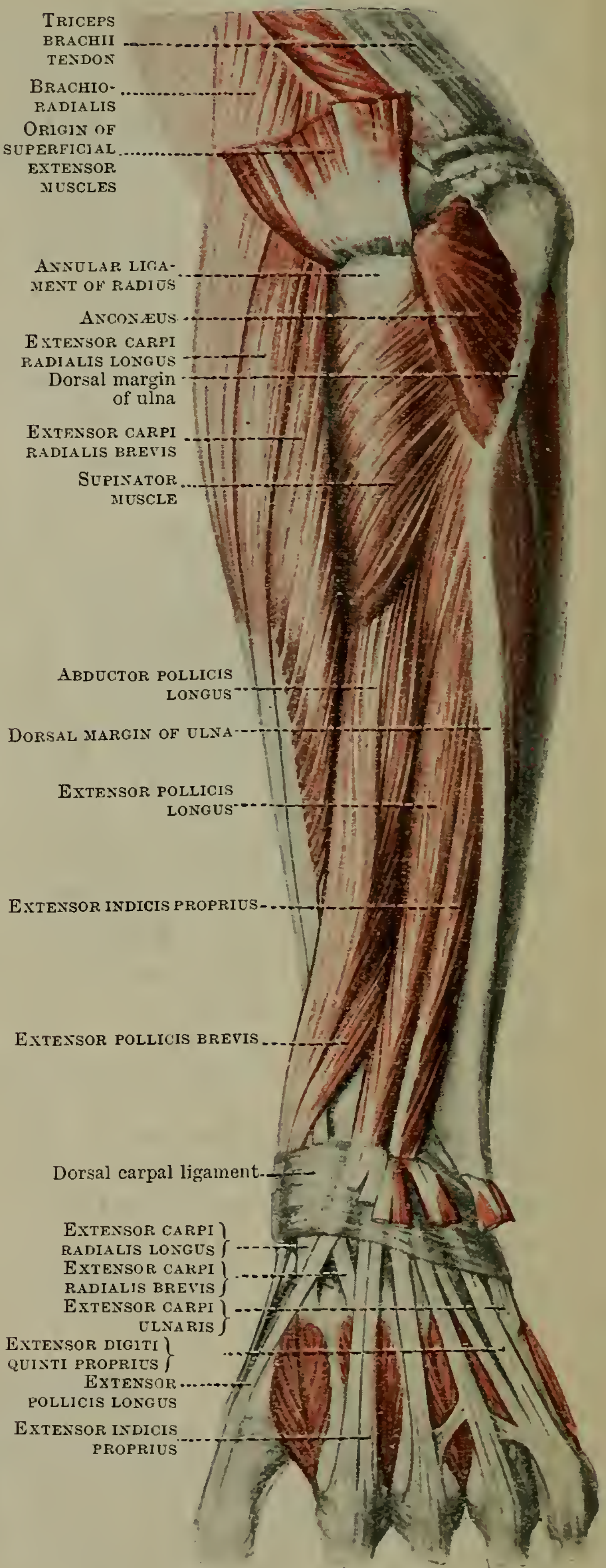
Triceps brachii tendon
Brachio-radialis
Origin of superficial extensor muscles
Annular ligament of radius
Anconæus
Extensor carpi radialis longus
Dorsal margin of ulna
Extensor carpi radialis brevis
Supinator muscle
Abductor pollicis longus
Dorsal margin of ulna
Extensor pollicis longus
Extensor indicis proprius
Extensor pollicis brevis
Dorsal carpal ligament
Extensor carpi radialis longus
Extensor carpi radialis brevis
Extensor carpi ulnaris
Extensor digiti quinti proprius
Extensor pollicis longus
Extensor indicis proprius

Fig. 331.—Deep Muscles on the Dorsum of the Left Forearm.

Nerve-Supply.—The supinator is supplied by a branch from the deep branch of the radial nerve, which arises from the nerve before the main trunk enters the muscle (C. 5. 6.).

Action.—The muscle is the main supinator of the forearm, and in this action it is assisted by the biceps.

M. Abductor Pollicis Longus.—The **abductor pollicis longus** (O.T. **extensor ossis metacarpi pollicis**) arises by fleshy fibres, distal to the supinator muscle, from the most proximal of the narrow impressions on the lateral half of the dorsal surface of the ulna; from the middle third of the dorsal surface of the radius; and from the intervening portion of the interosseous membrane (Fig. 329, p. 400).

The muscle passes obliquely, distally, and laterally, and becomes superficial in the distal part of the forearm, where it emerges between the radial extensors of the wrist and the common extensor of the fingers. With the extensor pollicis brevis tendon closely applied to its medial side, the tendon covers the insertion of the brachioradialis and passes through the most lateral compartment of the dorsal carpal ligament. It next covers the styloid process of the radius and the radial collateral ligament of the wrist joint, from which it is separated by the radial artery, and is **inserted** into the lateral side of the base of the first metacarpal bone (Fig. 325, p. 395). From the tendon, close to its insertion, a tendinous slip passes to the abductor pollicis brevis and the fascia over the thenar eminence, and another is frequently attached to the greater multangular bone.

Nerve-Supply.—The dorsal interosseous nerve (C. (5.) 6. 7. 8.).
Actions.—The muscle abducts and extends the metacarpal bone of the thumb, and assists in abduction and flexion of the wrist.

M. Extensor Pollicis Brevis.—The **extensor pollicis brevis**, an essentially human muscle, is a specialised portion of the previous muscle. It **arises** from a rhomboid impression on the dorsal surface of the radius, and from the interosseous membrane, distal to the abductor pollicis longus (Fig. 329, p. 400). It is closely adherent to that muscle, and accompanies it deep to the dorsal carpal ligament and over the radial artery to the thumb.

Its tendon is then continued along the dorsal surface of the first metacarpal bone, to be **inserted** into the dorsal surface of the base of the first phalanx of the thumb. Before reaching its insertion the tendon helps to form the capsule of the metacarpo-phalangeal joint.

Nerve-Supply.—The dorsal interosseous nerve (C. (5.) 6. 7. 8.).
Actions.—The muscle extends the thumb (or the metacarpo-phalangeal joint), and assists in abduction of the wrist.

M. Extensor Pollicis Longus.—The **extensor pollicis longus arises** from the lateral part of the dorsal surface of the ulna, in its middle third, and from the interosseous membrane, distal to the abductor pollicis longus (Fig. 329, p. 400). Its tendon grooves the dorsal surface of the radius, and occupies a special compartment under cover of the dorsal carpal ligament.

Extending obliquely across the dorsal surface of the hand, the tendon crosses the radial artery, helps to form the capsule of the first metacarpo-phalangeal articulation, and is **inserted** into the dorsal surface of the base of the second phalanx of the thumb.

At the wrist the tendons of the muscles of the thumb, the abductor pollicis longus and extensor pollicis brevis laterally, and the extensor pollicis longus medially, bound a hollow (the "anatomical snuff-box") best seen in extension of the thumb. In this situation the pulsation of the radial artery can readily be felt.

Nerve-Supply.—The dorsal interosseous nerve (C. (5.) 6. 7. 8.).
Actions.—This muscle is an extensor of the thumb and of the wrist, and assists in abduction of the hand.

M. Extensor Indicis Proprius.—The **extensor indicis proprius arises**, distal to the extensor pollicis longus, from the most distal impression on the dorsal surface of the ulna, extending distally from the middle of the body to within two inches of its distal end, and sometimes also from the interosseous membrane (Fig. 329, p. 400). Its tendon passes through a compartment of the dorsal carpal ligament along with the tendons of the extensor digitorum communis.

On the dorsum of the hand the tendon lies on the ulnar side of the tendon of the common extensor destined for the forefinger, and is **inserted** into the membranous expansion of that tendon on the dorsum of the first phalanx.

Nerve-Supply.—The dorsal interosseous nerve (C. (5.) 6. 7. 8.).
Actions.—The muscle is an extensor of the forefinger and wrist.

Movements of the Upper Limb.—The characteristic features of the movements of the upper limb are their range and refinement. The hand, in addition to its intrinsic powers, can be moved through a wide range and in several planes by the muscles acting on the wrist and radio-ulnar joints; this range is increased by the fore and aft movements at the elbow-joint, and the extensive movements of which the shoulder and clavicular joints are capable. The result is that the hand can be brought into a position to cover and guard any portion of the body. The precision and refinement of movement is made possible by the co-ordinate movements of the various muscles acting upon the several joints, so that actions can be performed (as raising the food to the mouth) in which all the articulations of the limb are brought into play; while others (such as writing) are possible by movements at the joints of the wrist and fingers along with fixation of the elbow-joint.

The power of the grip, which is such an important feature of the human hand, is due, in no small measure, to the existing ability to oppose the thumb to the other digits. This movement is only possible (1) because the metacarpal bone of the thumb is set in a plane at right angles to the plane in which the other metacarpals lie, and (2) because the carpo-metacarpal joint of the thumb allows a wide range of movement. As a result of the set of the thumb, flexion carries it medially across the palm, and a very small degree of rotation of its metacarpal bone enables the movement of opposition to be effected. When the fingers encircle a small object, the grip is strengthened by the overlapping thumb, which can then be opposed to the dorsal aspects of the third and, if the object be small enough, second phalanges of the index and middle fingers.

THE LOWER LIMB.

FASCIÆ AND MUSCLES OF THE THIGH AND BUTTOCK.

FASCIÆ.

The **superficial fascia** of the thigh and buttock is continuous above with the fascia of the abdomen and back, medially with that of the perineum, and distally with that of the leg. It presents noticeable features in the buttock and groin.

In the buttock the superficial fascia is of considerable thickness, and is usually loaded with fat, whereby it assists in forming the contour of the buttock and the fold of the nates.

In the groin it is divisible into *two layers*: a **superficial fatty layer**, continuous with a similar layer on the anterior surface of the abdominal wall above, and over the perineum medially, and a **deeper membranous layer**, which is attached above to the medial half of the inguinal ligament, and to the deep fascia of the thigh just distal to the lateral half of that ligament. Medially it is attached to the pubic arch, and below the level of the femoral triangle it blends inseparably with the superficial fatty layer. The separation of these two layers of the superficial fascia is occasioned by the presence between them of the inguinal and superficial subinguinal lymph glands, the great saphenous vein and its tributaries, and some small arteries. The attachment of the deeper layer of the fascia to the pubic arch and the inguinal ligament cuts off the superficial tissues of the thigh from the perineum and the abdominal wall, and prevents the passage into the thigh of fluid collected in the perineum or beneath the fascia of the abdominal wall.

The **deep fascia** or **fascia lata** forms a tubular investment for the muscles and vessels of the thigh and buttock. It is firmly attached above to the iliac crest, the sacro-tuberous ligament, the ischium, the pubic arch, the pubic symphysis and crest, and the inguinal ligament. In the distal part of the thigh it forms the intermuscular septa; and in relation to the knee, it is continuous with the deep fascia of the leg, gains attachment to the patella, the condyles of the tibia and the head of the fibula, and forms the collateral ligaments of the patella.

On the front of the thigh the deep fascia is thick and strong. It is pierced by numerous openings for vessels and nerves, the most important of which is the **fossa ovalis** (O.T. **saphenous opening**) for the passage of the great saphenous vein. A femoral hernia passes through this opening to reach the groin and anterior abdominal wall. It is an oval opening, of variable size, situated just distal to the medial half of the inguinal ligament, and immediately anterior to the femoral vessels. It is covered by the superficial fascia, and by a special layer of fascia, the **fascia cribrosa**, a thin perforated lamina attached to the margins of the opening. The lateral edge of the opening (*margo falciformis*) is formed by the sharp margin of the *iliac portion* of the fascia lata, which is attached above to the iliac crest and the inguinal ligament; the ill-defined medial edge is formed by the *fascia pectinea* which is continued proximally, behind the femoral sheath, over the pectineus muscle to the ilio-pectineal line and the capsule of the hip-joint. These two parts of the fascia lata are continuous at the distal concave margin of the fossa ovalis, forming a distinct **inferior cornu** over which the great saphenous vein passes immediately before it terminates in the femoral vein (Fig. 333, p. 406). As they pass proximally towards the pelvis they occupy different planes, the iliac portion being in front of the sheath of the femoral vessels, while the pectineal fascia is behind it. The **superior cornu** of the fossa ovalis, placed in front of the sheath, is derived solely from the iliac portion of the fascia lata. It forms a strong triangular band of fascia known as the **falciform margin**, attached above to the medial half of the inguinal ligament. It has an important share in directing the course of a femoral hernia upwards on to the abdominal wall.

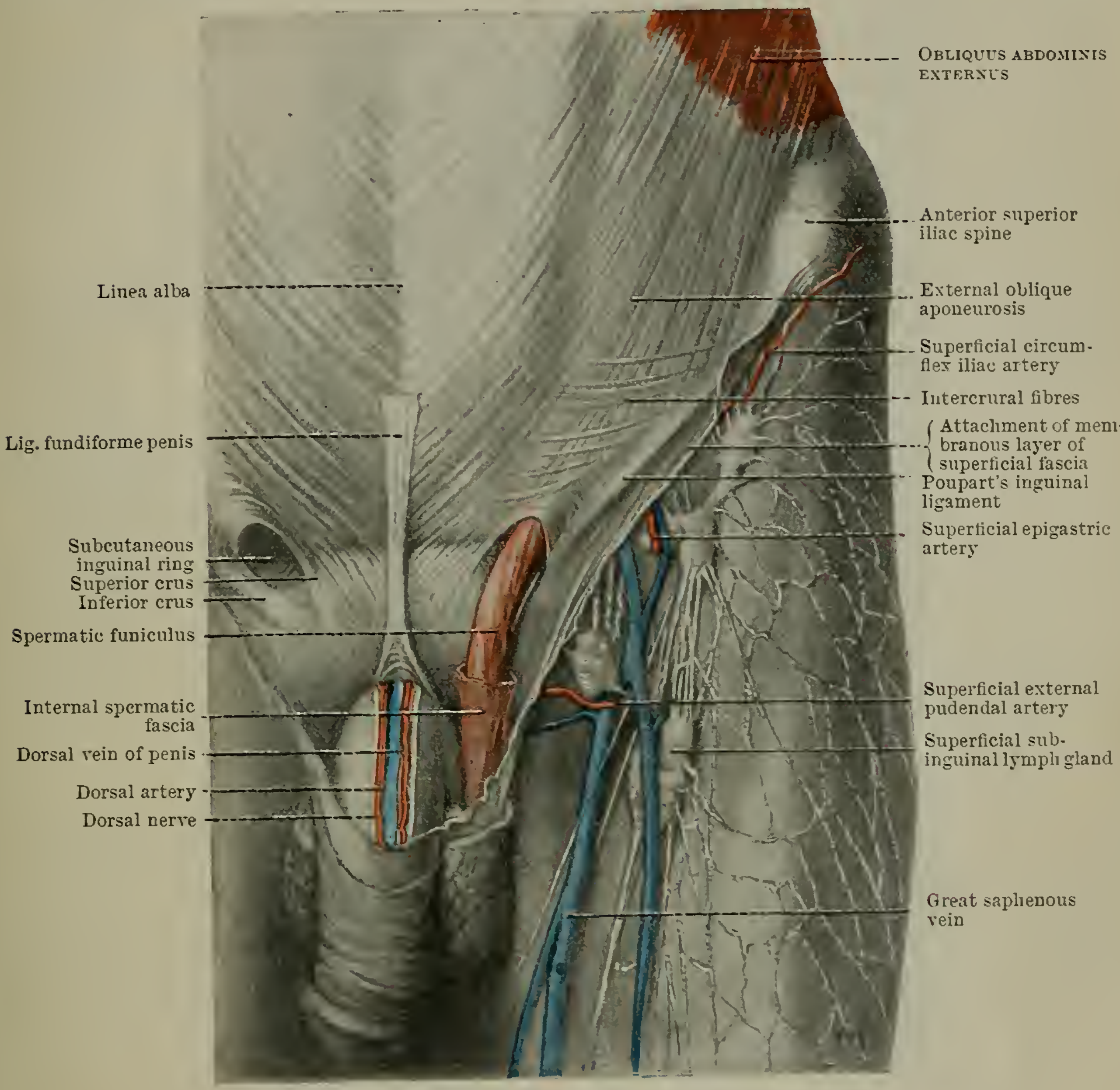
Obliquus abdominis externus
Anterior superior iliac spine
Linea alba
External oblique aponeurosis
Superficial circumflex iliac artery
Intercrural fibres
Lig. fundiforme penis
Attachment of membranous layer of superficial fascia
Poupart's inguinal ligament
Superficial epigastric artery
Subcutaneous inguinal ring
Superior crus
Inferior crus
Spermatic funiculus
Superficial external pudendal artery
Internal spermatic fascia
Superficial sub-inguinal lymph gland
Dorsal vein of penis
Dorsal artery
Dorsal nerve
Great saphenous vein

Fig. 332.—Superficial Anatomy of the Left Groin.

On the medial side of the thigh the fascia lata is thin where it covers the adductor muscles. At the knee it is associated with the tendons of the vasti muscles, and forms the **collateral ligaments of the patella**, attached to the borders of the patella and to the condyles of the tibia. On the lateral side of the thigh it forms the **tractus iliotibialis**—a broad thick layer of fascia which is attached above to the iliac crest, and receives the insertions of the tensor fasciæ latæ, and part of the glutæus maximus muscles; its distal attachment is to the capsule of the knee-joint and the lateral condyle of the tibia. A strong band of fascia continued proximally from the ilio-tibial tract, beneath the tensor fasciæ latæ muscle, joins the tendon of origin of the rectus femoris and the capsule of the hip-joint.

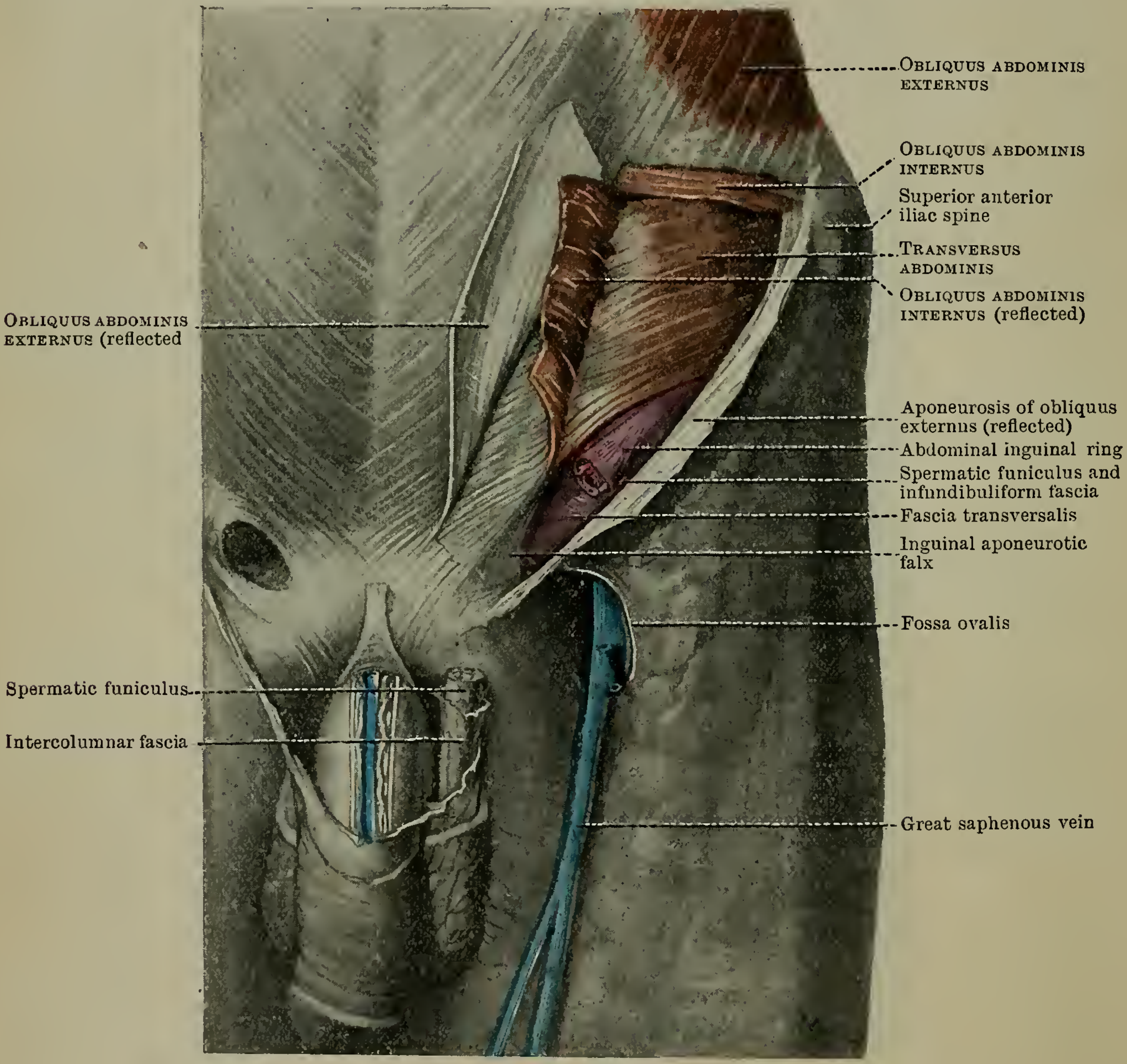
Obliquus abdominis externus
Obliquus abdominis internus
Superior anterior iliac spine
Transversus abdominis
Obliquus abdominis internus (reflected)
Obliquus abdominis externus (reflected
Aponeurosis of obliquus externus (reflected)
Abdominal inguinal ring
Spermatic funiculus and infundibuliform fascia
Fascia transversalis
Inguinal aponeurotic falx
Fossa ovalis
Spermatic funiculus
Intercolumnar fascia
Great saphenous vein

Fig. 333.—The Dissection of the Left Inguinal Canal.

On either side of the thigh above the knee an intermuscular septum is formed. The **lateral intermuscular septum** extends medially from the ilio-tibial tract to the lateral epicondylic line and linea aspera of the femur, and gives attachment to the vastus lateralis and vastus intermedius anteriorly, and the short head of the biceps posteriorly. The **medial intermuscular septum** in the distal third of the thigh is associated with, and to a large extent represented by, the tendon of insertion of the adductor magnus muscle. It is also related to the fascia which envelops the adductor muscles, and forms the sheaths for the sartorius and gracilis muscles. In the middle third of the thigh the fascia under the sartorius is greatly thickened by transverse fibres and binds together the vastus medialis and adductor longus and adductor magnus muscles. This layer of fascia roofs over the femoral vessels in their course through the *adductor canal* (Hunter's).

The fascia lata of the **buttock** is thick anteriorly where it covers and gives origin to the glutæus medius, but is much thinner posteriorly, where it splits to enclose the glutæus maximus muscle. Over the greater trochanter it becomes continuous with that part of the ilio-tibial tract, into which most of the fibres of the glutæus maximus gain insertion.

On the **posterior surface of the thigh** and over the **popliteal fossa** the fascia is strengthened by transverse fibres derived from the hamstring muscles. The **popliteal fascia** forming the roof of the popliteal fossa is specially thick, and is usually pierced by the small saphenous vein.

Femoral Sheath.—This is a conical membranous investment, derived from the fascial lining of the abdominal cavity, the fascia transversalis being carried distally in front of, and the fascia iliaca behind, the femoral vessels as they pass from the pelvis into the femoral triangle. The sheath is about an inch and a half in length, and is divided into three compartments—a lateral compartment for the artery, an intermediate compartment for the vein, and a medial compartment containing lymph vessels and fat, and named the **femoral canal.** This canal is the passage through which a femoral hernia enters the thigh. Its mouth or proximal limit is the **femoral ring,** bounded anteriorly by the inguinal ligament, posteriorly by the origin of the pectineus muscle from the pubis, medially by the *ligamentum lacunare* (*Gimbernati*), and laterally by the femoral vein. In front of it the fascia transversalis forming the sheath is thickened to form the **deep femoral arch.** The part of the inguinal ligament in front of the ring is called the **superficial femoral arch.** The inferior epigastric artery separates the ring from the abdominal inguinal ring. The canal ordinarily contains fat which is continuous above with the extra-peritoneal tissue. The ring is filled by a plug of fat or a lymph gland, constituting the **femoral septum.**

The femoral canal ends behind the fossa ovalis, covered by the fascia cribrosa, while the falciform margin crosses over it and conceals its proximal portion. The course of a femoral hernia is determined by this band. The hernia descends through the femoral ring, pushing the femoral septum before it; after passing through the femoral canal, it is directed forwards through the fossa ovalis. The anterior part of the hernia being pressed upon and retarded by the femoral arches, and by the falciform margin, the posterior part pushes onwards, hooks round the falciform margin, and is directed upwards over the inguinal ligament. The coverings of a femoral hernia, in addition to peritoneum and extra-peritoneal tissue (femoral septum), are femoral sheath, fascia cribrosa, superficial fascia, and skin.

MUSCLES OF THE THIGH AND BUTTOCK.

The muscles of the thigh and buttock are divisible into four main groups by their situation, action, and nerve-supply. On the **anterior surface** of the thigh are the quadriceps femoris, the sartorius, ilio-psoas, and pectineus muscles; on the **medial side** of the thigh are the adductor muscles; in the region of the **buttock** are the glutæi and rotators of the hip-joint; and on the **posterior aspect** of the thigh are the hamstring muscles.

THE MUSCLES ON THE ANTERIOR ASPECT OF THE THIGH.

The chief muscle on the anterior aspect of the thigh is the quadriceps femoris, which occupies the space between the tensor fasciæ latæ and ilio-tibial tract laterally, and the sartorius medially. The sartorius crosses the thigh obliquely; it separates the quadriceps femoris from the adductor muscles; it forms in the proximal third of the thigh the lateral boundary of the femoral triangle, and in the middle third of the thigh, the roof of the adductor canal (Hunter's). The ilio-psoas, passing into the thigh beneath the inguinal ligament, helps the pectineus and adductor longus to form the floor of the femoral triangle.

M. Sartorius.—The **sartorius,** a long strap-like muscle, arises from the anterior superior spine of the ilium and half of the margin of the notch below it (Fig. 343).

It passes obliquely across the front of the thigh, and, reaching its medial side, descends vertically across the medial side of the knee. It is **inserted,** by

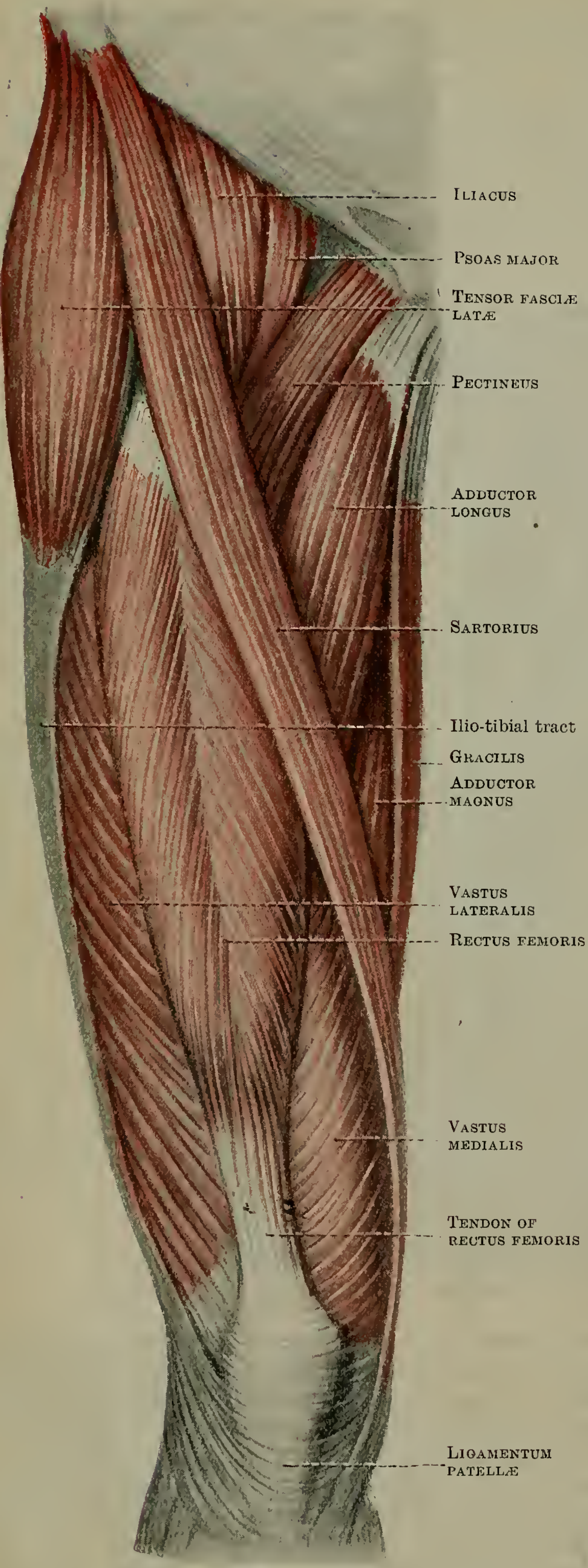

Fig. 334.—The Muscles of the Anterior Aspect of the Right Thigh.

aponeurotic fibres, into the medial surface of the body of the tibia just distal to the medial condyle, and by its borders into fascial expansions which join the capsule and the tibial collateral ligament of the knee-joint, and the fascia lata of the leg (Fig. 334).

The sartorius is superficial in its whole extent. Its proximal third forms the lateral boundary of the femoral triangle; its middle third forms the roof of the adductor canal and covers the femoral vessels; and its distal third is separated from the tendon of the gracilis muscle by the saphenous nerve and the saphenous branch of the arteria genu suprema. A bursa lies beneath the tendon at its insertion.

Nerve-Supply.—The sartorius is supplied by two sets of nerves associated with the two intermediate cutaneous branches of the femoral nerve (L. 2. 3.).

Actions.—The sartorius, "the tailor's muscle," is a flexor of the hip and knee joints. It also adducts the thigh and rotates it laterally, and assists in medial rotation of the tibia.

M. Quadriceps Femoris.—The **quadriceps femoris** is composed of four muscles—the rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis.

The rectus femoris is superficial except at its origin, which is covered by the glutæi, sartorius, and tensor fasciæ latæ muscles. The vasti lie on either side of the rectus muscle, the vastus lateralis being partially concealed by the tensor fasciæ latæ and ilio-tibial tract, the vastus medialis by the sartorius muscle. The vastus intermedius envelops the femur, and is concealed by the other muscles.

M. Rectus Femoris.—The **rectus femoris** has a double tendinous **origin.** (1) The *straight head* arises from the anterior inferior spine of the ilium (Fig. 214, p. 250); (2) the *reflected head* springs from a rough groove on the dorsum ilii just above the highest part of the acetabulum (Fig. 343, p. 417). A bursa lies beneath this head of origin. The two heads, bound together and connected to the capsule of the hip-joint by a band of fascia derived from the deep surface of the tensor fasciæ latæ (ilio-tibial tract), give rise to a single tendon which extends, for some distance, on the anterior surface of the muscle, and from which the muscular fibres arise. The muscular fibres springing from this tendon, and also from a median septal tendon, present a bipennate arrangement, and end below in a broad tendon which passes proximally, for some distance, along the posterior surface of the muscle. This tendon gradually narrows towards the knee, and spreading out again, is **inserted** into the proximal border of the patella. It receives laterally and medially parts of the insertions of the lateral and medial vasti muscles, and on its deep surface is joined by the insertion of the vastus intermedius.

M. Vastus Lateralis.—The **vastus lateralis** has an **origin**, partly fleshy, partly membranous, from (1) the capsule of the hip-joint, (2) the tubercle of the femur, (3) a concave area on the anterior surface of the shaft of the bone medial to the greater trochanter, (4) the distal border of the greater trochanter, (5) the lateral margin of the gluteal tuberosity of the femur and the tendon of the glutæus maximus, (6) the proximal half of the linea aspera, and (7) the fascia lata and lateral intermuscular septum (Fig. 220, p. 262).

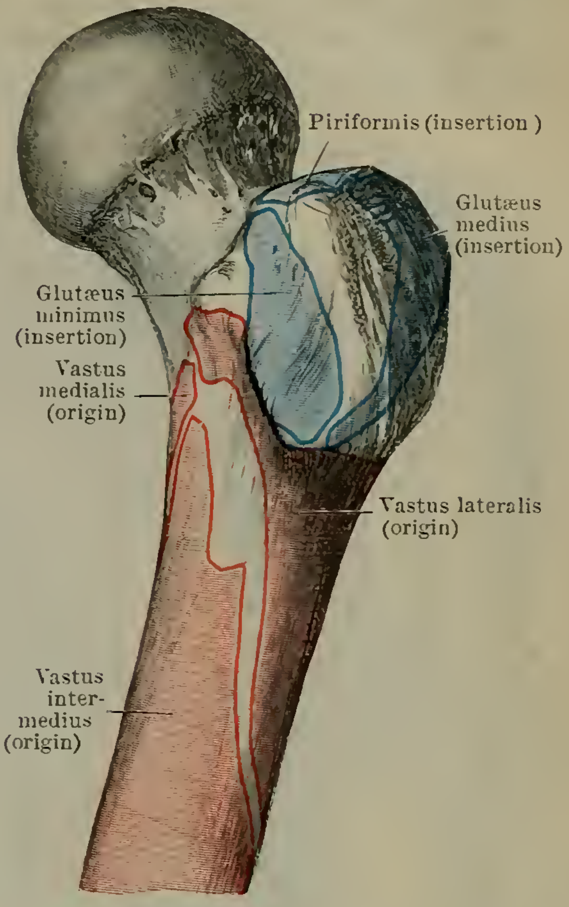
Piriformis (insertion)
Glutæus medius (insertion)
Glutæus minimus (insertion)
Vastus medialis (origin)
Vastus lateralis (origin)
Vastus intermedius (origin)

Fig. 335.—Muscle-Attachments to the Anterior Surface of the Proximal Part of the Left Femur.

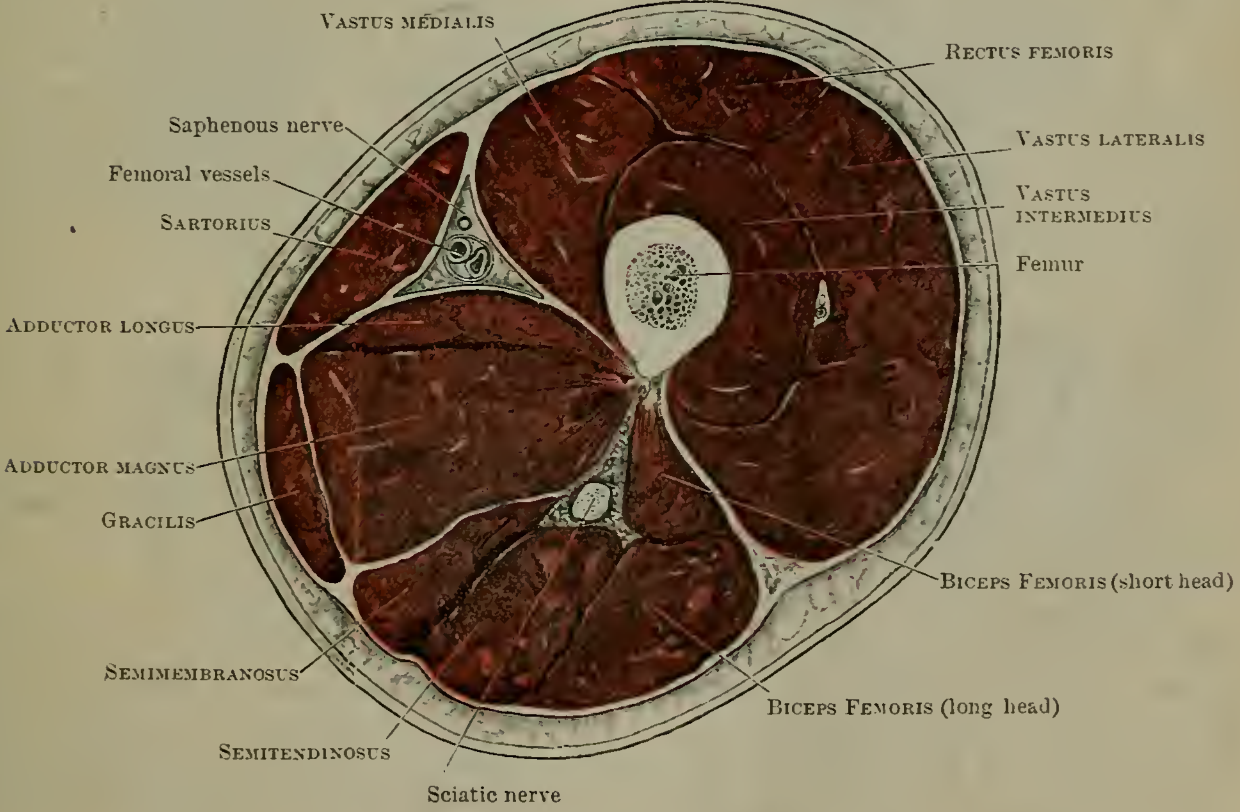

Fig. 336.—Transverse Section of the Thigh (Hunter's Adductor Canal).

It forms a thick, broad muscle directed distally and forwards, and is **inserted** by a broad membranous tendon into (1) the lateral border of the tendon of the rectus femoris, (2) the proximal and lateral border of the patella, and (3) the front of the lateral condyle of the tibia, covering, and to a large extent replacing, the antero-lateral part of the capsule of the knee-joint.

M. Vastus Medialis.—The **vastus medialis** is larger than the vastus lateralis and has a more extensive **origin**, from (1) the distal two-thirds or more of the spiral line, the linea aspera, and the proximal two-thirds of the line leading from the linea aspera to the medial condyle of the femur; and (2) the medial intermuscular septum and the tendon of the adductor magnus (Fig. 221, p. 263, and 344, p. 418).

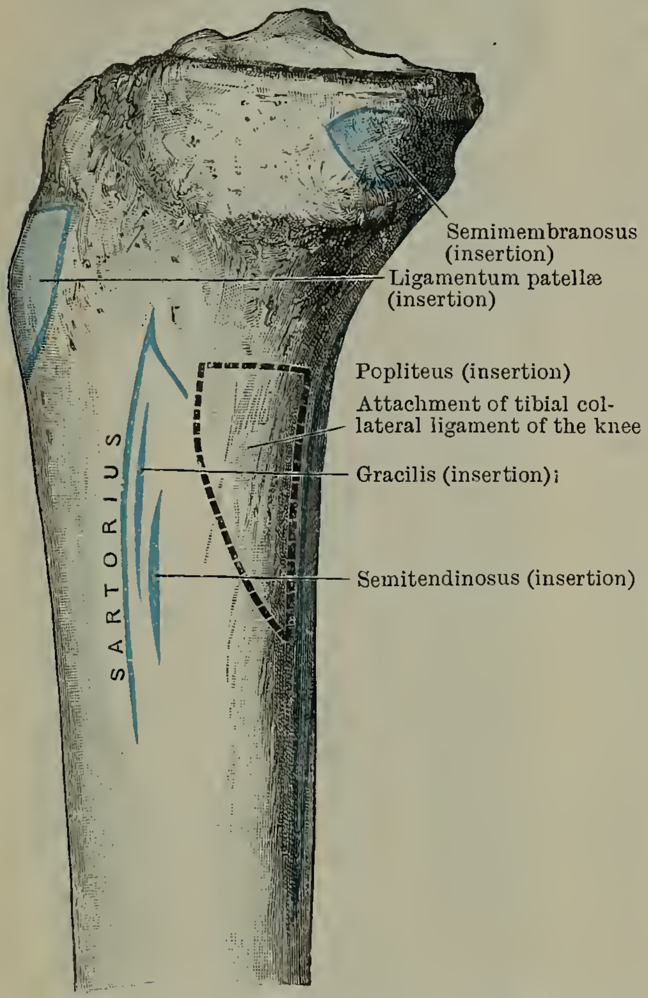
Semimembranosus (insertion)
Ligamentum patellæ (insertion)
Popliteus (insertion)
Attachment of tibial collateral ligament of the knee
Gracilis (insertion)
Semitendinosus (insertion)
SARTORIUS

Fig. 337.—Muscle-Attachments to the Medial Side of the proximal part of the Right Tibia.

From its origin the muscle is directed distally and laterally towards the knee, the most distal fibres being nearly horizontal; it is **inserted** by a strong aponeurotic tendon into (1) the medial border of the rectus tendon; (2) into the proximal and medial border of the patella; and (3) the front of the medial condyle of the tibia, covering and replacing the antero-medial part of the capsule of the knee-joint. The muscle conceals the medial side of the body of the femur and the vastus intermedius, with which it is closely incorporated in its distal two-thirds.

M. Vastus Intermedius. — The **vastus intermedius muscle** (O.T. **crureus**) **arises** by fleshy fibres from (1) the proximal two-thirds of the body of the femur on the anterior and lateral surfaces—but not the medial surface; (2) the distal half of the lateral lip of the linea aspera and the proximal part of the line leading therefrom to the lateral condyle; and (3) a corresponding portion of the lateral intermuscular septum (Figs. 219, p. 261, and 220, p. 262).

For the most part deeply placed, the muscle is directed distally to an **insertion** into the deep surface of the tendons of the rectus and vasti muscles by means of fibres which join a membranous expansion on its surface. It is closely adherent to the vastus lateralis muscle in the middle third of the thigh; it is inseparable from the vastus medialis below the proximal third. In the distal third of the thigh it conceals the articularis genu muscle, and the proximal prolongation of the synovial membrane of the knee-joint, which constitutes the suprapatellar bursa.

M. Articularis Genu.—The **articularis genu** (O.T. **subcrureus**) muscle consists of a number of separate bundles of muscular fibres **arising** deep to the vastus intermedius from the distal fourth of the anterior surface of the femur, and **inserted** into the synovial membrane of the knee-joint.

The four elements composing the quadriceps femoris muscle have been traced in their convergence to the patella. Their ultimate **insertion** is into the tubercle of the tibia (Fig. 350), by means of the **ligamentum patellæ**, and the vasti muscles are in addition connected with the **collateral ligaments of the patella**. The patella, indeed, is in one sense a sesamoid bone formed in the tendon of the muscle, the ligamentum patellæ being the real tendon of insertion, and the collateral ligaments fascial expansions from its borders. The insertion of the muscle forms the anterior part of the capsule of the knee-joint.

Nerve-Supply.—The parts of the quadriceps extensor are supplied by separate branches of the femoral nerve (L. 3. 4.).

Actions.—The quadriceps muscle is the great extensor of the leg at the knee-joint. The tendency for the patella to be pulled laterally as well as proximally is counteracted by the distal, horizontal fibres of the vastus medialis. The articularis genu draws proximally the synovial sheath of the joint during this movement.

When the knee is extended, the rectus femoris is in addition a flexor of the hip-joint. The straight head is taut when the movement begins, but it becomes somewhat relaxed and the reflected head is tightened when the thigh becomes bent.

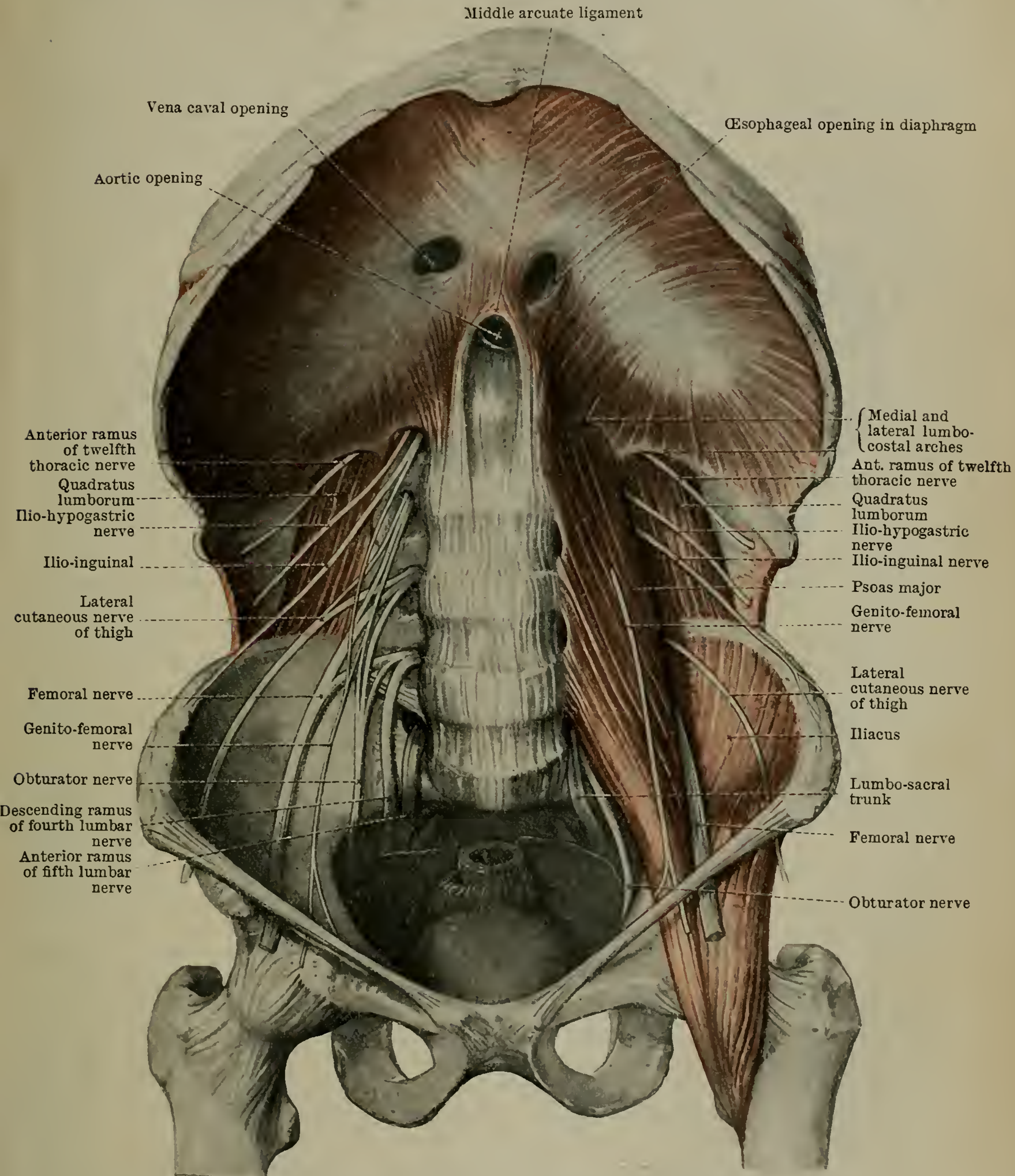

FIG. 338.—THE VESSELS AND NERVES ON THE POSTERIOR ABDOMINAL WALL.

When the body is in the recumbent position, with the knees extended, the two recti assist the ilio-psoas muscles to flex the body on the hips.

The **ilio-psoas muscle** is a compound muscle, consisting of two elements,—**psoas (major and minor)**, connecting the femur and pelvic girdle to the axial skeleton; and another element, the **iliacus**, extending between the hip bone and the femur. The muscles chiefly occupy the posterior wall of the abdomen and pelvis major, only their lower parts appear in the thigh below the inguinal ligament, in the lateral part of the femoral triangle.

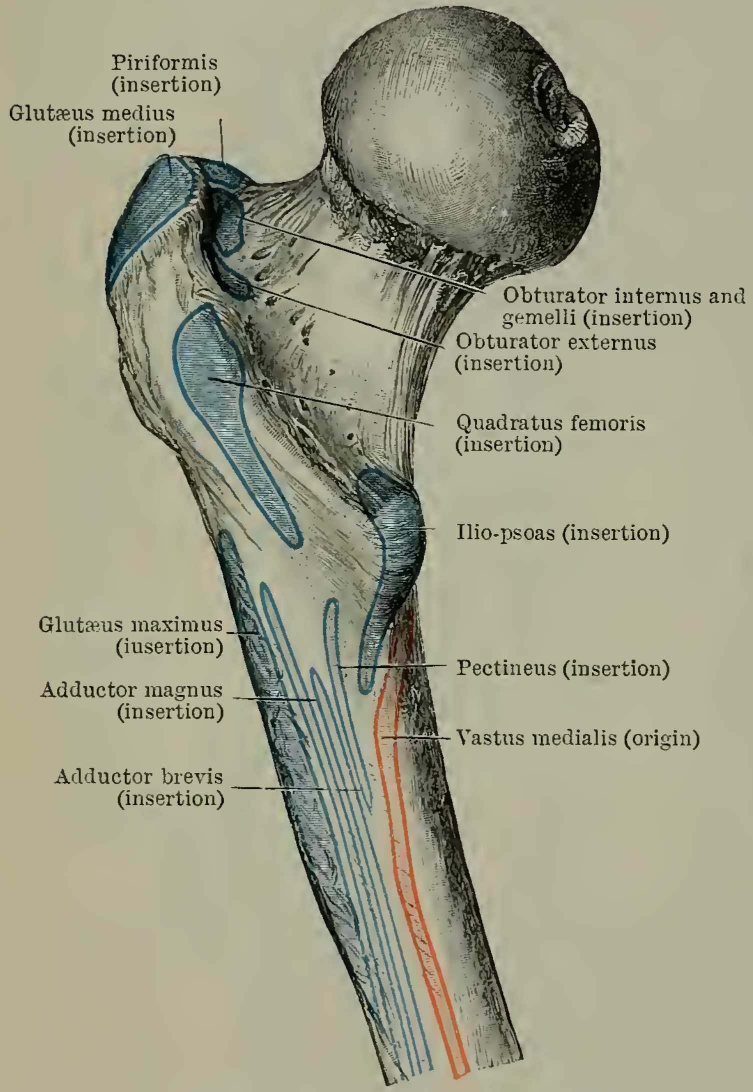
Piriformis (insertion)
Glutæus medius (insertion)
Obturator internus and gemelli (insertion)
Obturator externus (insertion)
Quadratus femoris (insertion)
Ilio-psoas (insertion)
Glutæus maximus (insertion)
Adductor magnus (insertion)
Pectineus (insertion)
Vastus medialis (origin)
Adductor brevis (insertion)

Fig. 339.—Muscle-Attachments to the Posterior Aspect of the Proximal Part of the Left Femur.

M. Psoas Major.—The psoas major is a large piriform muscle, which has an extensive **origin**, by fleshy fibres, from the vertebral column in the lumbar region. It arises from (1) the intervertebral fibro-cartilages above each lumbar vertebra, and the adjacent margins of the vertebræ—from the inferior border of the 12th thoracic to the superior border of the 5th lumbar vertebra; (2) from four aponeurotic arches which pass over the sides of the bodies of the first four lumbar vertebræ; and (3) from the transverse processes of all the lumbar vertebræ. The fibres form a fusiform muscle which at first is closely applied to the side of the vertebral column. Inferiorly, it follows the superior aperture of the pelvis and passes behind the inguinal ligament, to end in a tendon which is **inserted** into the apex of the lesser trochanter of the femur (Fig. 339). A bursa, which may be continuous with the synovial cavity of the hip-joint, separates the tendon from the pubis and the capsule of the hip-joint.

M. Psoas Minor.—The psoas minor is often absent (40 per cent). It **arises** from the intervertebral fibro-cartilage between the last thoracic and first lumbar vertebræ, and from the contiguous margins of those vertebræ. The muscle is closely apposed to the anterior surface of the psoas major.

It forms a slender fleshy belly, and is **inserted**, by a narrow tendon, into the middle of the linea terminalis and the ilio-pectineal eminence, its margins blending with the fascia covering the psoas major.

M. Iliacus. — The **iliacus muscle arises** in the pelvis major by fleshy fibres, mainly from a horseshoe-shaped origin around the margin of the iliac fossa; it has additional origins also from the ala of the sacrum, the anterior sacro-iliac, lumbo-sacral, and ilio-lumbar ligaments, and outside the pelvis, from the proximal part of the capsule of the hip-joint (ilio-femoral ligament). It is a fan-shaped muscle, and its fibres pass distally over the hip-joint towards the lesser trochanter of the femur.

Lying lateral to the psoas muscle, it passes through the femoral triangle, and is **inserted** by fleshy fibres (1) into the lateral side of the tendon of the psoas major; (2) into the concave anterior and upper surfaces of the lesser trochanter; and (3) into the body of the femur distal to the lesser trochanter for about an inch (Fig. 339); and (4) by its most lateral fibres into the capsule of the hip-joint. These fibres are often separate, forming the **iliacus minor**, or **iliocapsularis.**

Nerve-Supply.—The **psoas major** is supplied directly by branches from the anterior rami of the second and third lumbar nerves with additional branches in some cases from the first and fourth. The **psoas minor** receives a nerve from the first or second lumbar nerve. The **iliacus** is supplied by branches from the femoral nerve (L. 2. 3. 4.) within the abdomen.

Actions.—The psoas major and the iliacus flex the hip-joint, and this movement is accompanied by a slight degree of medial rotation. (N.B.—The axis of rotation does not correspond to the shaft of the femur but to a line drawn from the middle of its head to the centre of the intercondylic fossa.) In addition, acting from their insertions, they can flex the trunk on the lower limbs, and the psoas major can produce lateral flexion of the vertebral column.

The psoas minor assists in the latter movement, and can flex the pelvis on the vertebral column, or the vertebral column on the pelvis.

M. Pectineus.—The **pectineus** muscle **arises** by fleshy fibres from (1) the sharp anterior portion of the pectineal line of the pubis, and the triangular surface of the pubic bone in front of that line (Fig. 340, p. 414), and (2) the pectineal portion of the fascia lata which covers it.

Forming a broad muscular band, which lies in the floor of the femoral triangle, medial to the ilio-psoas, it is **inserted** by a thin flat tendon, about two inches in length, into the proximal half of the pectineal line, leading from the back of the lesser trochanter of the femur towards the linea aspera (Fig. 339, p. 412); its distal attachment being placed in front of the insertion of the adductor brevis muscle. The muscle may be occasionally divided into medial and lateral parts, the former innervated by the obturator, the latter by the femoral nerve.

Nerve-Supply.—The pectineus is always supplied by a branch of the femoral nerve (L. 2. 3.) which passes medially behind the femoral vessels to enter its lateral border. It receives in some instances an additional nerve from the obturator, or when that is present, the accessory obturator nerve.

Actions.—The muscle is mainly an adductor of the hip-joint. It is also a flexor of the hip.

THE MUSCLES ON THE MEDIAL SIDE OF THE THIGH.

The muscles on the medial side of the thigh include the adductor longus, the adductor brevis, the adductor magnus and the gracilis. The obturator externus also can be conveniently considered with this group.

The gracilis is superficially placed along the medial side of the thigh. The adductor muscles are placed in the medial part of the thigh between the hip bone and the femur, and in different vertical planes. The adductor longus is in the same plane as the pectineus and lies superficially in the femoral triangle; the adductor brevis, on a more posterior plane, is in contact with the obturator externus, and along with it is largely concealed by the pectineus and adductor longus; the adductor magnus, the largest and most posterior of these muscles, is in contact with the other adductors and the sartorius anteriorly, while its posterior surface is in relation to the hamstring muscles on the back of the thigh.

M. Gracilis.—The **gracilis muscle** is a long flat band placed on the medial side of the thigh and knee. It **arises** by a tendon from the lower half of the edge of the symphysis pubis, and for a similar distance along the border of the pubic arch (Fig. 340, p. 414).

Its tapering belly passes distally, on the medial side of the thigh to the knee, to end in a tendon, placed between the sartorius and semitendinosus, which expands to be **inserted** into the medial surface of the body of the tibia just distal to the medial condyle, behind the sartorius, and proximal to and in front of the semitendinosus (Fig. 339, p. 412). It is separated from the sartorius tendon by a bursa, and deep to its tendon is another bursa, common to it and the semitendinosus. It is superficial in its whole extent.

Nerve-Supply.—The anterior division of the obturator nerve (L. 2. 3.).

Actions.—The gracilis has a threefold action. It flexes the knee and adducts the thigh. When the knee is flexed, it can act as a medial rotation of the tibia.

M. Adductor Longus.—The **adductor longus** is a triangular muscle which lies in the floor of the femoral triangle and the floor of adductor canal (Hunter's). It **arises** from the anterior surface of the body of the pubis in the angle between the crest and symphysis (Fig. 340, p. 414).

It extends distally and laterally, it is **inserted** into the middle two-fourths of the medial lip of the linea aspera in front of the adductor magnus.

Nerve-Supply.—Obturator nerve (L. 2. 3.), anterior division.

M. Adductor Brevis.—The **adductor brevis** is a large muscle which **arises** from an elongated oval surface on the front of the body and upper part of the inferior ramus of the pubic bone, surrounded by the other muscles of this group (Fig. 340).

Directed distally and laterally the muscle expands, to be **inserted**, by a short aponeurotic tendon, behind the insertion of the pectineus, into the distal two-thirds of the line leading from the lesser trochanter of the femur to the linea aspera, and to the proximal fourth of the linea aspera itself (Fig. 339, p. 412).

Nerve-Supply.—Obturator nerve (L. 2. 3. 4.).
Actions.—Both muscles are adductors of the thigh, and assist in flexion and lateral rotation.

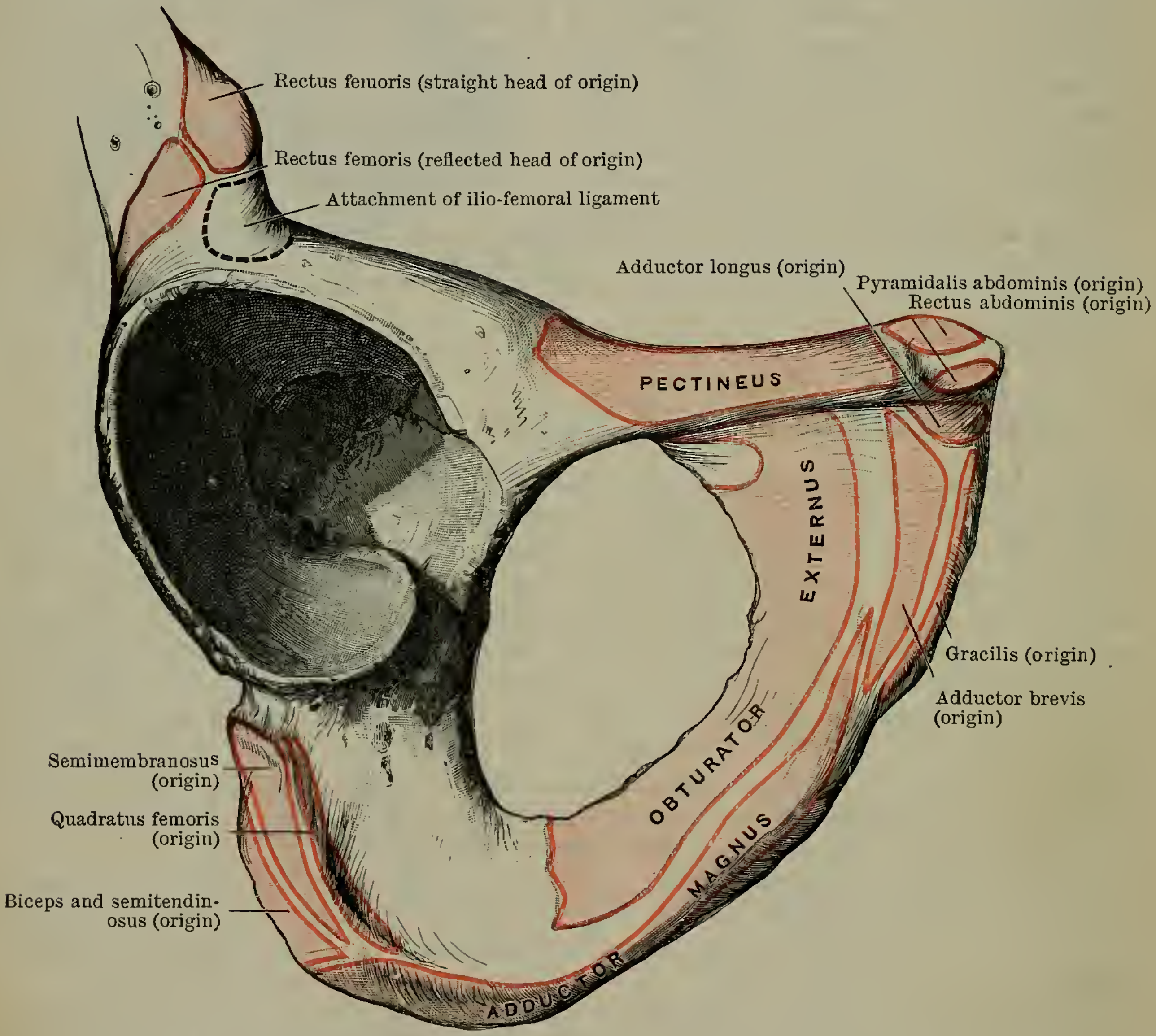
Rectus femoris (straight head of origin)
Rectus femoris (reflected head of origin)
Attachment of ilio-femoral ligament
Adductor longus (origin)
Pyramidalis abdominis (origin)
Rectus abdominis (origin)
PECTINEUS
EXTERNUS
OBTURATOR
Gracilis (origin)
Adductor brevis (origin)
MAGNUS
ADDUCTOR
Semimembranosus (origin)
Quadratus femoris (origin)
Biceps and semitendinosus (origin)

FIG. 340.—MUSCLE-ATTACHMENTS TO THE OUTER SURFACE OF THE RIGHT PUBIS AND ISCHIUM.

M. Adductor Magnus.—The **adductor magnus**, the largest of the adductor group, is a roughly triangular muscle. It **arises**, mainly by fleshy fibres, by a curved origin from the lower part of the lateral border and a large portion of the adjoining inferior surface of the sciatic tuberosity, from the edge of the inferior ramus of the ischium, and from the anterior surface of the inferior ramus of the pubic bone, its most anterior fibres arising between the obturator externus and adductor brevis (Fig. 340). Its upper fibres are directed horizontally and laterally from the pubic bone towards the proximal part of the femur; the lowest fibres are directed distally from the sciatic tuberosity to the medial condyle of the femur; while the intermediate fibres radiate obliquely laterally and distally.

The muscle is **inserted** by tendinous fibres (1) into the space distal to the insertion of the quadratus femoris, proximal to the linea aspera; (2) into the whole length of the linea aspera; (3) into the medial epicondylic line of the femur; and (4) into the adductor tubercle on the medial condyle of the femur, by means of a strong tendon, derived from the fibres which arise from the tuber ischiadicum, and closely connected with the tibial collateral ligament of the knee-joint. The part of the muscle attached to the space proximal to the linea aspera is often separated from the rest as the **adductor minimus.** The attachment to the linea aspera is interrupted by a series of tendinous arches which are thrown over the perforating branches of the profunda femoris artery, and the attachment to the epicondylic ridge is interrupted for the passage of the femoral vessels into the popliteal fossa.

The muscle is covered, anteriorly, by the other adductors and by the sartorius muscle. The profunda femoris artery separates it from the adductor longus muscle, while the femoral vessels are in contact with it in the distal part of the adductor canal. The posterior surface of the muscle is in relation with the hamstring muscles and the sciatic nerve.

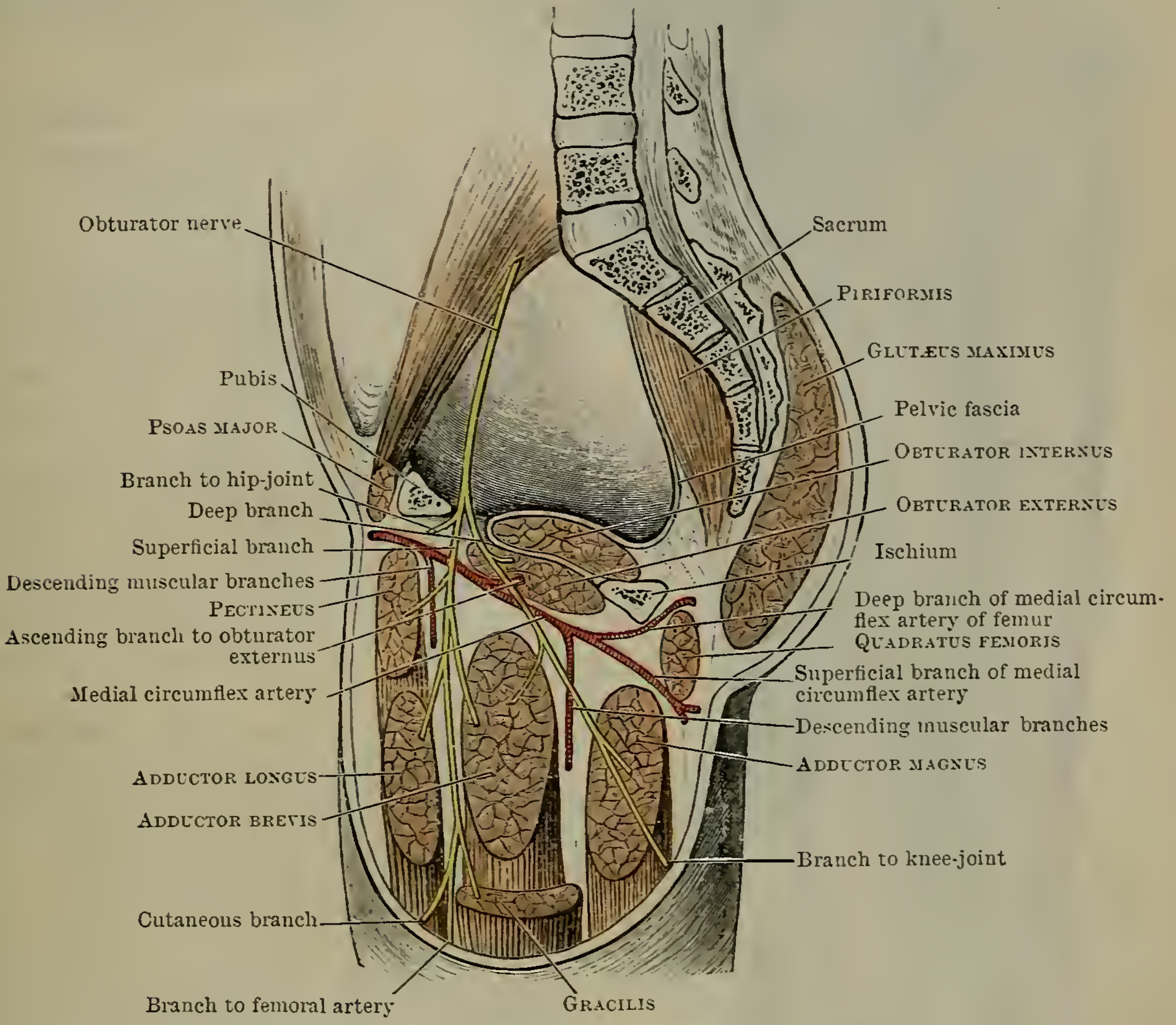

Fig. 341.—Scheme of the Course and Distribution of the Right Obturator Nerve.

Nerve-Supply.—The adductor magnus is a double muscle, and has a double nerve-supply. The medial part of the muscle extending between the tuber ischiadicum and the medial condyle of the femur, associated with the hamstring group of muscles, is supplied by the nerve to that group, viz. :—the tibial nerve (L. 4. 5. S. 1.). This enters the muscle on its posterior surface.

The adductor portion of the muscle is supplied on its anterior surface by the deep branch of the obturator nerve (L. 3. 4.).

Actions.—The proximal part of the muscle produces adduction, and assists in flexion and lateral rotation. The distal fibres extend the femur and may assist in medial rotation.

M. Obturator Externus.—The **obturator externus** is placed deeply, under cover of the previous muscles. It is a fan-shaped muscle lying horizontally in the angle between the hip bone and the neck of the femur.

It arises from the surfaces of the pubic bone and ischium which form the inferior half of the margin of the obturator foramen, and from the corresponding portion of the superficial surface of the obturator membrane (Figs. 340, p. 414, and 343, p. 417).

Its fibres converge towards the greater trochanter, and end in a stout tendon which, after passing distal to and posterior to the hip-joint, is **inserted** into the trochanteric fossa of the greater trochanter of the femur (Figs. 339, p. 412, and 344, p. 418).

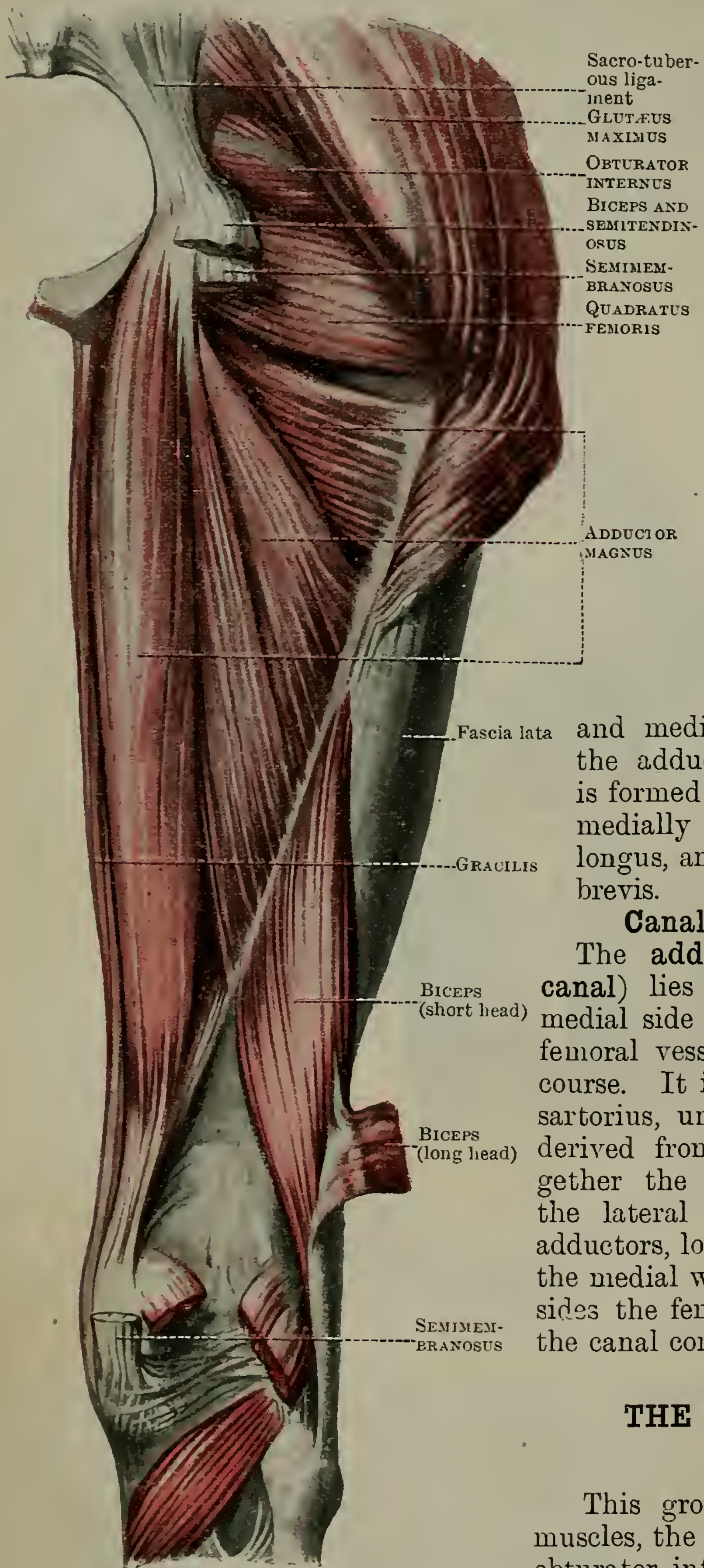

Fig. 312.—Deep Muscles on the Posterior Aspect of the Right Thigh.

Nerve-Supply.—The deep part of the obturator nerve (L. 3. 4.).

Actions.—This muscle is mainly a lateral rotator of the thigh; it also flexes and adducts it.

Trigonum Femorale.—The **femoral triangle** (O.T. **Scarpa's triangle**) is a large triangular space on the front of the thigh in its proximal third, which contains the femoral vessels in the proximal part of their course and the femoral nerve. It is bounded above by the inguinal ligament, laterally by the sartorius, and medially by the medial border of the adductor longus muscle. Its floor is formed laterally by the ilio-psoas, and medially by the pectineus, adductor longus, and a small part of the adductor brevis.

Canalis Adductorius Hunteri.—The **adductor canal** (O.T. **Hunter's canal**) lies in the middle third of the medial side of the thigh, and contains the femoral vessels in the distal part of their course. It is bounded superficially by the sartorius, under which is a dense fascia derived from the fascia lata, binding together the vastus medialis, which forms the lateral wall of the canal, and the adductors, longus and magnus, which form the medial wall or floor of the canal. Besides the femoral vessels and their sheath, the canal contains the saphenous nerve.

THE MUSCLES OF THE BUTTOCK.

This group includes the three glutæi muscles, the tensor fasciæ latæ, piriformis, obturator internus and gemelli, and quadratus femoris.

The glutæus maximus and tensor fasciæ latæ muscles are in the same plane, invested by envelopes of the fascia lata. The glutæus medius, partially covered by the glutæus maximus, conceals the glutæus minimus; while the piriformis, obturator internus, gemelli, and quadratus femoris intervene between the glutæus maximus and the posterior surface of the hip-joint.

M. Glutæus Maximus.—The **glutæus maximus** is a large quadrilateral muscle, with a crescentic **origin**. It arises from (1) a portion of the area on the dorsum ilii above the posterior gluteal line (Fig. 343); (2) the tendon of the sacrospinalis muscle; (3) the dorsal surface of the sacrum and coccyx (Fig. 345, p. 418); and (4) the posterior surface of the sacro-tuberous ligament. The fibres forming its superior and lateral border take origin directly from the fascia lata which covers the glutæus medius muscle.

The muscle forms a large fleshy mass, whose fibres are directed obliquely over the buttock, and are **inserted**, by short tendinous fibres, partly into the fascia lata (p. 404) over the greater trochanter of the femur (joining the ilio-tibial tract), and partly into the gluteal tuberosity (Fig. 344, p. 418). The fascia lata receives the insertion of the whole of the superficial fibres of the muscle and the superior half of the deep fibres. The inferior half of the deep portion of the muscle is inserted, for the most part, into the gluteal tuberosity; but the most inferior fibres of all are inserted into the fascia lata, and are thereby connected with the lateral intermuscular septum and the origin of the short head of the biceps.

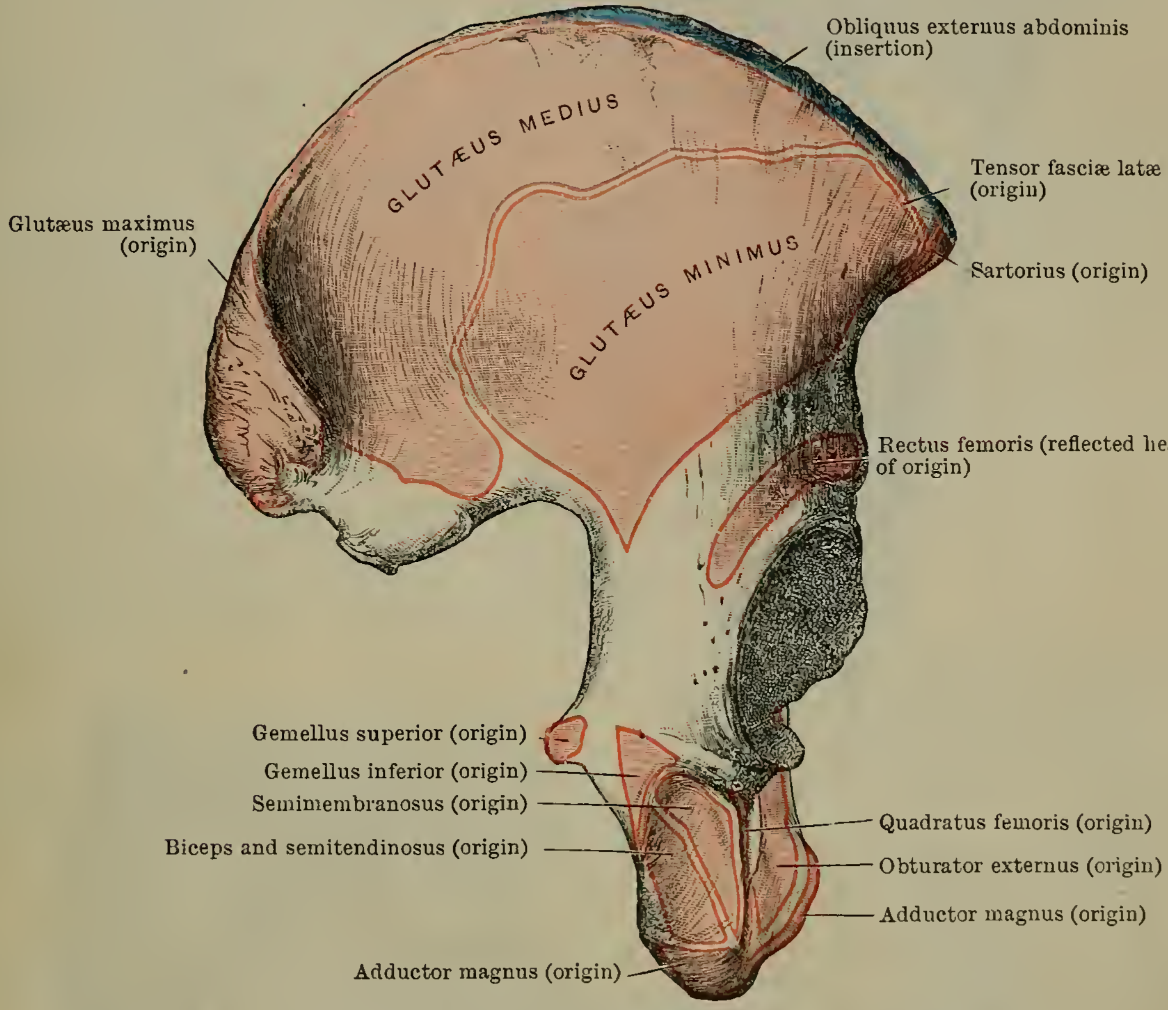
Obliquus externus abdominis (insertion)
GLUTÆUS MEDIUS
Tensor fasciæ latæ (origin)
Glutæus maximus (origin)
GLUTÆUS MINIMUS
Sartorius (origin)
Rectus femoris (reflected head of origin)
Gemellus superior (origin)
Gemellus inferior (origin)
Semimembranosus (origin)
Biceps and semitendinosus (origin)
Quadratus femoris (origin)
Obturator externus (origin)
Adductor magnus (origin)
Adductor magnus (origin)

Fig. 343.—Muscle-Attachments to the Right Dorsum Ilii and Tuber Ischiadicum.

The glutæus maximus is the coarsest and heaviest muscle in the body. By its weight it helps to form the fold of the nates. It is superficial in its whole extent. The glutæus medius is visible at its superior border, covered by the fascia lata; at its lower border the hamstring muscles and sciatic nerve appear on their way to the thigh. Three bursæ are deep to it: one (not always present) over the sciatic tuberosity, a second over the lateral side of the greater trochanter, and a third over the vastus lateralis. The fibres of the glutæus maximus arising from the coccyx may form a separate muscle (**agitator caudæ**).

Nerve-Supply.—Inferior gluteal nerve, from the sacral plexus (L. 5. S. 1. 2.).

Actions.—The glutæus maximus is mainly an extensor of the thigh, and has a powerful action in straightening the lower limb, as in climbing or running. Its lower fibres also adduct the thigh and rotate it laterally. Acting from its insertion the muscle is a powerful extensor of the trunk on the lower limbs, and is called into play when the body is raised from the sitting or stooping position.

M. Tensor Fasciæ Latæ.—The **tensor fasciæ latæ arises** from the iliac crest

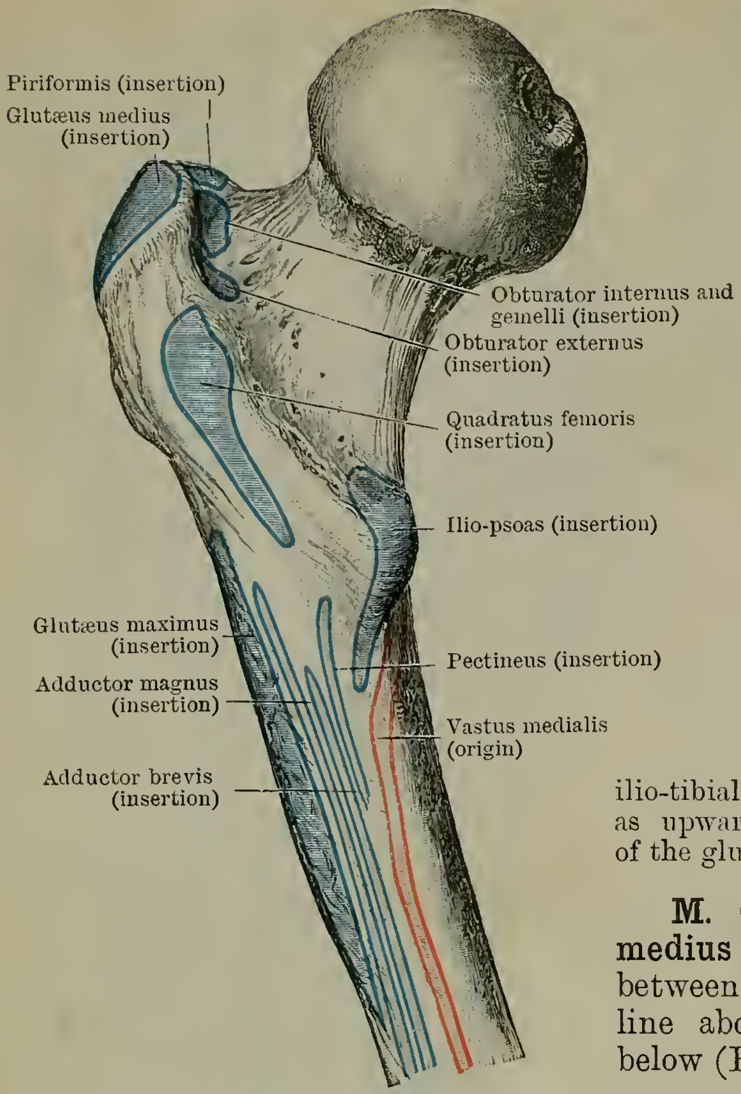
Piriformis (insertion)
Glutæus medius (insertion)
Obturator internus and gemelli (insertion)
Obturator externus (insertion)
Quadratus femoris (insertion)
Ilio-psoas (insertion)
Glutæus maximus (insertion)
Pectineus (insertion)
Adductor magnus (insertion)
Vastus medialis (origin)
Adductor brevis (insertion)

Fig. 344.—Muscle-Attachments to the Posterior Aspect of the proximal part of the Left Femur.

and the dorsum ilii just lateral to the anterior superior spine, and from the fascia covering its lateral surface (Fig. 343, p. 417).

It is **inserted**, distal to the level of the greater trochanter of the femur, into a splitting of the fascia lata (p. 404), and many of its fibres are continued into the **ilio-tibial tract** (p. 406). The muscle obscures the anterior borders of the glutæus medius and glutæus minimus.

Nerve - Supply. — The superior gluteal nerve from the sacral plexus (L. 4. 5. S. 1.) ends in this muscle after passing between the glutæus medius and glutæus minimus.

Actions.—It assists in abduction and medial rotation of the thigh, but its most important action is exerted as an extensor of the knee-joint through the ilio-tibial tract, which it draws forwards as well as upwards, so counteracting the backward pull of the glutæus maximus.

M. Glutæus Medius.—The **glutæus medius** arises from (1) the dorsum ilii, between the iliac crest and posterior gluteal line above and the anterior gluteal line below (Fig. 343, p. 417), and (2) the strong fascia lata covering its surface anteriorly.

It is a fan-shaped muscle, its fibres converging to the greater trochanter, to be **inserted** by a strong, short tendon into the postero-superior angle of the greater trochanter, and into a well-marked diagonal line on its lateral surface (Fig. 220, p. 262, and Fig. 344). The most anterior fibres of origin are inserted most distally on the trochanter, and a bursa is situated between the tendon and the bone.

The muscle is partly superficial, partly concealed by the glutæus maximus. It covers the glutæus minimus, and the superior gluteal nerve and the deep branches of the superior gluteal artery.

Nerve - Supply. —The superior gluteal nerve from the sacral plexus (L. 4. 5. S. 1.).

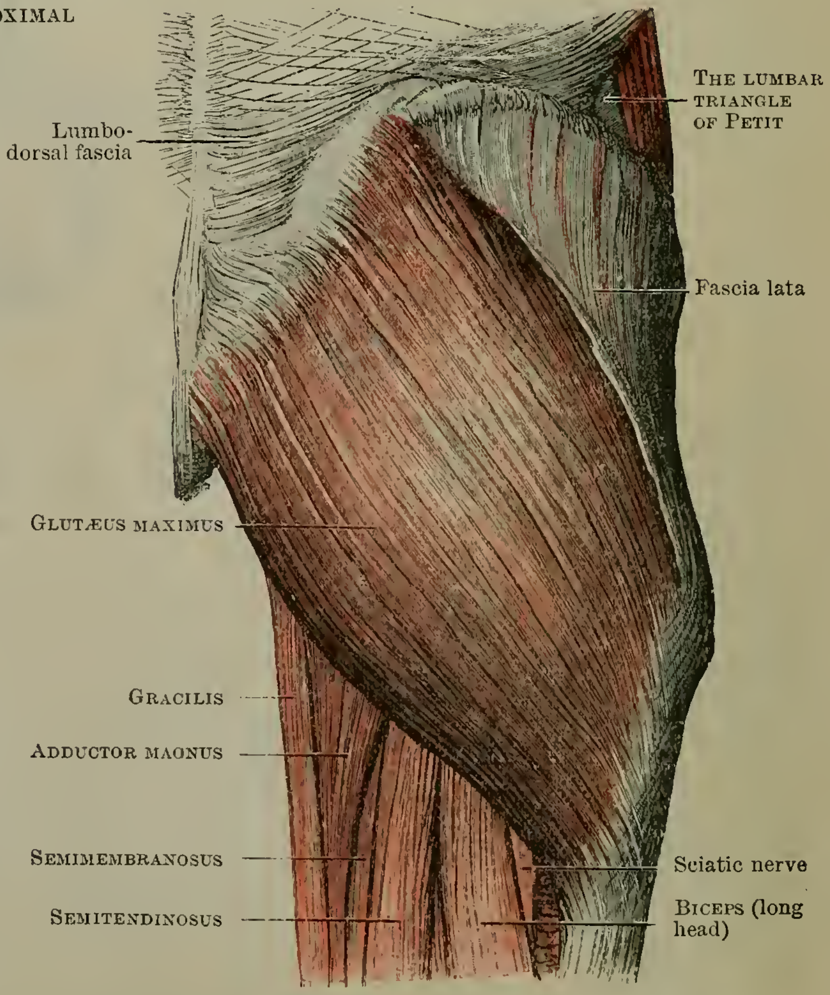

Fig. 345.—The Right Glutæus Maximus Muscle.

Actions.—This muscle is a powerful abductor of the thigh for all positions of the limb and a medial rotator of the extended thigh.

Both the glutæus medius and the glutæus minimus take an active part in the movements of the pelvis associated with walking. When one limb leaves the ground, the centre of gravity of the body no longer falls within the area of support, but the force of gravitation is successfully opposed by the abductors of the opposite side. Further, as one limb advances, the pelvis is rotated to the opposite side by the glutæus medius and minimus muscles of that side.

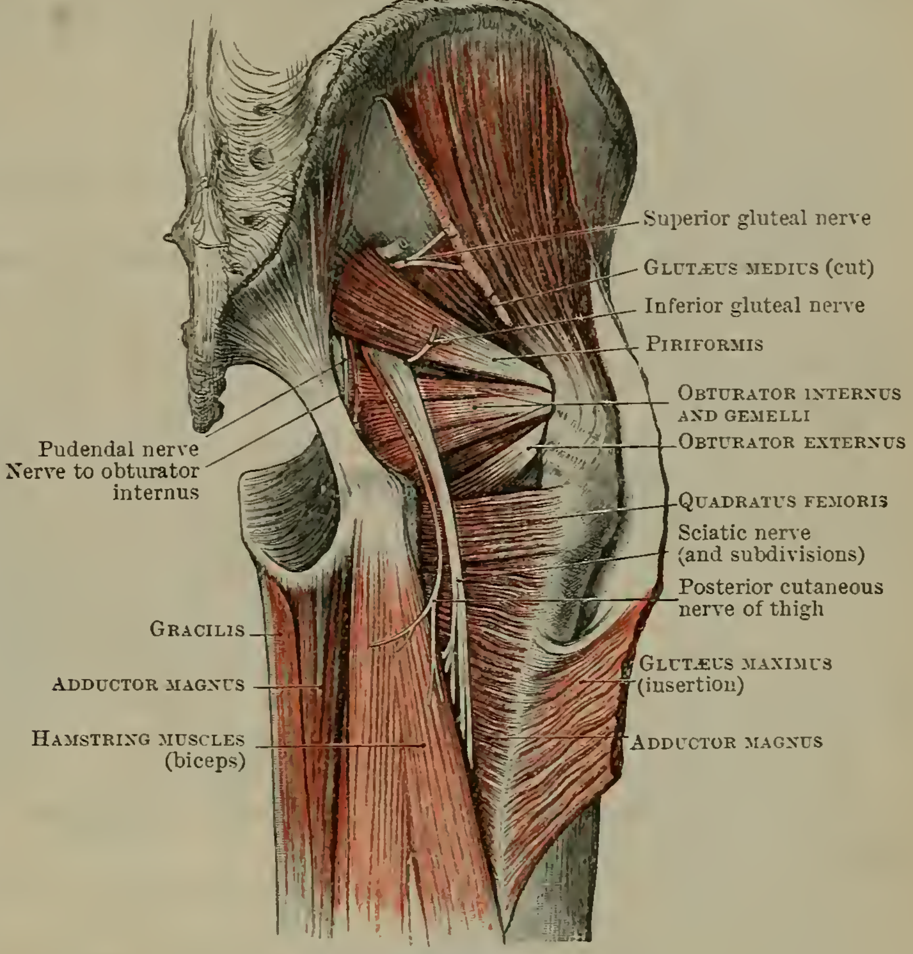
Superior gluteal nerve
GLUTÆUS MEDIUS (cut)
Inferior gluteal nerve
PIRIFORMIS
OBTURATOR INTERNUS AND GEMELLI
OBTURATOR EXTERNUS
Pudendal nerve
Nerve to obturator internus
QUADRATUS FEMORIS
Sciatic nerve (and subdivisions)
Posterior cutaneous nerve of thigh
GRACILIS
GLUTÆUS MAXIMUS (insertion)
ADDUCTOR MAGNUS
HAMSTRING MUSCLES (biceps)
ADDUCTOR MAGNUS

FIG. 346.—THE MUSCLES AND NERVES OF THE RIGHT BUTTOCK.

The glutæus maximus is reflected; and the glutæus medius is cut, in part, to show the glutæus minimus.

M. Glutæus Minimus.—The **glutæus minimus** arises, under cover of the glutæus medius, by fleshy fibres, from the dorsum ilii between the anterior and inferior gluteal lines (Fig. 343, p. 417).

This muscle is fan-shaped and its fibres converge to the antero-superior angle of the greater trochanter, covering the superior aspect of the capsule of the hip-joint. It is **inserted** into the anterior surface of the trochanter (Fig. 219, p. 261, and Fig. 347). A bursa is placed deep to the tendon in front of the medial part of the anterior surface of the greater trochanter.

Nerve-Supply.—The superior gluteal nerve from the sacral plexus (L. 4. 5. S. 1.).

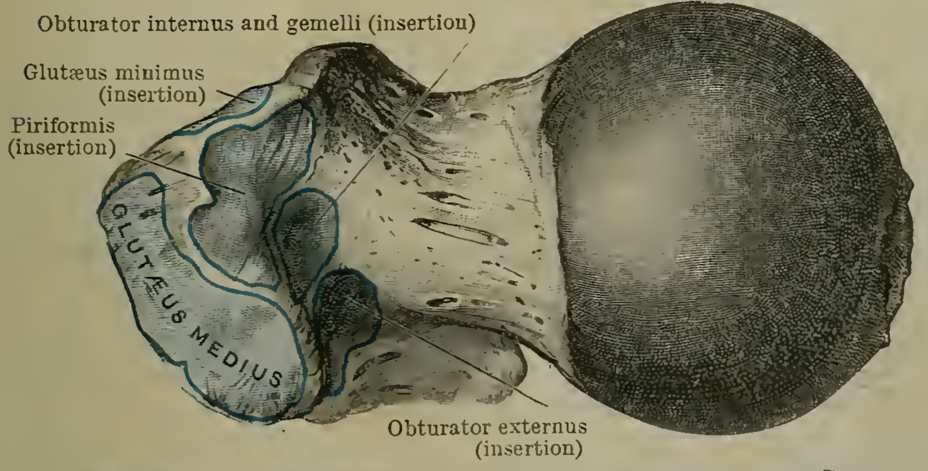
Obturator internus and gemelli (insertion)
Glutæus minimus (insertion)
Piriformis (insertion)
GLUTÆUS MEDIUS
Obturator externus (insertion)

FIG. 347.—MUSCLE-ATTACHMENTS TO THE PROXIMAL ASPECT OF THE GREATER TROCHANTER OF THE LEFT FEMUR.

Actions.—The muscle is primarily an abductor of the thigh. Its anterior fibres in addition produce medial rotation and its posterior fibres lateral rotation of the extended limb. The muscle also takes part in the movements of the pelvis associated with walking.

M. Piriformis.—The **piriformis** is one of the few muscles connecting the lower limb to the axial skeleton. It arises (1) within the pelvis from the roots of the vertebral arches of the second, third, and fourth sacral vertebræ, and from the adjacent part of the bone lateral to the anterior sacral foramina. Passing out through the greater sciatic foramen, it receives an origin from (2) the upper margin of the greater sciatic notch of the ilium, and (3) the pelvic surface of the sacro-tuberous ligament.

In the buttock it forms a rounded tendon, which is **inserted**, under cover of the glutæus medius, into a facet on the superior border and medial aspect of the greater trochanter of the femur (Figs. 344, 347, pp. 418, 419).

The piriformis, at its origin, covers part of the inner surface of the posterior wall of the pelvis minor. In the buttock it is covered by the glutæus maximus, and lies behind the capsule of the hip-joint, between the glutæus medius and superior gemellus.

Nerve-Supply.—Branches direct from the anterior rami of the first and second sacral nerves.

Actions.—The muscle is a lateral rotator of the extended thigh and an abductor of the flexed thigh.

M. Obturator Internus.—The **obturator internus arises** on the pelvic aspect of the hip bone, from (1) the whole of the margin of the obturator foramen (except the obturator notch); (2) the surface of the obturator membrane; (3) the whole of the pelvic surface of the hip bone behind and above the obturator foramen; and (4) the parietal pelvic fascia covering it medially.

It is a fan-shaped muscle. Its fibres converge to the lesser sciatic foramen, and end in several tendons, united together, which hook round the margin of the foramen (a bursa intervening), and after passing over the posterior surface of the hip-joint, are **inserted** into a facet on the medial surface of the greater trochanter of the femur above the trochanteric fossa (Figs. 219, p. 261, and 347, p. 419).

In the pelvis minor the muscle occupies the side wall, covered by the parietal pelvic fascia, which separates it from the pelvic cavity above and the ischio-rectal fossa below. In the buttock the tendon is embraced by the gemelli muscles which are attached to its superior and inferior margins.

The **gemelli muscles** form accessory portions of the obturator internus.

M. Gemellus Superior.—The **superior gemellus arises** from the gluteal surface of the ischial spine (Fig. 348, p. 421).

It is **inserted** into the upper margin and superficial surface of the tendon of the obturator internus muscle.

M. Gemellus Inferior.—The **gemellus inferior arises** from the superior part of the ischial tuberosity (Fig. 348, p. 421).

It is **inserted** into the inferior margin and superficial aspect of the tendon of the obturator internus.

Nerve-Supply.—The obturator internus and superior gemellus receive branches from a special nerve, the *nerve to the obturator internus* from the anterior aspect of the sacral plexus (S. 1. 2.). The inferior gemellus is supplied by the nerve to the quadratus femoris, a branch derived also from the anterior aspect of the sacral plexus (L. 4. 5. S. 1.).

Actions.—The obturator internus and gemelli are lateral rotators of the extended thigh, and abductors, when the limb is flexed.

M. Quadratus Femoris.—The **quadratus femoris arises** from the lateral margin of the tuber ischiadicum (Figs. 348, p. 421, and 214, p. 250). It is **inserted** into the quadrate tubercle and quadrate line of the femur (Fig. 344, p. 418).

The muscle is concealed by the glutæus maximus and the hamstring muscles. Its anterior surface is in contact with the obturator externus muscle and the lesser trochanter of the femur, a bursa intervening. The muscle is not infrequently fused with the adductor magnus.

Nerve-Supply.—A special nerve from the sacral plexus (L. 4. 5. S. 1.) which enters its deep (anterior) surface.

Actions.—The muscle is an adductor and lateral rotator of the thigh.

THE MUSCLES ON THE POSTERIOR ASPECT OF THE THIGH.

The Hamstring Muscles.

The muscles comprised in this series include the biceps, semitendinosus, and semimembranosus. A part of the adductor magnus, already described, also belongs, morphologically, to this group. They lie in the buttock and posterior aspect of the thigh, and diverge at the knee to bound the popliteal fossa. The origins of the muscles are concealed by the glutæus maximus. In the back of the thigh, enveloped by the fascia lata, they are placed behind the adductor magnus—the semitendinosus and semimembranosus medially, the biceps laterally. The former two muscles help to form the medial boundary of the popliteal fossa, of which the biceps is a lateral boundary.

M. Biceps Femoris.—The **biceps femoris** has a double **origin**. (1) *Its long head* arises, by means of a tendon, in common with the semitendinosus, from the inferior and medial facet upon the sciatic tuberosity (Fig. 214, p. 250, and Fig. 348) and from the sacro-tuberous ligament. This head, united for a distance of two or three inches with the semitendinosus, forms a separate fleshy mass, which extends to the distal third of the thigh, to end in a tendon joined by the short head of the muscle. (2) *The short head* arises separately from, (1) the whole length of the lateral lip of the linea aspera and the proximal two-thirds of the lateral epicondylic line of the femur, and (2) the lateral intermuscular septum. The proximal limit of its origin is sometimes blended with the insertion of the lowest fibres of the glutæus maximus.

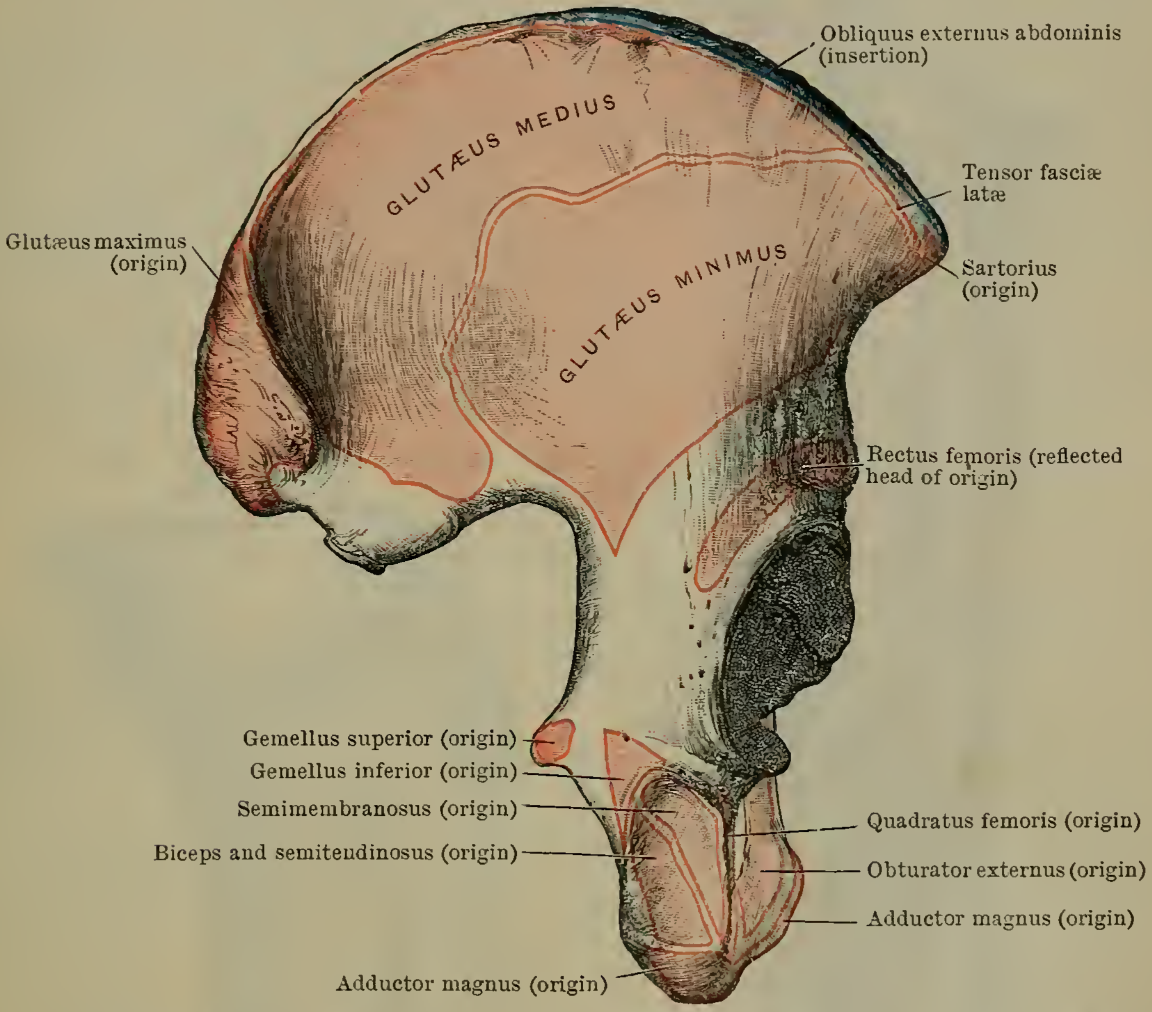
Obliquus externus abdominis (insertion)
GLUTÆUS MEDIUS
Tensor fasciæ latæ
Glutæus maximus (origin)
GLUTÆUS MINIMUS
Sartorius (origin)
Rectus femoris (reflected head of origin)
Gemellus superior (origin)
Gemellus inferior (origin)
Semimembranosus (origin)
Quadratus femoris (origin)
Biceps and semitendinosus (origin)
Obturator externus (origin)
Adductor magnus (origin)
Adductor magnus (origin)

FIG. 348.—MUSCLE-ATTACHMENTS TO THE RIGHT DORSUM ILII AND TUBER ISCHIADICUM.

The fibres of the short head, directed distally, join the tendon of the long head, and the muscle is **inserted** (1) into the head of the fibula by a strong tendon, which is split into two parts by the *fibular collateral* ligament of the knee-joint; (2) by a slip attached to the lateral condyle of the tibia; and (3) along its posterior border by an expansion to the deep fascia on the lateral aspect of the leg.

There is a bursa between the tendon and the fibular collateral ligament of the knee-joint.

The short head may be absent: there may be an additional origin from the ischium or femur; and the long head may send a slip to the gastrocnemius or tendo calcaneus (Achillis) (**tensor fasciæ suralis**).

Nerve-Supply.—The long head is supplied by the sciatic (tibial part, L. 5. S. 1. and 2.) and the short head by the common peroneal nerve (L. 5. S. 1. 2.).

Actions.—The muscle is a powerful flexor of the knee-joint, and through its long head, assists in extension of the thigh. When the knee is flexed, the biceps is a lateral rotator of the leg.

M. Semitendinosus.—The **semitendinosus** arises, in common with the long head of the biceps, from the inferior and medial facet upon the ischial tuberosity (Fig. 348, p. 421). Separating from the common tendon, two or three inches from its origin, the muscle forms a long, narrow band which becomes tendinous in the middle third of the thigh lying on the surface of the semimembranosus.

Passing over the medial side of the knee it spreads out and becomes membranous, and is **inserted** (1) into the medial side of the body of the tibia just distal to the medial condyle, distal to the gracilis and behind the sartorius (Fig. 350), and (2) into the deep fascia of the leg. A bursa separates it from the sartorius superficially, and another, common to it and the gracilis, lies deep to its insertion. The belly of the muscle is marked by an oblique septal tendinous intersection about its middle.

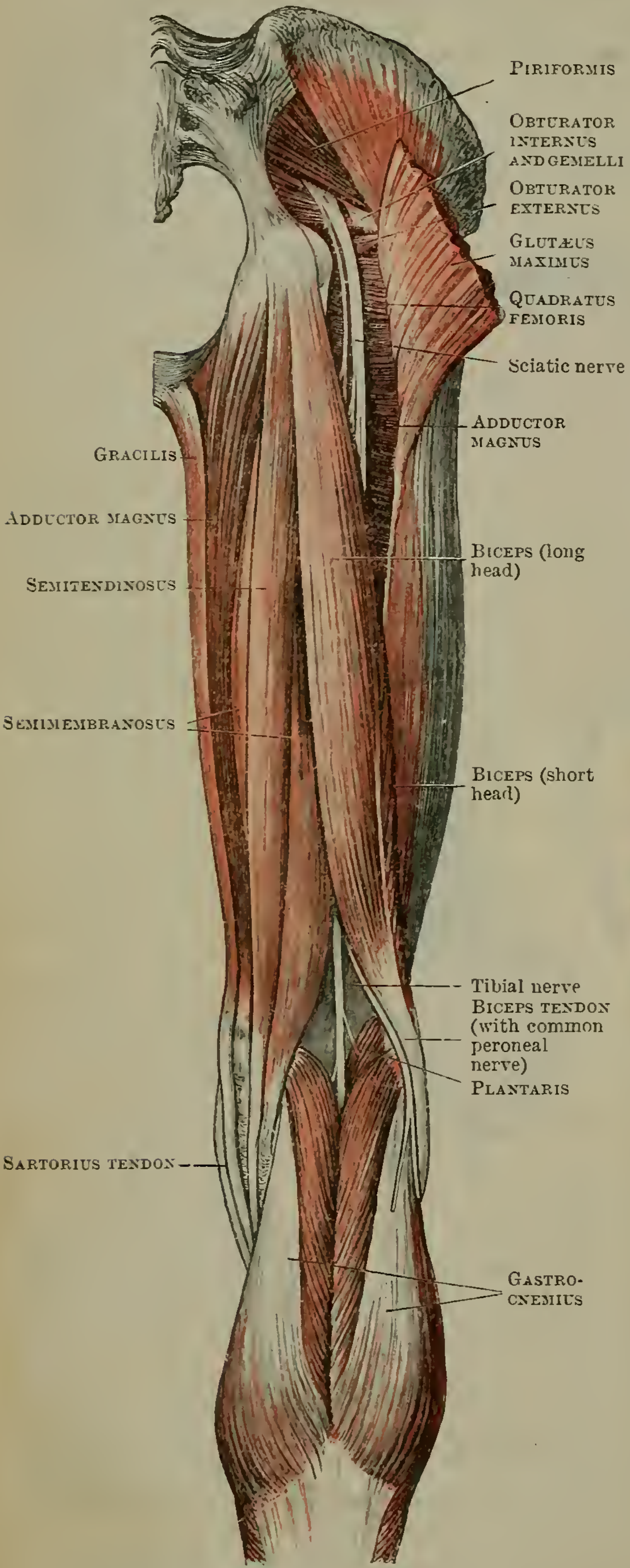

Fig. 349.—The Muscles on the Posterior Aspect of the Right Thigh.

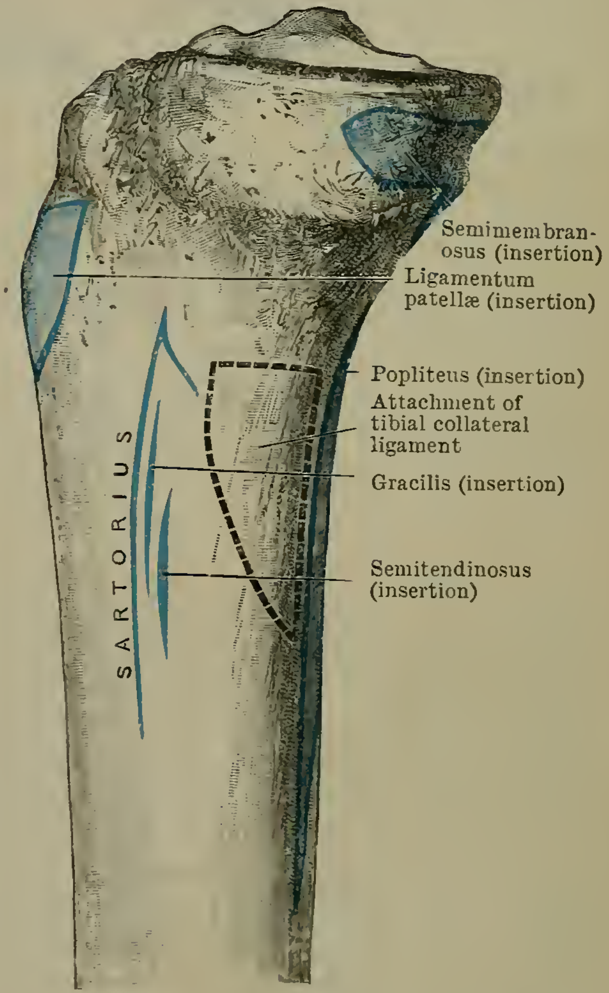
Semimembranosus (insertion)
Ligamentum patellæ (insertion)
Popliteus (insertion)
Attachment of tibial collateral ligament
Gracilis (insertion)
SARTORIUS
Semitendinosus (insertion)

Fig. 350.—Muscle-Attachments to the Medial Surface of the Proximal Part of the Right Tibia.

Nerve-Supply.—The semitendinosus is supplied by two branches from the sciatic nerve, tibial part (L. 5. S. 1. 2.).

Actions.—A flexor of the knee. a medial rotator of the flexed tibia, and an extensor of the hip.

M. Semimembranosus.—The **semimembranosus** arises by a tendon from the superior and lateral facet on the ischial tuberosity (Figs. 214, p. 250, and 349, p. 422). In the proximal third of the thigh the tendon gives place to a rounded fleshy belly, which lies anterior to the ischial portions of the biceps and semitendinosus muscles.

Becoming tendinous, at the back of the knee, it is **inserted** into the horizontal groove on the postero-medial aspect of the medial condyle of the tibia (Figs. 227, p. 270, and 350, p. 422). A bursa lies deep to the tendon at its insertion. It has three *additional membranous insertions*: (1) a fascial band extends distally and medially to join the posterior border of the *tibial collateral* ligament of the knee-joint; (2) another fascial band extends distally and laterally, forms the fascia covering the popliteus muscle (*popliteus fascia*), and is attached to the oblique line of the tibia; and (3) a third strong band extends proximally and laterally to the back of the lateral condyle of the femur, forming the oblique popliteal ligament of the knee-joint.

The membranous origin of the muscle is concealed by the proximal parts of the semitendinosus and long head of the biceps. The tendon of insertion covers the origin of the medial head of the gastrocnemius.

Nerve-Supply.—It is innervated by the sciatic nerve, tibial part (L. 5. S. 1. 2.).

Actions.—A flexor of the knee, a medial rotator of the flexed tibia, and an extensor of the hip.

THE FASCIÆ AND MUSCLES OF THE LEG AND FOOT.

FASCIÆ.

The **superficial fascia** of the leg and foot presents no special features except in the sole, where it is greatly thickened by pads of fat, particularly under the tuberosity of the calcaneus, and under the balls of the toes.

The **deep fascia** has numerous important attachments about the knee. Posteriorly it forms the *popliteal fascia*, and is joined by expansions from the tendons of the sartorius, gracilis, semitendinosus, and biceps femoris muscles. In front of the knee it is attached to the patella, the ligamentum patellæ, and the tubercle of the tibia; medially and laterally it is connected to the condyles of the tibia and the head of the fibula, and helps to form the **collateral patellar ligaments**—broad fascial bands which pass obliquely from the sides of the patella to the condyles of the tibia, and are joined by fibres of the vasti muscles. Passing into the leg, the fascia blends, over the medial surface of the tibia, with the periosteum of the bone. It extends round the lateral side of the leg from the anterior crest to the medial border of the tibia, binding together and giving origin to the muscles, and gaining an attachment to the distal part of the body of the fibula. **Two septa** pass from its deep surface; one septum (anterior peroneal septum), attached to the anterior crest of the fibula, encloses the superficial peroneal nerve, and separates the extensor from the peronæi muscles. The other septum (posterior peroneal septum) is attached to the lateral crest of the fibula, and separates the peronæi from the flexor muscles. From the last-named septum another extends across the back of the leg; it forms a partition between the superficial and deep flexor muscles, and encloses the posterior tibial vessels and the tibial nerve. It gives rise to subordinate septa attached to the vertical line of the tibia and the medial crest of the fibula, which separate the tibialis posterior from the flexors of the toes on either side.

At the ankle the deep fascia is strengthened by additional transverse fibres, which give rise to thickened bands named the ligamentum laciniatum, lig. transversum cruris, lig. cruciatum cruris and the retinacula of the peroneal muscles. They were formerly known as the annular ligaments.

The **ligamentum laciniatum** stretches between the medial malleolus and the tuberosity of the calcaneus. While it is continuous, at its proximal border, with the general investment of the deep fascia, it is chiefly formed by the septal layer covering the deep muscles on the back of the leg. It sometimes gives insertion to the plantaris muscle. It is continuous, distally, with the plantar aponeurosis, and gives origin to the abductor hallucis muscle. It is pierced by the calcanean vessels and nerve. Along with the posterior tibial vessels and the tibial nerve, the tendons of the tibialis posterior, flexor digitorum longus, and flexor hallucis longus, pass beneath it, each enclosed in a separate mucous sheath.

The **superior peroneal retinaculum** is a thickened band of the deep fascia stretching between the lateral malleolus and the calcaneus. It binds down the tendons of the peronæi, as they pass behind the lateral malleolus, invested by a single mucous sheath while the **inferior peroneal retinaculum** is attached proximally to the apex of the lateral malleolus, and crosses the peroneus brevis tendon to reach the trochlear process (O.T. peroneal tubercle). From this attachment its fibres are continued over the peroneus longus tendon to the lateral surface of the calcaneus.

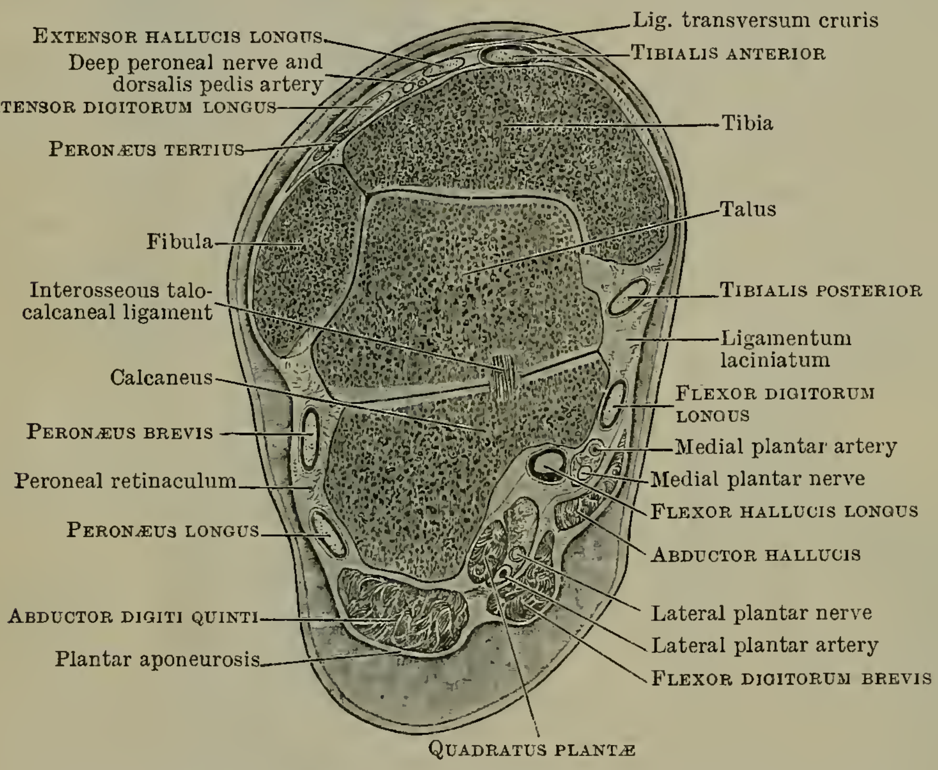

Fig. 351.—Frontal Section through the Left Ankle-Joint, Talus, and Calcaneus.

The **ligamentum transversum cruris**, broad and undefined at its proximal and distal borders, stretches across the front of the ankle between the two malleoli. This band binds down, to the distal end of the tibia, the tendons of the tibialis interior and extensor muscles of the toes. One mucous sheath is found deep to it, surrounding the tendon of the tibialis anterior.

Ligamentum Cruciatum Cruris.—On the dorsum of the foot, where the general covering of deep fascia is much thinner, a special well-defined band, named the **ligamentum cruciatum cruris**, stretches over the extensor tendons. It has an attachment laterally to the lateral border of the dorsal surface of the calcaneus. It divides into two bands as it passes medially over the dorsum of the foot—a *proximal part*, which joins the lig. transversum cruris and is attached to the medial malleolus, and a *distal part*, which passes across the dorsum of the foot, and joins the fascia of the sole at its medial border. Deep to this ligament are three special compartments with separate mucous sheaths, one for the tibialis anterior tendon, a second for that of the extensor hallucis longus, and a third for the extensor digitorum longus and peronæus tertius tendons. Occasionally the ligament is joined by an additional band, which is attached proximally to the lateral malleolus.

The **plantar aponeurosis** is of great importance. In the centre of the sole it forms a thick triangular band, attached posteriorly to the tuberosity of the calcaneus. It spreads out anteriorly and separates into *five slips*, which are directed forwards to the bases of the toes. These slips as they separate are joined together by ill-defined bands of transverse fibres, which constitute the **fasciculi transversi aponeurosis plantæ**. The slip for each toe straddles the flexor tendons and is attached on each side to the deep transverse metatarsal ligament and the base of the first phalanx. Distally it is continuous with the fibrous layer of the digital sheath.

This central portion of the plantar aponeurosis assists in preserving the arch of the foot, by drawing the toes and the calcaneus together.

On each side it is continuous with a much thinner layer, which covers the lateral and medial muscles of the sole and joins the fascia of the dorsum of the foot at each border. It also gives rise to intermuscular septa, which pass deeply on each side of the flexor digitorum brevis, enclosing that muscle in a separate sheath, and giving investments on either side to the abductor muscles of the great and little toes. At the lateral border of the foot the **calcaneo-metatarsal ligament**, a thickened band of the fascia, connects the tuberosity of the calcaneus with the base of the fifth metatarsal bone.

The **digital sheaths**, though smaller, are the same in arrangement as those of the fingers (p. 387). **Vaginal ligaments** are present in relation to the first and second phalanges.

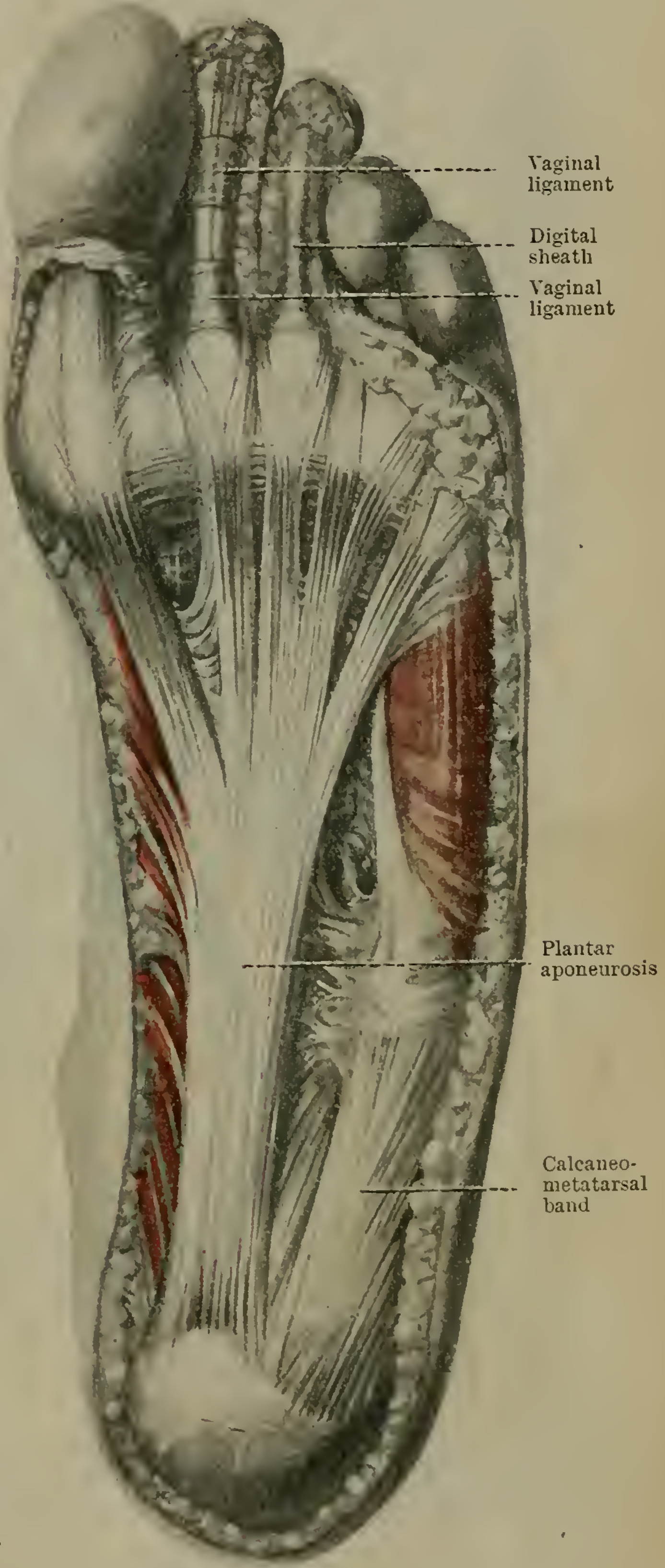

Fig. 352.—The Left Plantar Fascia.

THE MUSCLES OF THE LEG AND FOOT.

The muscles of the leg and foot are divisible into three series: (1) the extensor muscles on the front of the leg and dorsum of the foot; (2) the peronæi on the lateral aspect of the leg; and (3) the flexor muscles on the back of the leg and in the sole of the foot.

The Muscles on the Front of the Leg and Dorsum of the Foot.

The muscles on the front of the leg and dorsum of the foot include two groups: (1) on the front of the leg, the tibialis anterior, long extensors of the toes and peronæus tertius; and (2) on the dorsum of the foot, the extensor digitorum brevis.

On the front of the leg the tibialis anterior and the extensor digitorum longus and peronæus tertius are superficially placed, and conceal the extensor hallucis longus muscle. On the dorsum of the foot the extensor digitorum brevis muscle lies beneath the tendons of the long extensor of the toes.

M. Tibialis Anterior.—The **tibialis anterior arises** from the lateral condyle and the proximal two-thirds of the lateral surface of the body of the tibia, from the interosseous membrane, from the fascia over it, and from an intermuscular septum laterally. The muscle ends in a strong tendon which becomes free in the distal third of the leg. It passes distally and medially over the front of the distal end of the tibia, the ankle-joint and the dorsum of the foot to be **inserted** into a facet on the medial surface of the first cuneiform and the medial side of the base of the first metatarsal bone (Fig. 226, p. 269). Special compartments, lined by a separate mucous sheath, are provided for the tendon under both the transverse and the cruciate ligaments.

The **tibio-fascialis anterior** is a separated portion of the muscle occasionally present, inserted into the fascia on the dorsum of the foot.

Nerve-Supply.—Deep peroneal nerve (L. 4. 5. S. 1.).

Actions.—The muscle is a dorsi-flexor of the ankle, and (in combination with the tibialis posterior) it inverts the foot.

M. Extensor Digitorum Longus.—The **extensor digitorum longus** arises, by fleshy fibres, from the lateral side of the lateral condyle of the tibia, from the proximal two-thirds or more of the anterior part of the medial surface of the body of the fibula, from the fascia over it, from intermuscular septa on either side, and from the anterior aspect of the interosseous membrane in its proximal part.

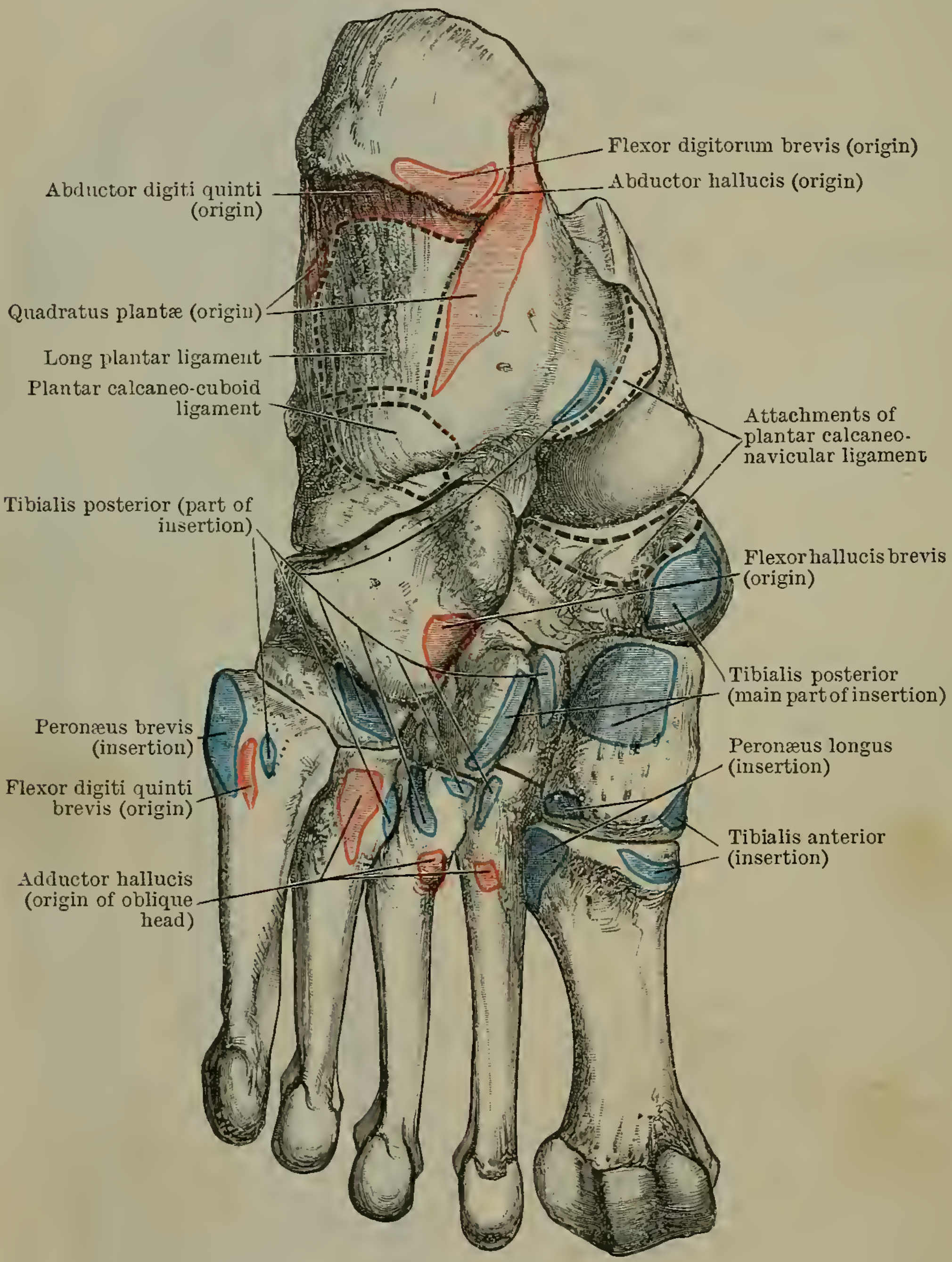
Flexor digitorum brevis (origin)
Abductor hallucis (origin)
Abductor digiti quinti (origin)
Quadratus plantæ (origin)
Long plantar ligament
Plantar calcaneo-cuboid ligament
Attachments of plantar calcaneo-navicular ligament
Tibialis posterior (part of insertion)
Flexor hallucis brevis (origin)
Tibialis posterior (main part of insertion)
Peronæus brevis (insertion)
Peronæus longus (insertion)
Flexor digiti quinti brevis (origin)
Tibialis anterior (insertion)
Adductor hallucis (origin of oblique head)

FIG. 353.—MUSCLE-ATTACHMENTS TO LEFT TARSUS AND METATARSUS (Plantar Aspect).

It gives rise to a tendon which, passing deep to the ligamentum transversum, subdivides in front of the ankle into four smaller tendons. These, with the tendon of the peronæus tertius, are provided with a mucous sheath as they lie in the most lateral compartment under the ligamentum cruciatum cruris. They are **inserted** into the four lateral toes, exactly in the same way as the corresponding tendons in the hand (see p. 400). They form membranous expansions on the dorsum of the first phalanx, joined by the tendons of the extensor digitorum brevis, lumbricales, and interossei, and each then separates into one central and two collateral slips, attached respectively to the middle and terminal phalanges.

Nerve-Supply.—Deep peroneal nerve (L. 4. 5. S. 1.).
Actions.—A dorsi-flexor of the ankle and an extensor of the four lateral toes.

M. Peronæus Tertius.—The **peronæus tertius** is a separated portion of the extensor digitorum longus. It is an essentially human muscle. It arises (inseparably from the extensor digitorum longus) from the distal part of the medial surface of the fibula, and from the intermuscular septum lateral to it.

The tendon of the muscle is **inserted** into the dorsal aspect of the base of the fifth metatarsal bone.

Nerve-Supply.—Deep peroneal nerve (L. 4. 5. S. 1.).
Actions.—The muscle dorsi-flexes the ankle and raises the lateral border of the foot (as in skating or dancing).

M. Extensor Hallucis Longus.—The **extensor hallucis longus** arises from the anterior part of the medial surface of the fibula in its middle three-fifths, deep to the origin of the extensor digitorum longus, and for a corresponding extent from the interosseous membrane. Its tendon passes over the dorsum of the foot, to be **inserted** into the base of the terminal phalanx of the great toe. As it lies under cover of the transverse ligament, this tendon occupies the same compartment as the extensor digitorum longus and the peronæus tertius, but it is provided with a special compartment, lined by a separate mucous sheath, as it lies under the cruciate ligament.

The **extensor primi internodii longus** and **extensor ossis metatarsi hallucis** are occasional separate slips of this muscle inserted into the proximal phalanx and the metatarsal bone.
Nerve-Supply.—Deep peroneal nerve (L. 4. 5. S. 1.).
Actions.—This muscle dorsi-flexes the ankle, and extends the great toe.

M. Extensor Digitorum Brevis.—The **extensor digitorum brevis** arises, on the dorsum of the foot, from a special impression on the fore part of the dorsal surface of the calcaneus, and from the deep surface of the ligamentum cruciatum cruris.

It usually gives rise to four fleshy bellies, from which narrow tendons are directed forwards and medially, to be **inserted** into the four medial toes. The three lateral tendons join those of the long extensor muscle to form the membranous expansions on the dorsum of the toes. The *most medial tendon* (**extensor hallucis brevis**), after crossing the dorsalis pedis artery, is inserted separately into the base of the first phalanx of the great toe.

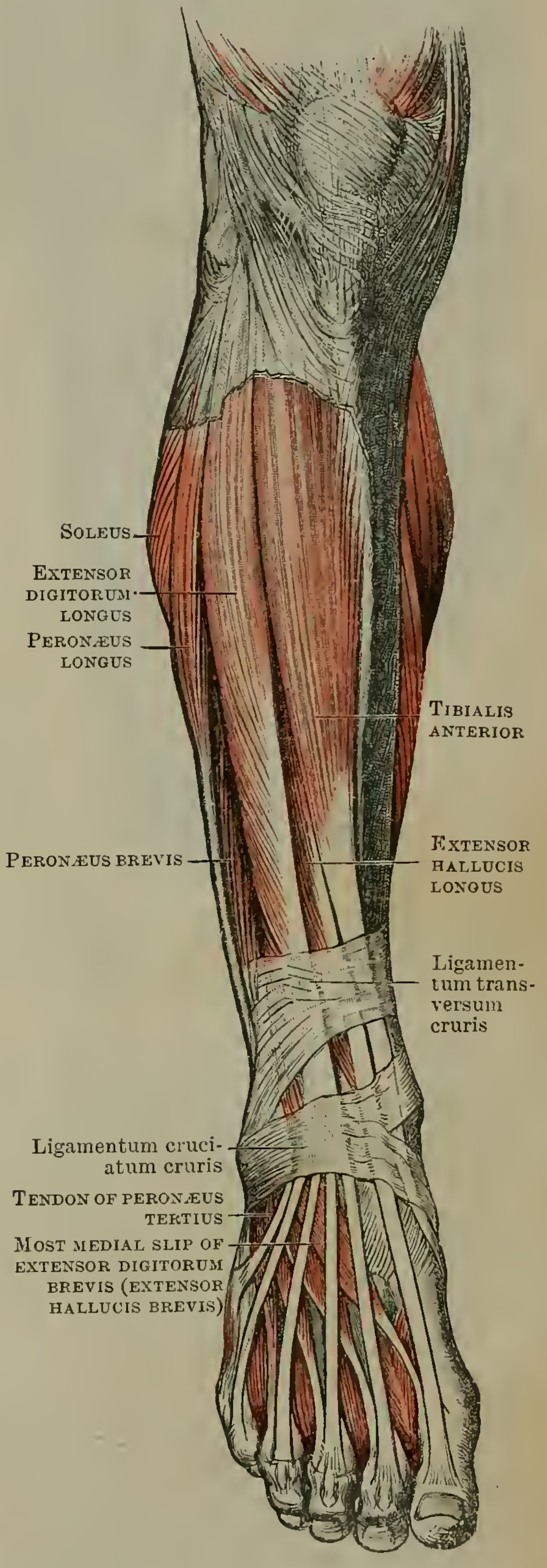
Soleus
Extensor digitorum longus
Peronæus longus
Tibialis anterior
Peronæus brevis
Extensor hallucis longus
Ligamentum transversum cruris
Ligamentum cruciatum cruris
Tendon of peronæus tertius
Most medial slip of extensor digitorum brevis (extensor hallucis brevis)

FIG. 354.—MUSCLES OF THE FRONT OF THE RIGHT LEG AND DORSUM OF THE RIGHT FOOT.

Nerve-Supply.—Deep peroneal nerve (L. 4. 5. S. 1.).
Actions.—Extension of the four medial toes.

The Muscles on the Lateral Side of the Leg.

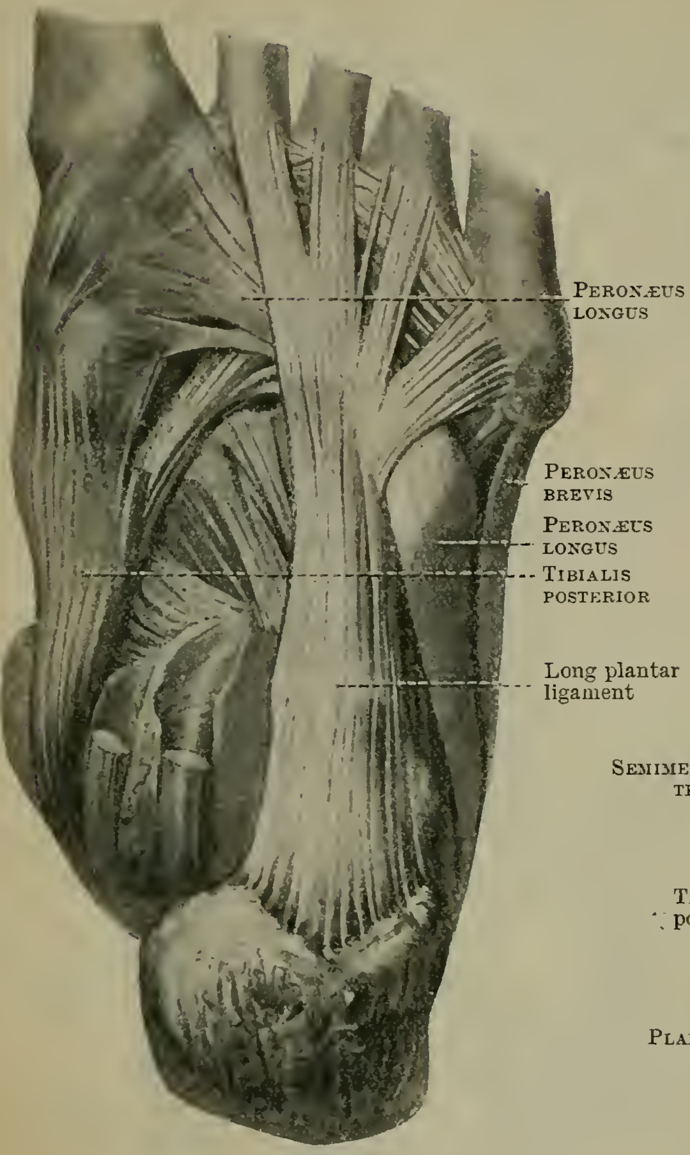

Fig. 355.—The Insertions of the Tibialis Posterior and Peronæus Longus in the Sole of the Left Foot.

These muscles comprise the peronæi,—longus and brevis. They are placed on the lateral side of the leg between the extensor digitorum longus in front, and the soleus and flexor hallucis longus behind, enclosed in a special osteo-fascial compartment.

M. Peronæus Longus. — The **peronæus longus** arises from the lateral condyle of the tibia, from the head and the proximal two-thirds of the lateral surface of the body of the fibula, from intermuscular septa on either side, and from the fascia over it.

It forms a stout tendon, which lies superficial to the peronæus brevis, and hooks round the lateral malleolus deep to the superior peroneal ~~retinaculum~~. It then crosses the lateral side of the calcaneus, where it diverges from the peronæus brevis tendon, passing below the trochlear process and under the inferior peroneal retinaculum. Finally, 7 traversing the groove on the cuboid bone, it is directed across the sole of the foot to be **inserted** into the lateral sides of the first cuneiform and the base of the first metatarsal bones (Fig. 353, p. 426). As it enters the sole of the foot a *fibro-cartilage* is formed in the tendon, which plays over a smooth tubercle on the cuboid bone, a bursa intervening. In its passage across the foot the tendon is enclosed in a sheath derived from the long plantar (long calcaneo-cuboid) ligament and

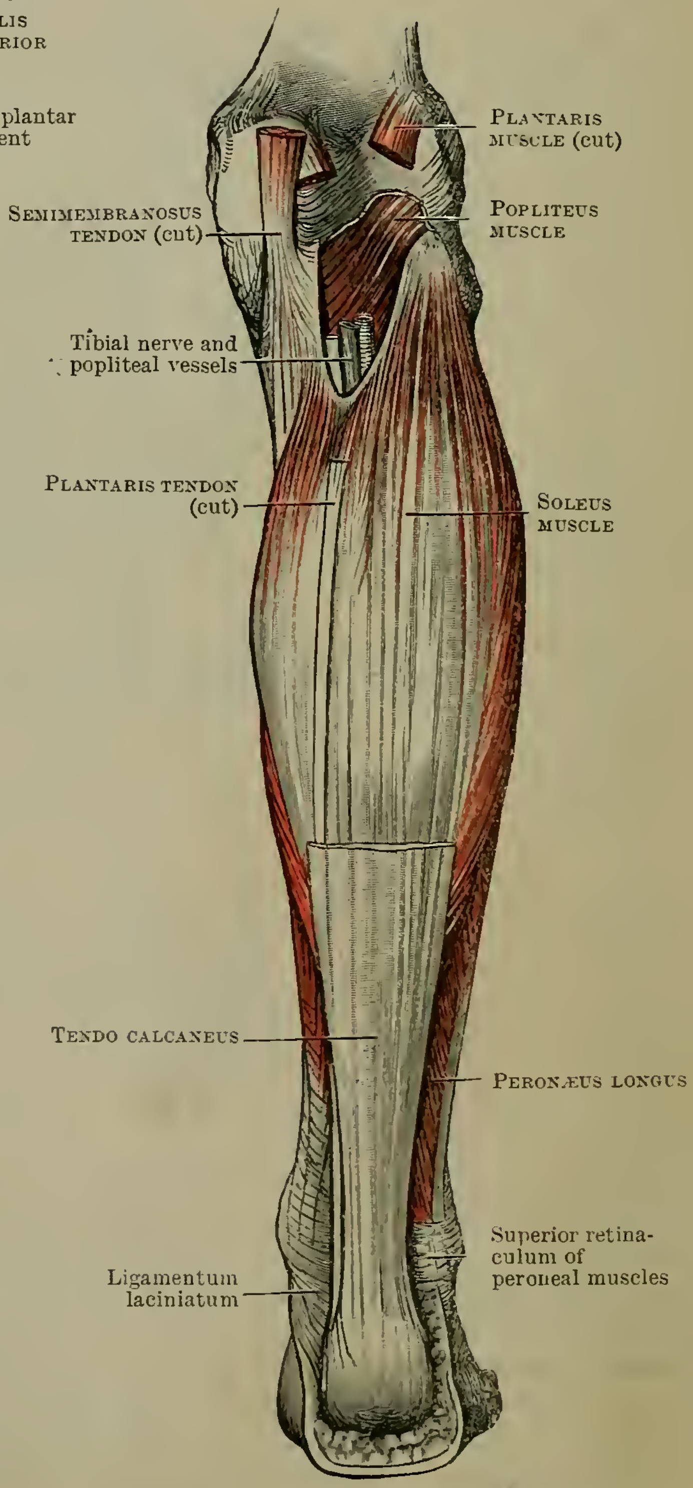

Fig. 356.—The Right Soleus Muscle.

the tibialis posterior tendon. A second mucous sheath invests this part of the tendon.

Nerve-Supply.—Superficial peroneal nerve (L. 4. 5. S. 1.).
Actions.—This muscle is an evertor and a plantar flexor of the foot. It supports the transverse arch of the foot by its passage across the sole to its insertion.

M. Peronæus Brevis.—The **peronæus brevis arises** by fleshy fibres from the distal two-thirds of the lateral surface of the body of the fibula, and from an intermuscular septum along its anterior border.

Its tendon grooves the back of the lateral malleolus and the lateral side of the calcaneus, invested by a mucous sheath common to it and the peronæus longus, and is **inserted** into the tuberosity and dorsal surface of the base of the fifth metatarsal bone.

The peronæus longus and brevis may be fused together, or additional slips may be present, as **peronæus accessorius, peronæus digiti quinti, peronæocalcaneus externus,** and **peronæocuboideus.**
Nerve-Supply.—Superficial peroneal nerve (L. 4. 5. S. 1.).
Actions.—An evertor and plantar flexor of the foot.

The Muscles on the Posterior Aspect of the Leg.

The muscles on the back of the leg are divisible into two groups, superficial and deep.

The superficial group comprises the gastrocnemius and soleus (constituting together the **triceps suræ**) and the plantaris. They form the prominence of the calf of the leg. The gastrocnemius is superficial except at its origin, where the two bellies, forming the boundaries of the popliteal fossa, are overlapped by the tendons of the hamstring muscles. The soleus muscle is partially concealed by the gastrocnemius and plantaris, and becomes superficial in the distal part of the leg on each side of the common tendon (tendo calcaneus).

M. Gastrocnemius.—The **gastrocnemius arises** by *two heads,* medial and lateral, by means of strong tendons which are prolonged over the surface of the muscle. The **lateral head** arises from an impression on the proximal and posterior part of the lateral surface of the lateral condyle of the femur, and from the distal end of the lateral epicondylic line; while the **medial head** arises from a prominent rough mark on the popliteal surface of the femur, proximal to the medial epicondyle. Each head has an additional origin from the back of the capsule of the knee-joint. A bursa lies deep to each tendon of origin; in the case of the medial head it frequently communicates with the synovial cavity of the articulation, but such a communication is comparatively rare in the case of the lateral head.

The two fleshy bellies, of which the medial is the larger, remain separate and are inserted into the posterior surface of a broad, membranous tendon, which narrows distally and constitutes the **tendo calcaneus.**

Becoming thicker in the distal part of the leg, where it receives, on its anterior surface, the insertion of the soleus, the tendo calcaneus is inserted into the middle part of the posterior surface of the calcaneus. A bursa intervenes between the tendon and the bone, immediately proximal to its insertion.

Nerve-Supply.—Each head of the muscle is innervated by a branch from the tibial nerve (S. 1. 2.).
Actions.—The muscle is a powerful flexor of the knee and extensor of the ankle.

M. Plantaris.—The **plantaris arises** by fleshy fibres from the lateral epicondylic line of the femur for about an inch at its distal end, from the adjacent part of the popliteal surface of the femur, and from the oblique ligament of the knee-joint.

It forms a narrow fleshy slip ending in a tendon which runs distally in the back of the leg, to be **inserted** into the medial side of the tuberosity of the calcaneus or the tendo calcaneus, or the ligamentum laciniatum. The tendon of the muscle, although apparently a rounded bundle, can be drawn out into a fine, aponeurotic sheet, two or three inches in width.

The plantaris lies between the lateral head of the gastrocnemius and the sole

In the distal half of the leg its tendon lies along the medial border of the tendo calcaneus. The muscle is not always present.

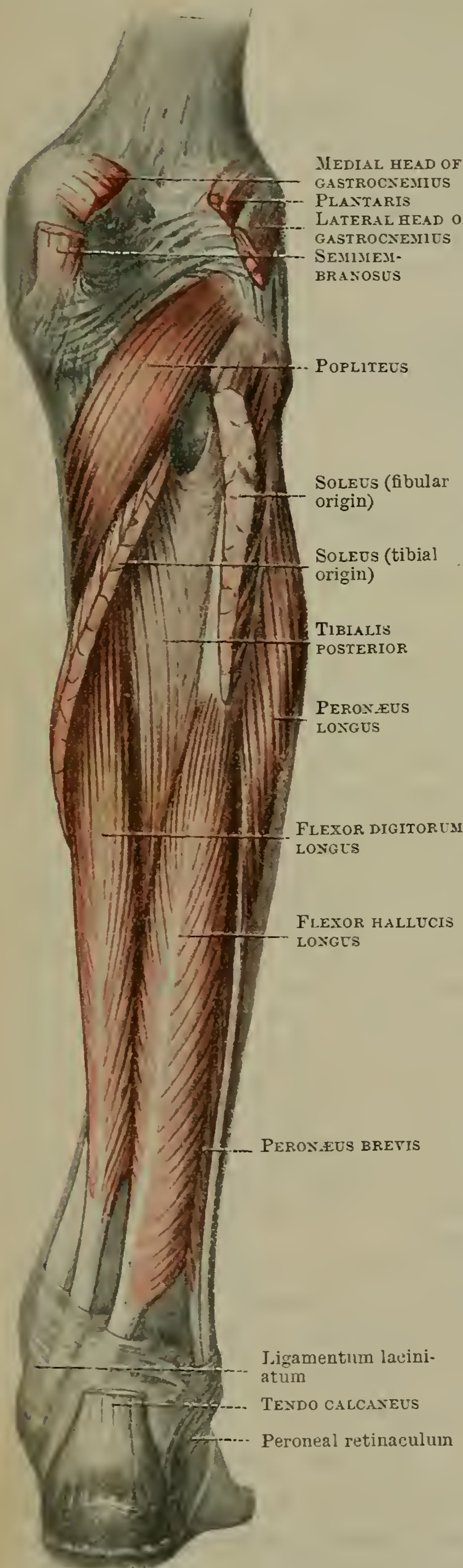

Fig. 357.—The Deep Muscles on the Back of the Right Leg.

Nerve-Supply.—Tibial nerve (L. 4. 5. S. 1.).

Actions.—The muscle is an accessory flexor of the knee and extensor of the ankle.

M. Soleus.—The **soleus** has a triple origin from (1) the posterior surfaces of the head and the proximal third of the body of the fibula; (2) a fibrous arch (**arcus tendineus m. solei**) stretching over the popliteal vessels and tibial nerve, between the tibia and fibula; and (3) the oblique line, and the middle third of the medial border of the tibia (Fig. 358).

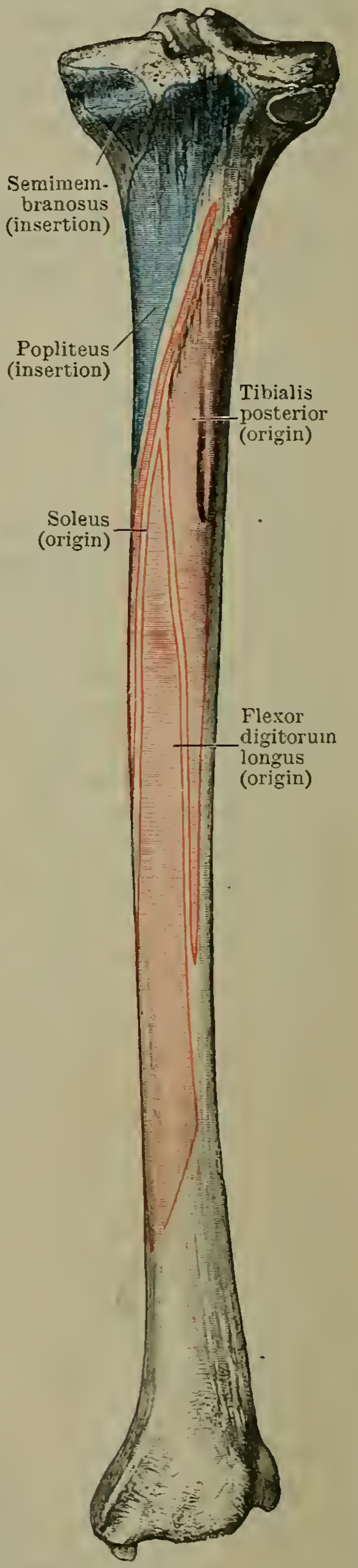
Semimembranosus (insertion)
Popliteus (insertion)
Tibialis posterior (origin)
Soleus (origin)
Flexor digitorum longus (origin)

Fig. 358.—Muscle-Attachments to the Posterior Surface of the Right Tibia.

From their origin the proximal muscular fibres are directed distally to join a tendon, placed on the superficial aspect of the muscle, which is inserted into the tendo calcaneus; the more distal fibres are inserted directly into the tendo calcaneus to within one or two inches of the calcaneus.

Nerve-Supply.—Two nerves supply this muscle. One from the tibial nerve in the popliteal space enters its superficial surface (S. 1. 2.); the other from the tibial nerve in the back of the leg supplies the deep surface of the muscle (L. 5. S. 1. 2.).

Actions.—The soleus is a powerful extensor of the ankle.

The **deep muscles** of the back of the leg comprise the popliteus, flexor digitorum longus, flexor hallucis longus, and tibialis posterior.

The popliteus muscle is deeply placed in the distal part of the floor of the popliteal fossa, and is covered by the popliteal vessels and tibial nerve. The flexor digitorum longus lies on the tibia, the flexor hallucis longus on the fibula, and e tibialis posterior, lying between them, is related to the interosseous membrane and both bones of the leg. All these muscles are concealed by the superficial group, and are bound down to the bones of the leg by layers of the deep fascia.

M. Popliteus.—The **popliteus arises**, by a stout tendon, from a rough impression in front of a groove on the lateral aspect of the lateral epicondyle of the femur. The tendon passes between the lateral meniscus and the capsule of the knee-joint, and pierces the posterior ligament, from which it takes an additional fleshy origin.

The muscle is **inserted**, by fleshy fibres, (1) into a triangular surface on the back of the tibia above the oblique line (Fig. 358, p. 430), and (2) into the fascia over it (the popliteus fascia, derived from the tendon of the semimembranosus muscle).

Intracapsular at its origin, the tendon is partially invested by the synovial stratum of the joint, which protrudes along it for a short distance after it has pierced the posterior ligament.

Nerve - Supply. — The popliteus is supplied by a branch of the tibial nerve (L. 4. 5. S. 1.), which winds round the distal border of the muscle and enters it in its deep surface.

Actions.—A medial rotator of the tibia, and a flexor of the knee. It is believed that this muscle is responsible for the unlocking movement of medial rotation of the tibia which occurs immediately prior to, or synchronous with the initial stages of flexion of the fully extended knee-joint.

M. Flexor Digitorum Longus.—The **flexor digitorum longus** lies in both the back of the leg and the sole of the foot. Its **origin** is, by fleshy fibres, from the posterior surface of the body of the tibia in its middle three-fifths, distal to the oblique line, and medial to the vertical line and the origin of the tibialis posterior, from the fascia over it, and from an intermuscular septum on each side (Fig. 357, p. 430).

Its tendon, after crossing obliquely over the tendon of the tibialis posterior, passes deep to the ligamentum laciniatum, invested in a special mucous sheath, and enters the sole of the foot. There it crosses superficial to the tendon of the flexor hallucis longus, by which it is separated from the plantar calcaneo-navicular ligament. Finally, it divides into four subordinate tendons, which are **inserted** into the four lateral toes in precisely the same manner as the flexor digitorum profundus is inserted in the hand (p. 391). Each tendon enters the digital sheath of the toe, perforates the tendon of the flexor digitorum brevis, and is inserted into the base of the terminal phalanx. **Vincula accessoria (longa and brevia)** are present as in the hand.

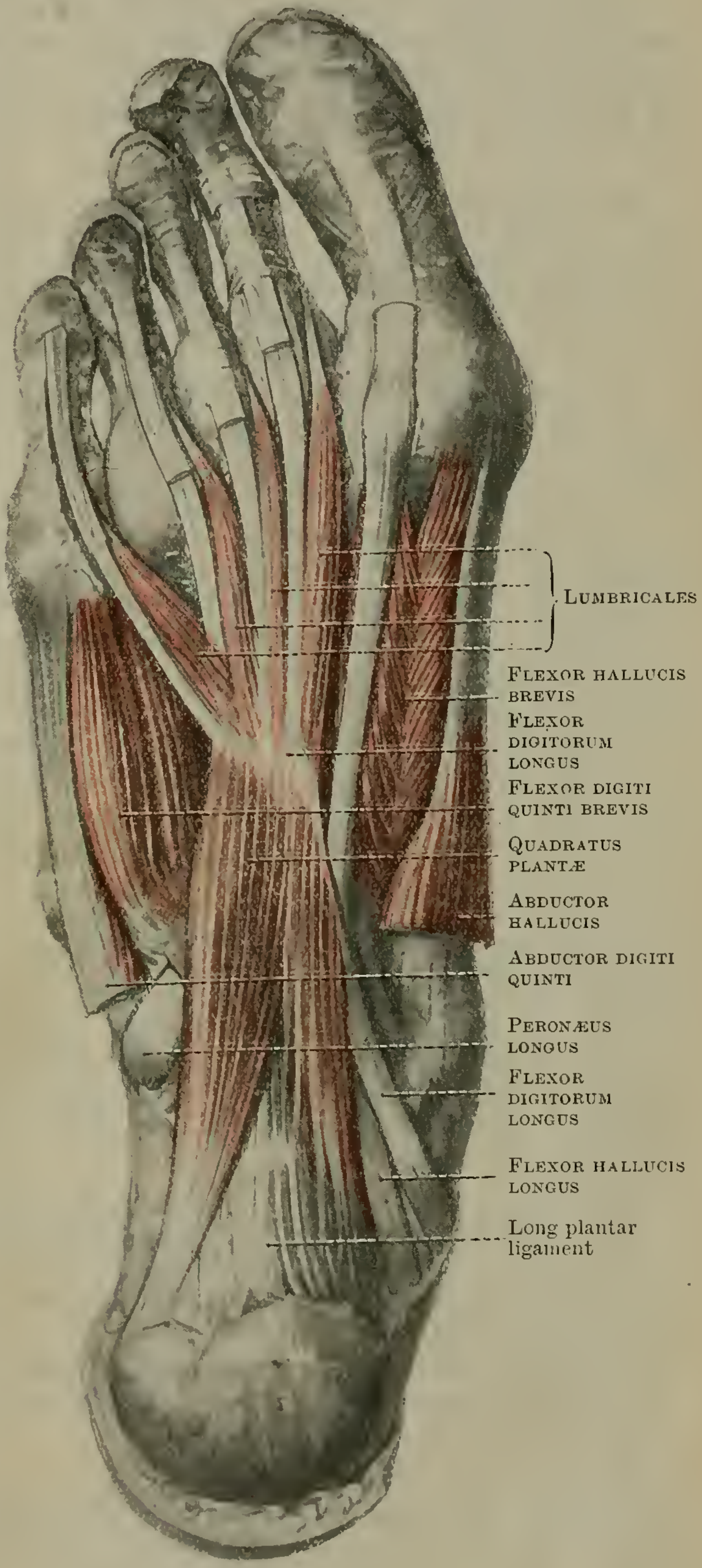

Fig. 359.—The Muscles of the Right Foot (Second Layer).

The tendon of the flexor hallucis longus sends a fibrous band to the tendon of the flexor digitorum longus as it crosses it in the sole of the foot; the band usually passes to the tendons destined for the second and third toes. Associated with this muscle in the sole of the foot are the lumbricales and quadratus plantæ muscles.

Mm. Lumbricales.—The **lumbricales** are four small muscles which **arise** in association with the tendons of the flexor digitorum longus in the sole. The *first muscle* arises by a single origin from the tibial side of the tendon of the flexor digitorum longus for the second toe; each of the *other three* arises by two heads from the adjacent sides of two tendons.

Each muscle is **inserted** into the dorsal expansion of the extensor tendon, the metatarso-phalangeal capsule, and the base of the first phalanx, precisely as in the case of the lumbrical muscles of the hand. Each muscle passes forwards on the tibial side of the corresponding toe, superficial to the transverse metatarsal ligament.

Nerve-Supply.—The flexor digitorum longus is supplied by the tibial nerve (L. 5. S. 1.). The first lumbrical is supplied by the medial plantar nerve (L. 4. 5. S. 1.); the other three, by the lateral plantar nerve (S. 1. 2.).

Actions.—The flexor digitorum longus flexes the four lateral toes and is a plantar flexor of the ankle. The lumbrical muscles have a similar action to those of the hand; they flex the metatarso-phalangeal, and extend the interphalangeal joints of the four lateral toes.

M. Quadratus Plantæ.—The **quadratus plantæ** (O.T. **accessorius**) arises by two heads: (1) the lateral tendinous head, which may be absent, springs from the lateral border of the plantar surface of the calcaneus and from the lateral border of the long plantar ligament; (2) the medial head, which is fleshy, arises from the concave medial surface of the calcaneus in its whole extent, and from the medial border of the long plantar ligament (Fig. 353, p. 426). The long plantar ligament separates the two origins.

The two heads unite to form a flattened band, which is **inserted** into the dorsal aspects of the tendons of the flexor digitorum longus, and usually into those destined for the second, third, and fourth toes.

In the sole of the foot the tendons of the flexor digitorum longus, along with the lumbricales and quadratus plantæ, and the flexor hallucis longus muscles, constitute the second layer of muscles, lying between the abductors of the great and little toes and the flexor digitorum brevis superficially, and the flexor brevis and adductor of the great toe more deeply.

Nerve-Supply.—Lateral plantar nerve (S. 1. 2.).

Actions.—The muscle is an accessory flexor of the toes, assisting the long flexor of the toes. It tends to draw the tendons into which it is inserted into the middle of the sole of the foot.

M. Flexor Hallucis Longus.—The **flexor hallucis longus** arises between the tibialis posterior and the peronæi muscles, from the distal two-thirds of the posterior surface of the body of the fibula, from the fascia over it, and from intermuscular septa on either side.

Its tendon passes deep to the ligamentum laciniatum, enclosed in a special mucous sheath, and after grooving the posterior surface of the distal end of the tibia, the talus, and the plantar surface of the sustentaculum tali of the calcaneus, it is directed forwards in the sole of the foot, to be **inserted** into the base of the terminal phalanx of the great toe.

In the foot it crosses over the deep aspect of the tendon of the flexor digitorum longus, and gives to it a strong fibrous slip, which is prolonged into the tendons for the second and third toes.

Nerve-Supply.—Tibial nerve (L. 5. S. 1. 2.).

Actions.—The muscle is one of the most important in the leg and foot. It is primarily a flexor of the great toe, but it also assists in plantar flexion of the foot. By its position in relation to the tarsus and inferior calcaneo-navicular ligament, it has an important share in maintaining and supporting the arch of the foot.

M. Tibialis Posterior.—The **tibialis posterior** has a fourfold fleshy **origin** in the leg. It arises (1) from the proximal four-fifths of the medial surface of the body of the fibula between the medial crest and the interosseous crest; (2) from the distal part of the lateral condyle, and from the proximal two-thirds of the body of the tibia, distal to the oblique line and between the vertical line and the interosseous border (Fig. 358, p. 430); (3) from the interosseous membrane; and (4) from the fascia over it and the septa on either side. The muscle gives rise to a strong tendon which passes deep to the ligamentum laciniatum, invested by a special mucous sheath, and grooves the back of the medial malleolus, on its way to the medial border of the foot.

After crossing over the plantar calcaneo-navicular ligament between the sustentaculum tali and the navicular bone, the tendon spreads out and is **inserted** by three bands into (1) the tubercle of the navicular bone and the plantar surfaces of the first and second cuneiform bones, (2) the plantar aspects of the bases of the second, third, fourth, and sometimes the fifth metatarsal bones, the second and third cuneiform bones, and the groove on the cuboid, and (3) into the medial border of the sustentaculum tali of the calcaneus (Fig. 353, p. 426).

The **peronæo-calcaneus** muscle, when present, arises from the fibula, and is **inserted** into the calcaneus.

Nerve-Supply.—Tibial nerve (L. 5. S. 1.).

Actions.—The muscle is an invertor and a plantar flexor of the foot. In addition, through its numerous accessory insertions, it assists in the maintenance of the arches of the foot.

The Muscles in the Sole of the Foot.

The muscles in the sole of the foot are divisible into four layers placed deep to the plantar aponeurosis.

The *first layer* includes the abductor hallucis, flexor digitorum brevis, and abductor digiti quinti. The *second layer* consists of the lumbricales and quadratus plantæ, together with the tendons of the flexor hallucis longus and flexor digitorum longus. The *third layer* comprises the flexor hallucis brevis, adductor hallucis, and flexor digiti quinti brevis. The *fourth layer* consists of the interossei (plantar and dorsal), placed between the metatarsal bones: and the tendons of insertion of the tibialis posterior and peronæus longus.

FIRST LAYER.

M. Abductor Hallucis.—The **abductor hallucis** has a double **origin**: (1) by a short tendon from the medial side of the medial process of the tuberosity of the calcaneus (Fig. 360, p. 434), and (2) by fleshy fibres from the ligamentum laciniatum, the plantar aponeurosis which covers it, and the intermuscular septum between it and the flexor digitorum brevis.

The muscle lies superficially, along the medial border of the sole; its tendon is **inserted**, along with part of the flexor hallucis brevis, into the medial side of the base of the first phalanx of the great toe.

Nerve-Supply.—Medial plantar nerve (L. 4. 5. S. 1.).

Actions.—A flexor and abductor of the great toe at the metatarso-phalangeal joint.

M. Flexor Digitorum Brevis.—The **flexor digitorum brevis** has likewise a double **origin**: (1) from the anterior part of the medial process of the tuberosity of the calcaneus (Fig. 353, p. 426), and (2) from the thick central part of the plantar aponeurosis which covers it, and from the intermuscular septa on either side.

It passes forwards, and gives rise to four slender tendons, which are **inserted** into the second phalanges of the four lateral toes, after having been perforated by the long flexor tendons, just as in the case of the tendons of the flexor digitorum sublimis of the hand (p. 390).

Nerve-Supply.—Medial plantar nerve (L. 4. 5. S. 1.).

Actions.—The muscle is a flexor of the toes, acting on the metatarso-phalangeal and first interphalangeal articulations of the four lateral toes.

M. Abductor Digiti Quinti.—The **abductor digiti quinti** also has a double **origin**: (1) by fleshy and tendinous fibres from the anterior part of both processes of the tuberosity of the calcaneus, partly concealed by the flexor digitorum brevis (Fig. 353, p. 426), and (2) by fleshy fibres from the lateral portion of the plantar aponeurosis and the calcaneo-metatarsal ligament, and from the intermuscular septum between it and the flexor digitorum brevis.

Its tendon lies along the fifth metatarsal bone, and is **inserted** into the lateral side of the posterior end of the first phalanx of the little toe. The most lateral fibres usually obtain an additional insertion into the lateral side of the plantar surface of the fifth metatarsal bone.

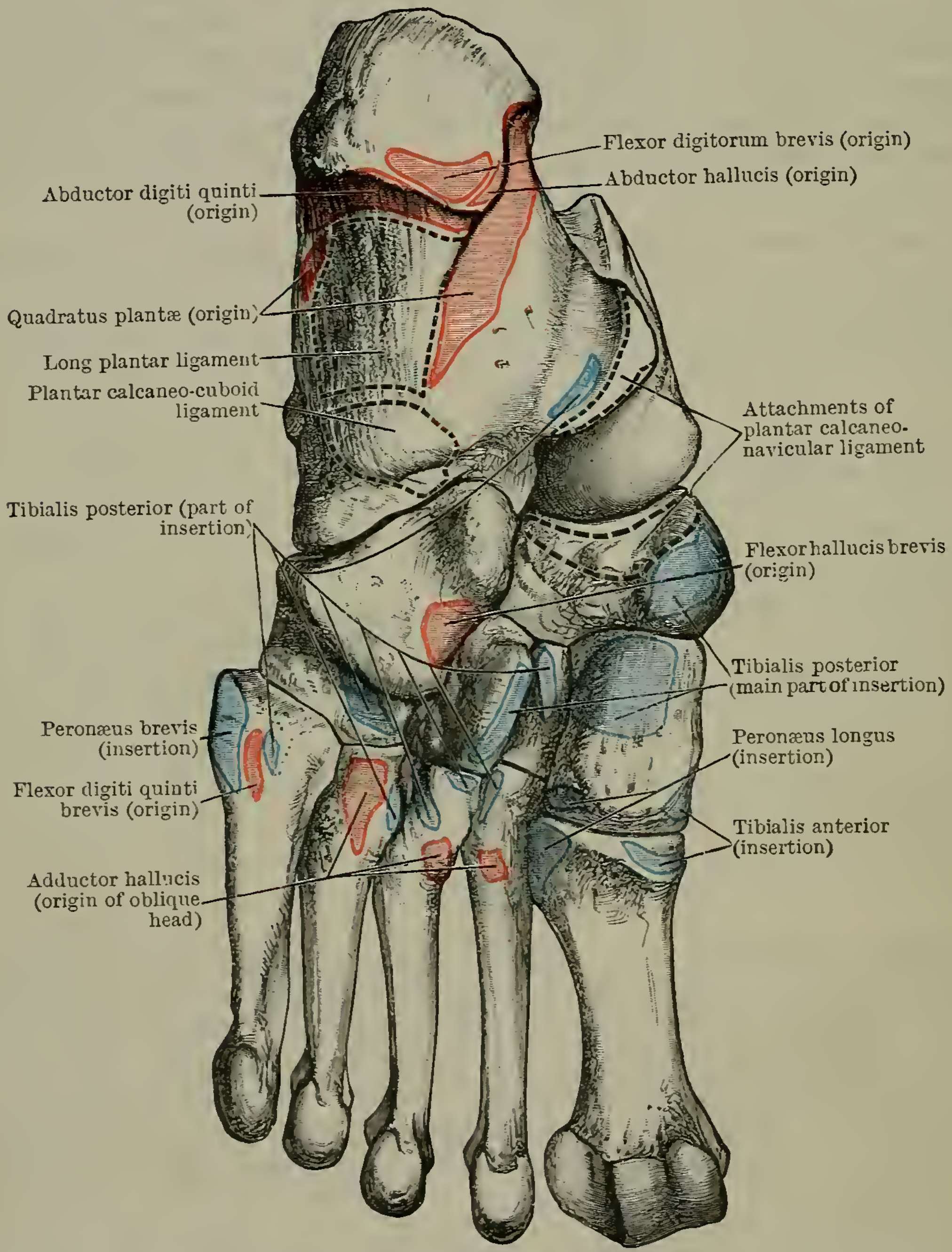
Flexor digitorum brevis (origin)
Abductor hallucis (origin)
Abductor digiti quinti (origin)
Quadratus plantæ (origin)
Long plantar ligament
Plantar calcaneo-cuboid ligament
Attachments of plantar calcaneo-navicular ligament
Tibialis posterior (part of insertion)
Flexor hallucis brevis (origin)
Tibialis posterior (main part of insertion)
Peronæus brevis (insertion)
Peronæus longus (insertion)
Flexor digiti quinti brevis (origin)
Tibialis anterior (insertion)
Adductor hallucis (origin of oblique head)

Fig. 360.—Muscle-Attachments to Left Tarsus and Metatarsus (Plantar Aspect).

Nerve-Supply.—Lateral plantar nerve (S. 1. 2.).
Actions.—Flexion and abduction of the little toe at the metatarso-phalangeal joint.

SECOND LAYER.

The tendons of the long flexors of the toes, the **lumbricales** and **quadratus plantæ muscles**, constituting the **second layer of muscles**, have already been described (p. 432). They lie deep to the abductor hallucis and the flexor digitorum brevis, and occupy the hollow of the tarsus and the space between the first and fifth metatarsal bones; their deep surfaces are in contact with the adductor of the great toe and the interossei muscles.

THIRD LAYER.

M. Flexor Hallucis Brevis.—The **flexor hallucis brevis** arises by tendinous fibres from (1) the medial part of the plantar surface of the cuboid bone (Fig. 353, p. 426), and (2) the tendon of the tibialis posterior. Directed forwards, over the first metatarsal bone, the muscle separates into two parts, between which is the tendon of the flexor hallucis longus.

Each portion gives rise to a tendon which is **inserted** into the corresponding side of the base of the first phalanx of the great toe; in each tendon, under the metatarso-phalangeal articulation, a sesamoid bone is developed. The medial tendon is united with the insertion of the abductor, the lateral tendon with the insertions of the adductor muscle of the great toe.

Nerve-Supply.—Medial plantar nerve (L. 4. 5. S. 1.).

Actions.—A flexor of the metatarso-phalangeal joint of the great toe.

M. Adductor Hallucis.—The **adductor hallucis** consists of two parts. The **oblique head** of the muscle **arises** (1) from the sheath of the peronæus longus, and (2) from the plantar surfaces of the bases of the second, third, and fourth metatarsal bones (Fig. 360, p. 434). It lies in the hollow of the foot, on a deeper plane than the long flexor tendons and lumbricales, and on the lateral side of the flexor hallucis brevis, and it runs obliquely medially and forwards, to be **inserted** on the lateral side of the base of the first phalanx of the great toe between and along with the flexor brevis and the transverse head of the adductor hallucis.

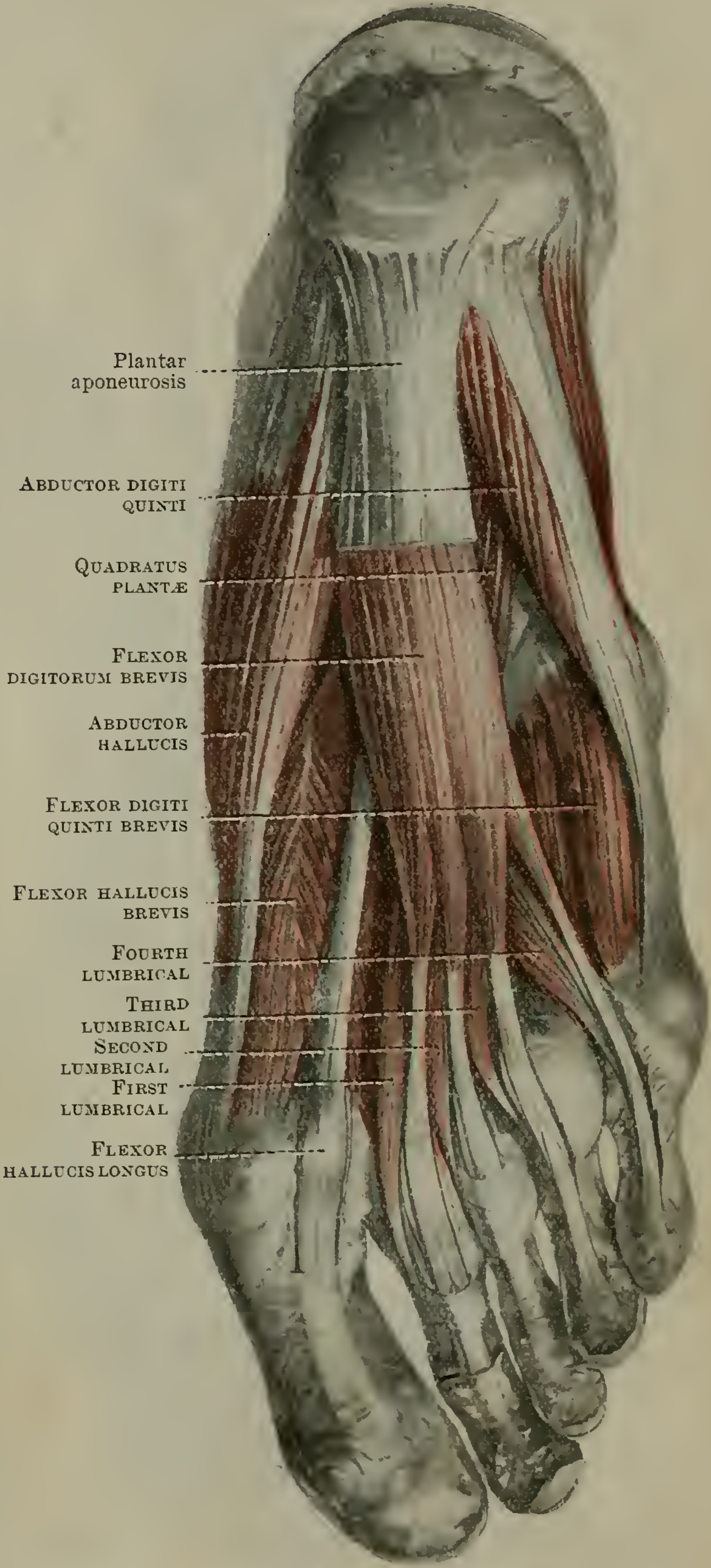

Fig. 361.—Superficial Muscles of the Right Foot.

The **transverse head arises** from (1) the capsules of the lateral four metatarso-phalangeal articulations and (2) the transverse metatarsal ligament.

It runs transversely medially under cover of the flexor tendons and lumbricales, and is **inserted**, along with the oblique head, into the lateral side of the base of the first phalanx of the great toe.

Nerve-Supply.—Lateral plantar nerve (S. 1. 2.).
Actions.—Flexion and adduction of the great toe towards the middle line of the foot.

M. Flexor Digiti Quinti Brevis.—The **flexor digiti quinti brevis arises** from (1) the sheath of the peronæus longus and (2) the base of the fifth metatarsal bone (Fig. 360, p. 434).

Partially concealed by the abductor digiti quinti, the muscle passes along the fifth metatarsal bone, to be **inserted**, in common with that muscle, into the lateral side of the base of the first phalanx of the little toe.

Nerve - Supply. — Lateral plantar nerve (S. 1. 2.).
Actions.—Flexion of the little toe.

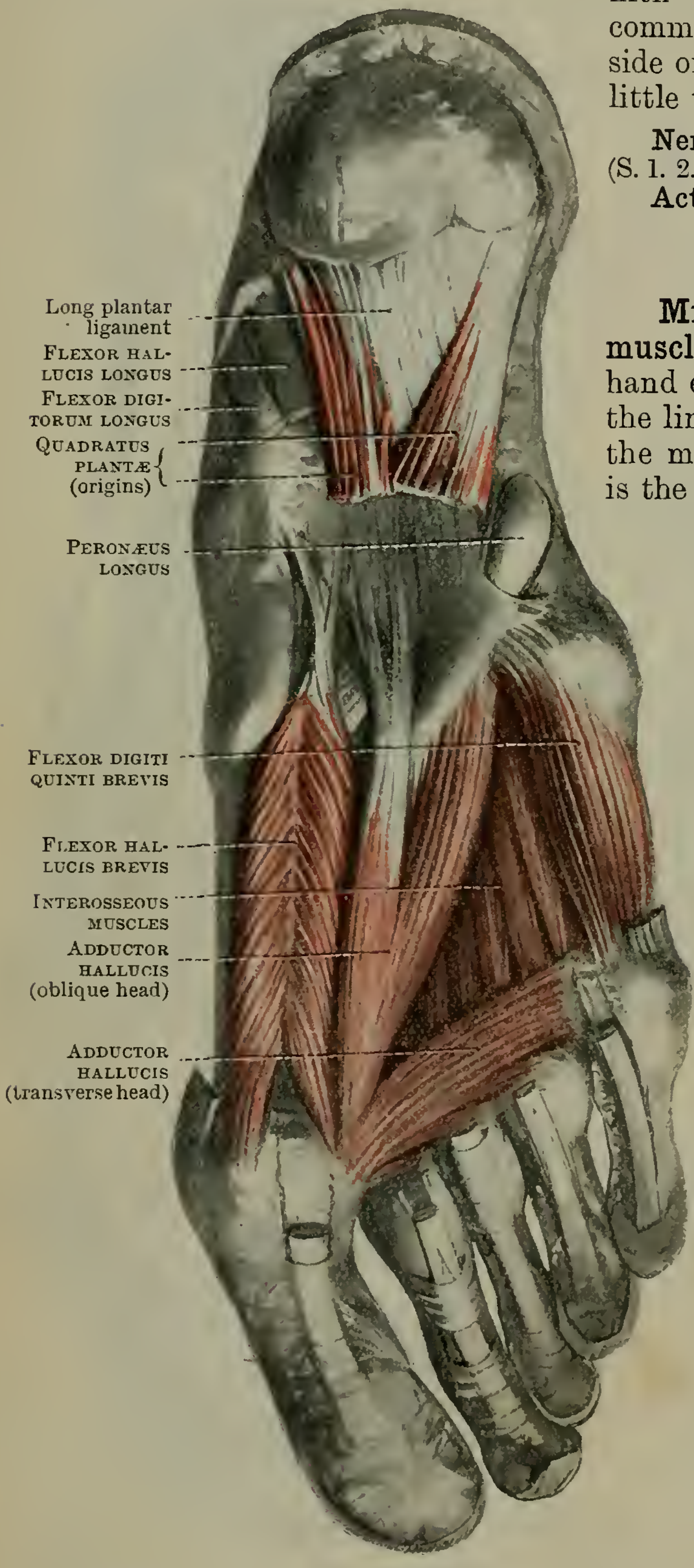

FIG. 362.—DEEP MUSCLES OF THE SOLE OF THE FOOT.

FOURTH LAYER.

Mm. Interossei. — The **interossei muscles** of the foot resemble those of the hand except in one respect. In the hand the line of reference is the middle line of the middle finger, whereas, in the foot, it is the middle line of the second toe.

There are four dorsal and three plantar muscles, which occupy together the four interosseous spaces, and project into the hollow of the foot.

The **four dorsal muscles**, one in each interosseous space, **arise** by two heads each from the shafts of adjacent metatarsal bones.

Each gives rise to a tendon, which, after passing dorsal to the transverse metatarsal ligament, is **inserted** on the dorsum of the foot, into the side of the first phalanx, the metatarso-phalangeal capsule, and the dorsal expansion of the extensor tendon. The *first* and *second muscles* are inserted respectively into the medial and lateral sides of the proximal end of the first phalanx of the second toe. The *third* and *fourth muscles* are inserted into the lateral sides of the third and fourth toes.

The **three plantar muscles** occupy the three lateral interosseous spaces. Each **arises**, by a single head, from the medial side of the third, fourth, and fifth metatarsal bones respectively.

Each ends in a tendon which passes dorsal to the transverse metatarsal ligament, and is **inserted**, in the same manner as the dorsal muscles, into the medial sides of the third, fourth, and fifth toes.

Nerve-Supply.—Lateral plantar nerve (S. 1. 2.).
Actions.—The muscles are flexors of the metatarso-phalangeal joints, and extensors of the interphalangeal joints of the four lateral toes. The dorsal interossei *abduct* the toes into which

they are inserted from the middle line of the second toe. The plantar interossei *adduct* the three lateral toes towards the second toe.

Movements of the Lower Limb generally.

The characteristic features of the lower limb are stability and strength, and its muscles and joints are both subservient to the functions of transmission of weight and of locomotion. In the standing position the centre of gravity of the trunk falls between the heads of the femora, and is located about the middle of the body of the last lumbar vertebra. It is transmitted from the sacrum through the posterior sacro-iliac ligaments to the hip bone, and through the bones of the lower limb to the arch of the foot, where the talus distributes it backwards through the calcaneus to the heel, and forwards through the tarsus and metatarsus to the balls of the toes.

Locomotion.—The three chief means of progression are walking, running, and leaping. In **walking**, the body and its centre of gravity are inclined forwards, the trunk oscillates from side to side as it is supported alternately by each foot, the arms swing alternately with the corresponding leg, and one foot is always on the ground. The act of progression is performed by the leg, aided in two ways by gravity. The movements of the leg occur in the following way. At the beginning of a step, one leg, so to speak, "shoves off"; the heel is raised and the limb is extended. By the action of the muscles flexing the hip and knee-joints, and extending the ankle-joint and toes, this limb is raised from the ground sufficiently to clear it, and passes forwards by the action of gravity, aided by the force given to the movement by the extensor muscles. After passing the line of the centre of gravity the flexion of the joints ceases, the muscles relax, and the limb gradually returns to the ground. The other limb then passes through the same cycle, the weight of the body now resting on the limb which is in contact with the ground. As the foot reaches the ground it, as it were, rolls over it; the heel touches it first, then the sole, and lastly, as the foot leaves the ground again, only the toes. In **running**, the previous events are all exaggerated. The time of the event is diminished, while the force and distance are increased. Both feet are off the ground at one time; the action of flexors and extensors alternately is much more powerful, so that on the one hand the knees are drawn upwards to a greater extent in the forward movement, and not the whole foot, but only the toes reach the ground in the extension of the limb. The attempt is made to bring the foot to the ground in front of the line of the centre of gravity. At the same time the trunk is sloped forwards much more than in walking. In **leaping**, the actions of the limbs are still more exaggerated. The movements of flexion of the limb are still more marked, and the foot reaches the ground still farther in front of the line of the centre of gravity.

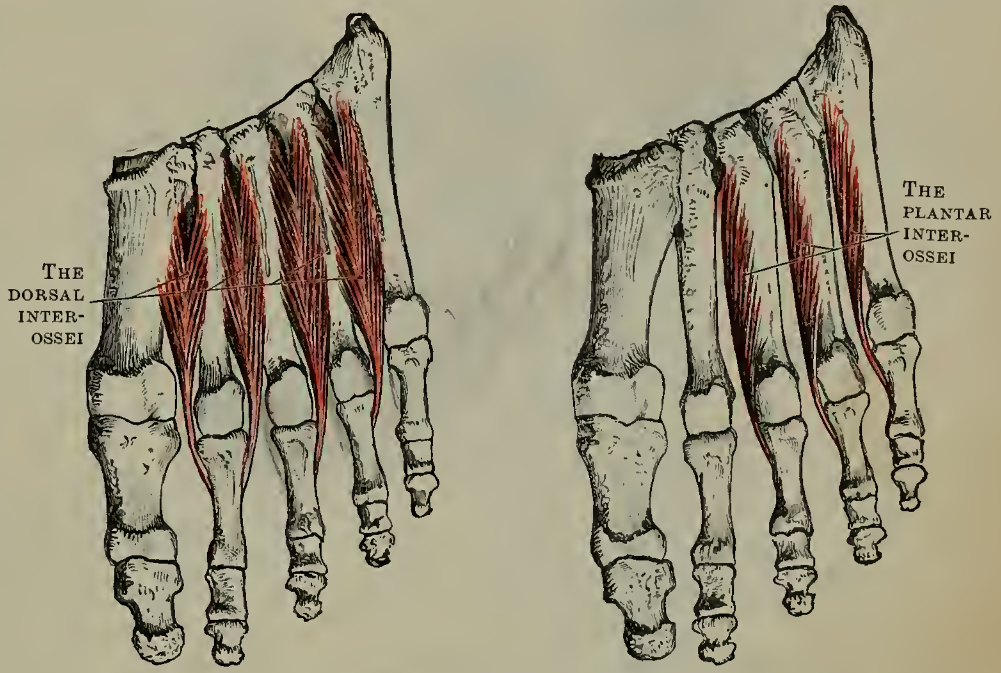

FIG. 363.—INTEROSSEOUS MUSCLES OF THE RIGHT FOOT.

AXIAL MUSCLES.

THE FASCIÆ AND MUSCLES OF THE BACK.

THE FASCIÆ OF THE BACK.

The general fascial investments of the back have been described along with the superficial muscles associated with the shoulder-girdle (p. 368). The latissimus dorsi muscle has been described as arising in large part from the **posterior layer of the lumbo-dorsal fascia.** This is a strong fibrous lamina which conceals the sacrospinalis muscle. In the loin it extends from the spines of the lumbar vertebræ, laterally, to the interval between the last rib and the iliac crest, where it joins the middle layer. Below the loin the posterior layer of the lumbo-dorsal fascia is attached to the iliac crest, and more medially blends with the subjacent tendinous origin of the sacrospinalis. The layer can be followed upwards over the sacrospinalis in the region of the thorax, where it is attached laterally to the ribs and is continuous with the intercostal aponeuroses. In the lower part of the thorax it is replaced by the muscular slips of the serratus posterior inferior; in the upper part of the thorax it passes beneath the serratus posterior superior and blends with the deep cervical fascia.

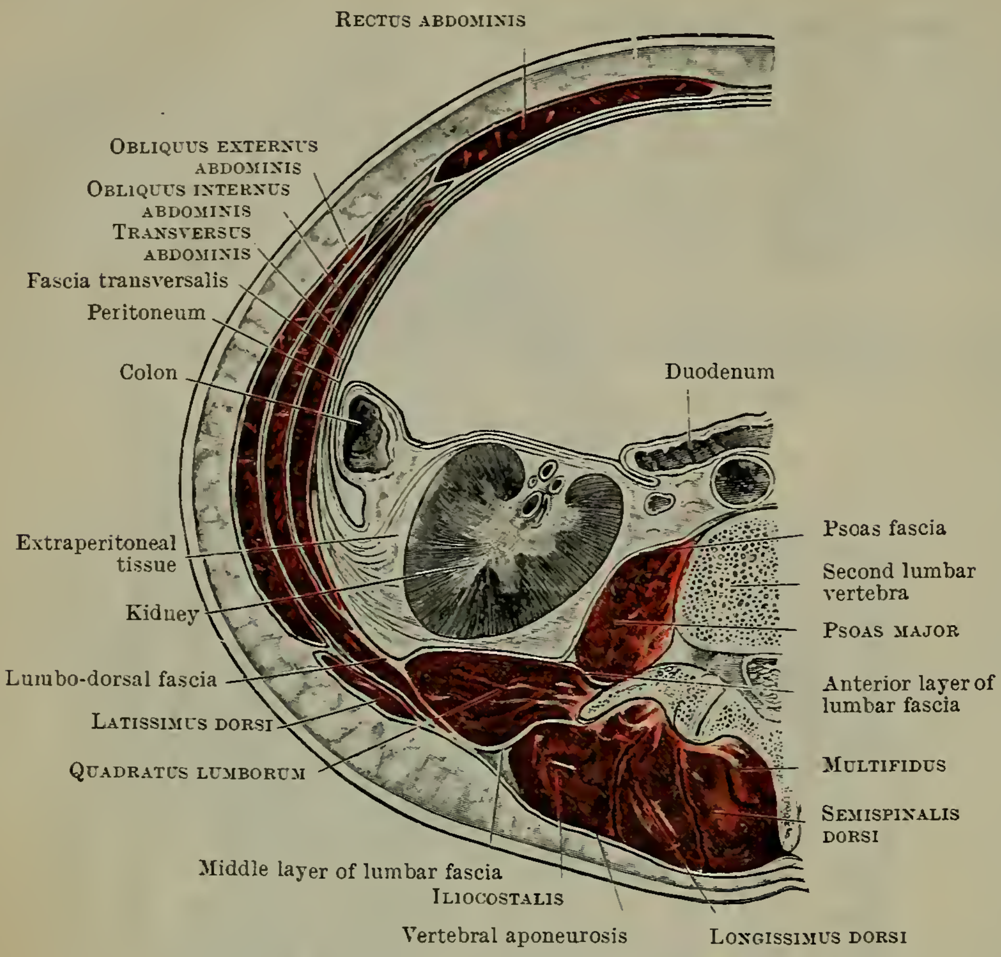

FIG. 364.—TRANSVERSE SECTION THROUGH THE ABDOMEN, OPPOSITE THE SECOND LUMBAR VERTEBRA.

Fascia Lumbodorsalis.—The **lumbo-dorsal fascia** consists of three fascial strata, called respectively the posterior layer, just described; the middle, and the anterior layers. They unite at the lateral margin of the sacrospinalis muscle to form a narrow ligamentous band which connects the last rib to the iliac crest and gives partial origin to the obliquus internus and the transversus abdominus muscles. The **middle layer** stretches laterally from the ends of the transverse processes of the lumbar vertebræ, between the sacrospinalis behind and the quadratus lumborum muscle in front. The **anterior layer** is attached to the anterior aspects of the transverse processes of the lumbar vertebræ. It covers the anterior surface of the quadratus lumborum muscle, and separates it from the psoas major.

THE MUSCLES OF THE BACK.

The muscles of the back are arranged in four series according to their attachments: (1) vertebro-scapular and vertebro-humeral, (2) vertebro-costal, (3) vertebro-cranial, and (4) vertebral. They are in irregular strata, the most superficial muscles having the most widely spread attachments.

The first series of muscles of the back, connecting the axial skeleton to the upper limb, have already been described. They are arranged in two layers: (1) trapezius and latissimus dorsi superficially; (2) levator scapulæ, and rhomboidei, deep to the trapezius (p. 369).

The remaining muscles are almost entirely axial, and may be divided into four groups: (1) serrati posteriores, superior and inferior; splenius capitis and splenius cervicis; (2) sacrospinalis and semispinalis capitis; (3) semispinalis dorsi and cervicis (transversospinales); and (4) the small deep muscles (rotatores, interspinales, intertransversarii, and suboccipital muscles). They extend from the sacrum to the head, forming a cylindrical column in the loin, filling up the vertebral groove in the thorax, and giving rise to the muscular mass at the back of the neck.

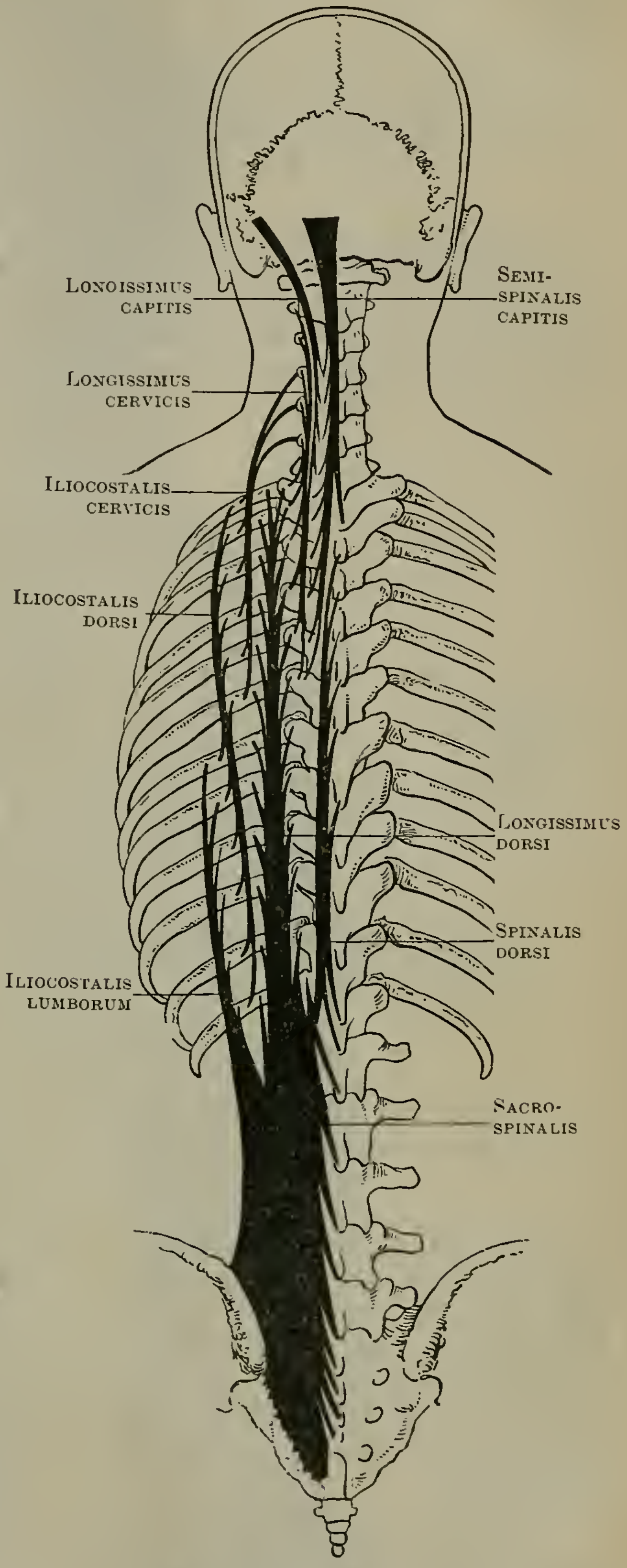

Fig. 365.—Schematic Representation of the Parts of the Left Sacrospinalis Muscle.

First Group.

M. Serratus Posterior Superior.—The **serratus posterior superior** has a membranous **origin** from the ligamentum nuchæ and the spines of the last cervical and upper three or four thoracic vertebræ. It is directed obliquely downwards and laterally, to be **inserted**, by separate slips, into the second, third, fourth, and fifth ribs. The muscle is concealed by the vertebro-scapular muscles, and crosses obliquely over the splenius, sacrospinalis, and semispinalis capitis. It lies superficial to the lumbo-dorsal fascia.

Nerve-Supply.—Second and third intercostal nerves.

Actions.—It elevates the ribs to which it is attached, thus acting as an accessory muscle of inspiration.

M. Serratus Posterior Inferior.—The **serratus posterior inferior** has a membranous **origin**, through the medium of the lumbo-dorsal fascia, from the last two thoracic and first two lumbar spinous processes.

It forms four muscular bands which pass almost horizontally to an **insertion** into the last four ribs. The muscular slips overlap one another from below upwards. The muscle is on the same plane as the posterior layer of the lumbo-dorsal fascia, and is concealed by the latissimus dorsi.

Nerve-Supply.—Lower, usually tenth and eleventh, intercostal nerves.

Actions.—The principal action of this muscle is to assist the diaphragm, by fixing the lower ribs.

M. Splenius.—The **splenius muscle** is a broad, flattened band which occupies the back of the neck and the upper part of the thoracic region. It arises from the ligamentum nuchæ (from the level of the fourth cervical vertebra downwards) and from the spinous processes of the last cervical and higher (four to six) thoracic vertebræ.

Its fibres extend upwards and laterally into the neck, separating in their course into an upper and a lower part. The upper part forms the **splenius capitis**, which is **inserted** into the mastoid portion of the temporal bone and the lateral part of the superior nuchal line of the occipital bone (Fig. 370, p. 445). The lower part forms the **splenius cervicis**, which is **inserted** into the posterior tubercles of the transverse processes of the upper three or four cervical vertebræ, under cover of the origin of the levator scapulæ.

The muscle is partially concealed by the trapezius and sterno-mastoid, and appears between them in the floor of the posterior triangle of the neck (splenius capitis). It is covered by the rhomboid muscles, levator scapulæ, and serratus posterior superior.

Nerve-Supply.—Posterior rami of cervical and upper thoracic nerves.

Actions.—The splenius cervicis assists in extension and lateral movement of the spine to the same side. The splenius capitis helps in the movements of raising the head, and also of lateral flexion and rotation to the same side.

Second Group.

M. Sacrospinalis.—The **sacrospinalis** (O.T. **erector spinæ**) possesses vertebral, vertebro-cranial, and vertebro-costal attachments. It consists of an elongated mass composed of separate slips extending from the sacrum to the skull. Simple at its origin, it becomes more and more complex as it is traced upwards towards the head.

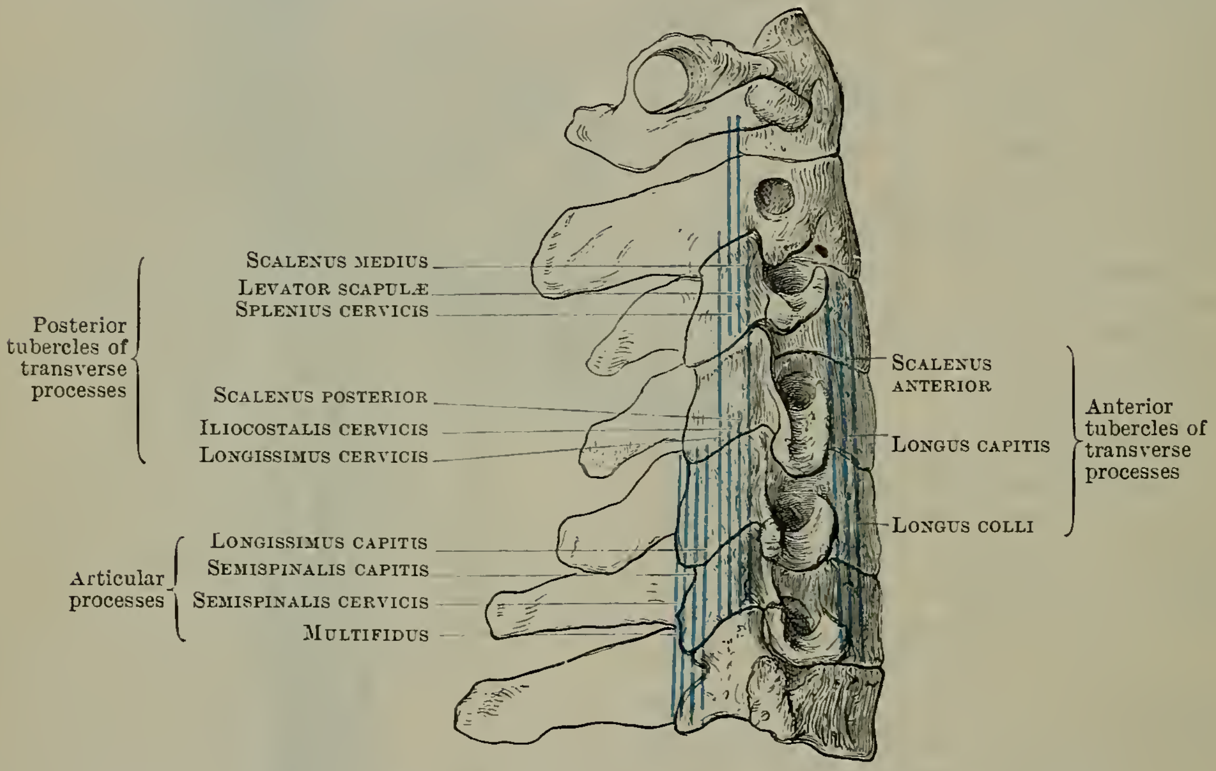

Fig. 366.—Scheme of Muscular-Attachments to the Transverse and Articular Processes of the Cervical Vertebræ.

It **arises** (1) by fleshy fibres from the iliac crest; (2) from the posterior sacro-iliac ligament; and (3) by tendinous fibres continuous with the former from the iliac crest, the dorsum of the sacrum, and the spines of the upper sacral and all the lumbar vertebræ. Its fibres extend upwards through the loin, enclosed between the posterior and middle layers of the lumbo-dorsal fascia, and separate into two columns—a **lateral portion** derived from the lateral fleshy origin, the **iliocostalis**, and a **medial portion** comprising the remaining larger part of the muscle, the **longissimus**.

M. Iliocostalis.—The **iliocostalis lumborum** is **inserted** by six slender slips into the lower six ribs.

Medial to the insertion of each of these slips is the origin of the **iliocostalis dorsi** (O.T. **accessorius**), which, **arising** from the lower six ribs medial to the iliocostalis lumborum, is **inserted** in line with it by similar slips into the upper six ribs.

The **iliocostalis cervicis** (O.T. **cervicalis ascendens**) **arises** in the same way by six slips from the upper six ribs, medial to the insertions of the previous muscle. It forms a narrow band, which, extending into the neck, is **inserted** into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ, behind the scalenus posterior. *The iliocostales, lumborum, dorsi, and cervicis form together a continuous muscular column, and constitute the most lateral group of the component elements of the sacrospinalis.*

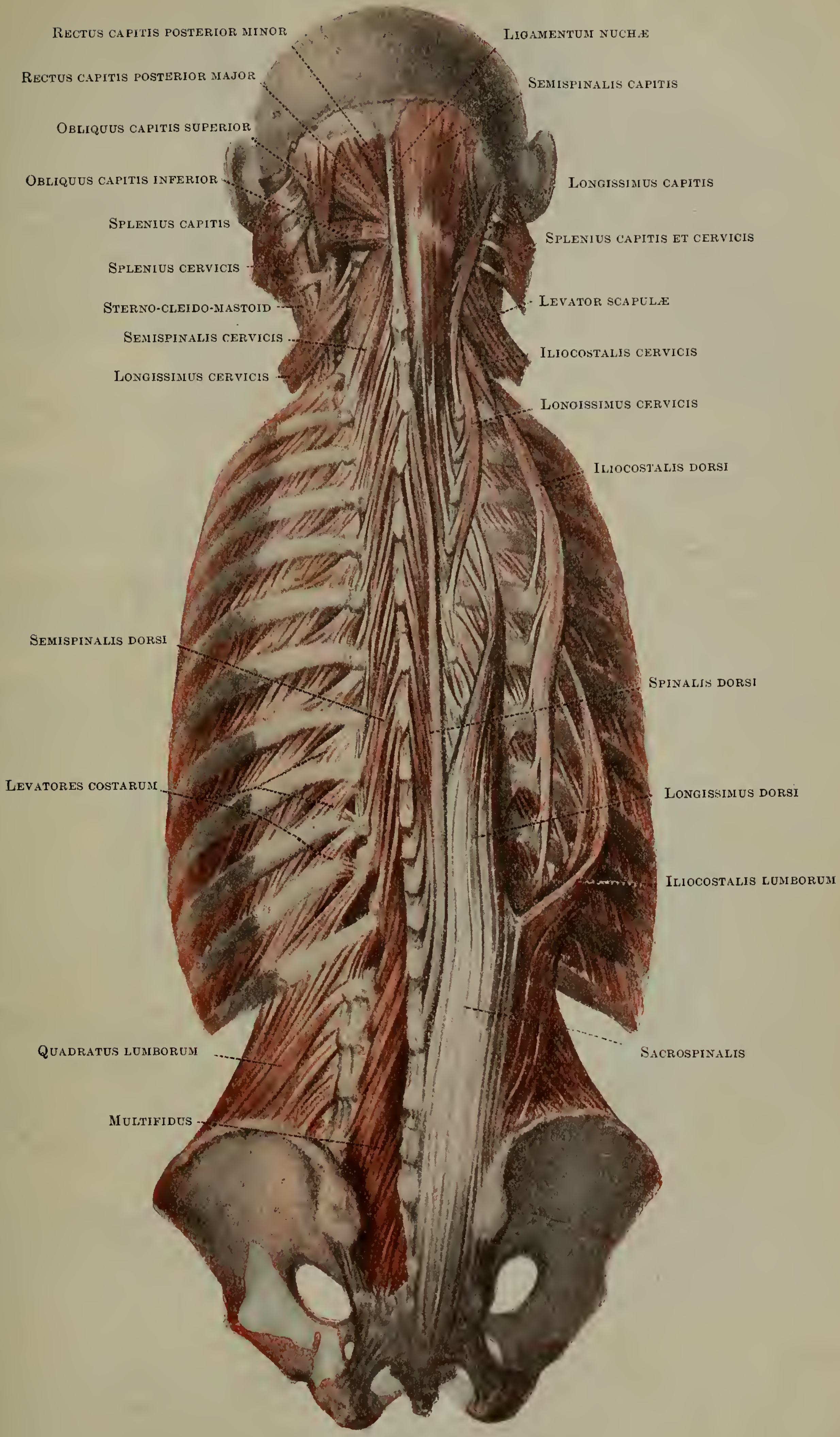

Fig. 367.—The Deep Muscles of the Back.

M. Longissimus.—The **longissimus** is the largest element in the sacrospinalis muscle. The longissimus dorsi forms the middle column of the muscle. It is continued up into the neck as the longissimus cervicis and longissimus capitis. Mostly tendinous, on the surface, at its origin, it becomes fleshy in the upper part of the loin. It is thickest in the loin, and becomes thinner as it passes upwards in the back between the column formed by the iliocostalis and its upward continuations laterally, and the spinalis dorsi medially.

It is **inserted** by two series of slips, medial and lateral, laterally into nearly all the ribs, and medially into the transverse processes of the thoracic and the accessory processes of the upper lumbar vertebræ. It is prolonged upwards into the neck by its association with the common origin of the longissimus cervicis and the longissimus capitis.

The **longissimus cervicis (transversalis cervicis)** has an **origin** from the transverse processes of the upper six thoracic vertebræ, medial to the insertions of the longissimus dorsi.

Extending upwards into the neck, it is **inserted** into the posterior tubercles of the transverse processes of the second, third, fourth, fifth, and sixth cervical vertebræ. It is concealed in the neck by the iliocostalis cervicis and splenius cervicis muscles.

The **longissimus capitis (trachelo-mastoid) arises**, partly by an origin common to it and the previous muscle, from the transverse processes of the upper six thoracic vertebræ, and partly by an additional origin from the articular processes of the lower four cervical vertebræ.

Separating from the longissimus cervicis, the muscle ascends through the neck as a narrow band which is **inserted** into the mastoid portion of the temporal bone, deep to the splenius capitis muscle. In the neck the muscle is placed between the splenius capitis and semispinalis capitis.

M. Spinalis Dorsi.—The **spinalis dorsi** forms the medial column of the sacrospinalis. It lies in the thoracic region, and **arises** by tendinous fibres from the lower two thoracic and upper two lumbar spinous processes, and also directly from the tendon of the longissimus dorsi.

It is a narrow muscle which lies close to the thoracic spinous processes medial to the longissimus dorsi, and is **inserted** into the upper (four to eight) thoracic spines. It is not prolonged into the neck.

The **semispinalis capitis** (O.T. **complexus**) closely resembles in position and attachments the longissimus capitis.

It takes **origin** from the transverse processes of the upper six thoracic and the articular processes of the lower four cervical vertebræ, medial to the longissimus cervicis and longissimus capitis. It has an additional origin also from the spinous process of the last cervical vertebra.

It forms a broad muscular sheet which extends upwards in the neck, to be **inserted** into the medial impression between the superior and inferior nuchal lines of the occipital bone (Fig. 370, p. 445.) The medial portion of the muscle is separate, and forms the **biventer cervicis**, consisting of two fleshy bellies with an intervening tendon, placed vertically in contact with the ligamentum nuchæ. The muscle is covered mainly by the splenius and longissimus capitis muscles. It conceals the semispinalis cervicis and the medial part of the suboccipital triangle.

Nerve-Supply.—Posterior rami of spinal nerves.

Actions.—The several parts of the sacrospinalis muscle have a complex action, on the vertebral column, head, ribs, and pelvis. The muscle serves as an extensor of the vertebral column, and assists in lateral movement and rotation. The longissimus capitis and semispinalis capitis assist in extension, lateral movement and rotation of the head. The whole muscle helps in extension and lateral movement of the pelvis in the act of walking.

Third Group.

This group comprises the semispinales (dorsi and cervicis) and multifidus. They occupy the vertebral furrow, under cover of the sacrospinalis and semispinalis capitis muscles. They are only incompletely separate from one another. The semispinales, dorsi and cervicis, form a superficial stratum, the multifidus being

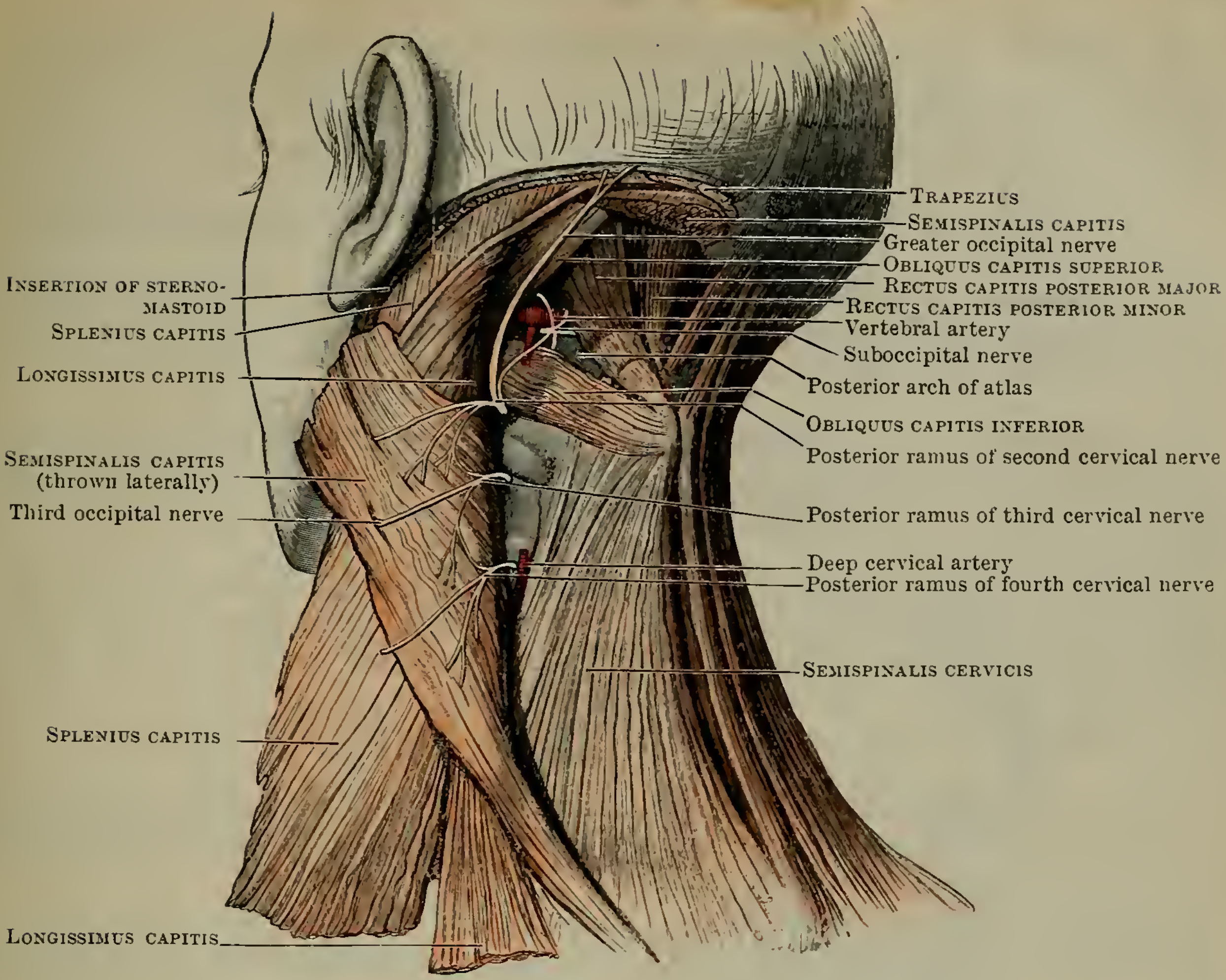
Trapezius
Semispinalis capitis
Greater occipital nerve
Obliquus capitis superior
Rectus capitis posterior major
Rectus capitis posterior minor
Vertebral artery
Suboccipital nerve
Posterior arch of atlas
Obliquus capitis inferior
Posterior ramus of second cervical nerve
Posterior ramus of third cervical nerve
Deep cervical artery
Posterior ramus of fourth cervical nerve
Semispinalis cervicis
Insertion of sterno-mastoid
Splenius capitis
Longissimus capitis
Semispinalis capitis (thrown laterally)
Third occipital nerve
Splenius capitis
Longissimus capitis

Fig. 368.—The Suboccipital Triangle of the Left Side.

more deeply placed. The more superficial muscles have the longer fibres; the fibres of the multifidus pass over fewer vertebræ. Both muscles extend obliquely upwards from transverse to spinous processes.

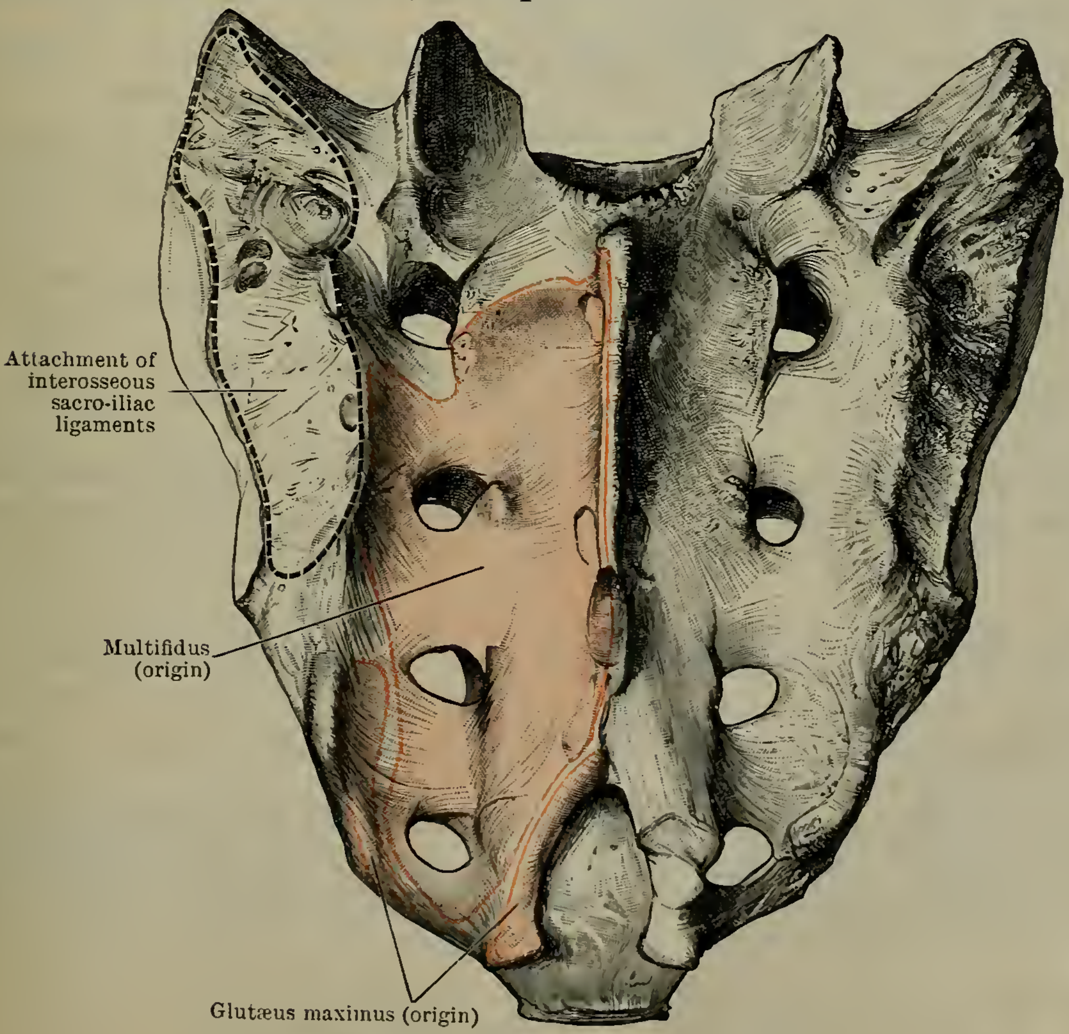

Fig. 369.—Muscle-Attachments to the Sacrum (Dorsal Aspect).

M. Semispinalis.—The **semispinalis muscle** extends from the loin to the second cervical vertebra. Its fibres are artificially separated into an inferior part, the **semispinalis dorsi**, and a superior part, the **semispinalis cervicis.**

The **semispinalis dorsi arises** from the transverse processes of the lower six thoracic vertebræ.

It is **inserted** into the spinous processes of the last two cervical and first four thoracic vertebræ.

The **semispinalis cervicis arises** from the transverse processes of the upper six thoracic, and the articular processes of the lower four cervical vertebræ.

It is **inserted** into the spines of the cervical vertebræ from the second to the fifth.

M. Multifidus.—The **multifidus** (O.T. **multifidus spinæ**) differs from the previous muscle in extending from the sacrum to the second cervical vertebra, and in the shortness of its fasciculi, which pass over fewer vertebræ to reach their insertion.

It **arises** from the sacrum, from the posterior sacro-iliac ligament (Fig. 369, p. 443), from the mamillary processes of the lumbar vertebræ, from the transverse processes of the thoracic vertebræ, and from the articular processes of the lower four cervical vertebræ.

It is **inserted** into the spines of the vertebræ up to and including the second cervical.

Lying in contact with the vertebral laminæ and, in the thoracic region, with the rotatores, the muscle is covered in the neck and back by the semispinalis, and in the loin by the sacrospinalis muscle.

Nerve-Supply.—Posterior rami of the spinal nerves.
Actions.—These muscles are concerned in extension, lateral movement and rotation of the spine.

Fourth Group.

This group includes several sets of small muscles, which are vertebro-cranial or intervertebral in their attachments.

The muscles bounding the **suboccipital triangle** are four in number—obliqui capitis, inferior and superior, and recti capitis posteriores, major and minor.

These muscles are concealed by the semispinalis capitis, longissimus capitis, and splenius capitis; they enclose a triangular space (the suboccipital triangle) in which the vertebral artery, the posterior ramus of the suboccipital nerve, and the posterior arch of the atlas are contained.

The **obliquus capitis inferior arises** from the spine of the epistropheus, and is **inserted** into the transverse process of the atlas.

Nerve-Supply.—Posterior ramus of the first cervical (suboccipital) nerve.
Actions.—Extension, lateral flexion and rotation of the atlas (and therefore the head) on the epistropheus.

M. Obliquus Capitis Superior.—The **obliquus capitis superior arises** from the transverse process of the atlas, and is **inserted** into the occipital bone deep and lateral to the semispinalis capitis and above the inferior nuchal line (Fig. 370, p. 445).

The upper border of the muscle is closely related to the posterior belly of the digastric at its origin, and the occipital artery runs backwards between them.

Nerve-Supply.—Posterior ramus of the first cervical (suboccipital) nerve.
Actions.—Elevation, lateral movement and rotation of the head on the atlas. The last-named movement is usually very limited.

M. Rectus Capitis Posterior Major.—The **rectus capitis posterior major arises** from the spine of the epistropheus, and is **inserted** into the occipital bone deep to the obliquus capitis superior and semispinalis capitis and below the inferior nuchal line (Fig. 370).

Nerve-Supply.—Posterior ramus of the first cervical (suboccipital) nerve.
Actions.—Elevation, lateral movement and rotation of the head.

M. Rectus Capitis Posterior Minor.—The **rectus capitis posterior minor** **arises** deep to the preceding muscle from the posterior tubercle of the atlas, and is **inserted** into the occipital bone below the inferior nuchal line, medial to and beneath the rectus capitis posterior major (Fig. 370).

Nerve-Supply.—Posterior ramus of the first cervical (suboccipital) nerve.
Actions.—Elevation and lateral movement of the head.

Mm. Rotatores.—The **rotatores** are eleven pairs of small muscles occupying the vertebral groove in the thoracic region, deep to the semispinalis dorsi, of which they form the deepest fibres. Each consists of a small slip **arising** from the transverse process and **inserted** into the lamina of the vertebra directly above.

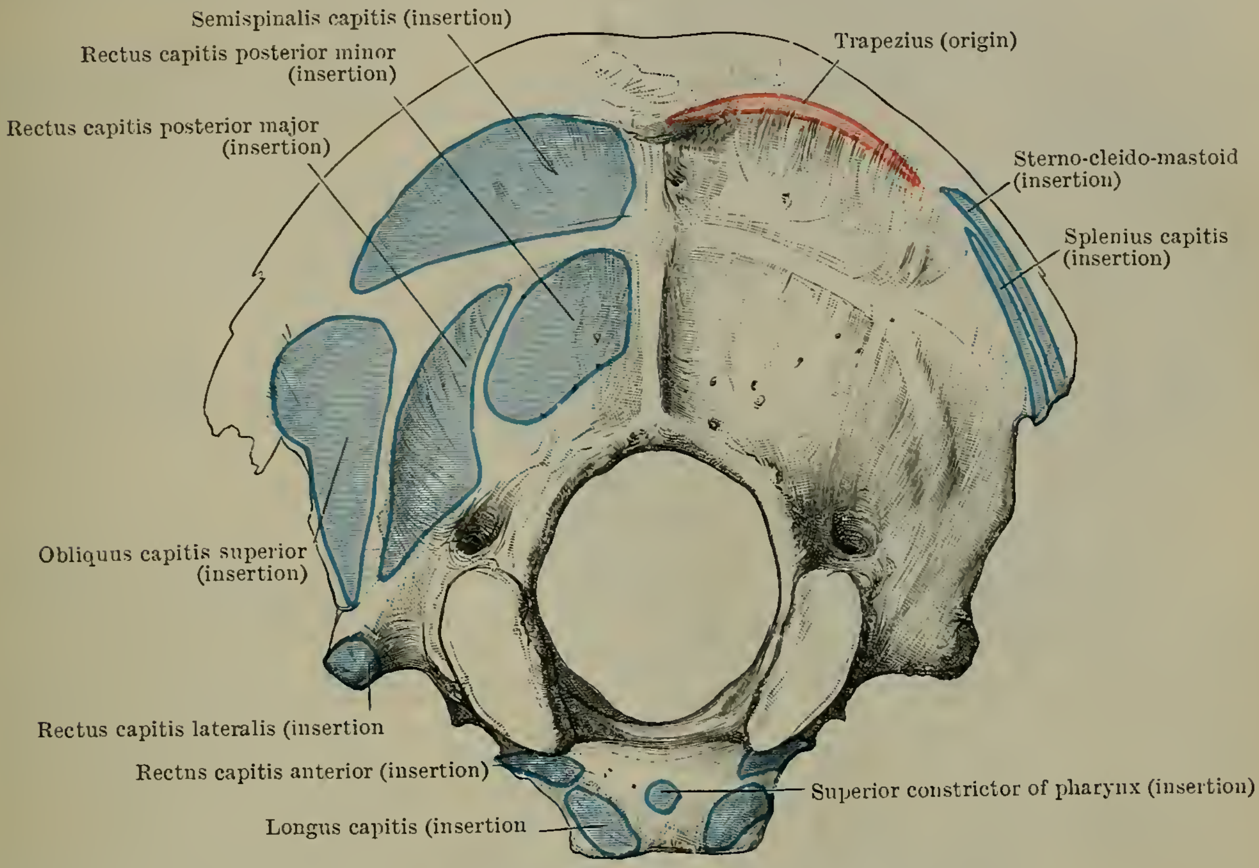
Semispinalis capitis (insertion)
Rectus capitis posterior minor (insertion)
Rectus capitis posterior major (insertion)
Trapezius (origin)
Sterno-cleido-mastoid (insertion)
Splenius capitis (insertion)
Obliquus capitis superior (insertion)
Rectus capitis lateralis (insertion
Rectus capitis anterior (insertion)
Longus capitis (insertion
Superior constrictor of pharynx (insertion)

FIG. 370.—MUSCLE-ATTACHMENTS TO THE OCCIPITAL BONE.

Nerve-Supply.—Posterior rami of the thoracic nerves.
Actions.—Extension and rotation of the vertebral column.

Mm. Interspinales.—The **interspinales** are bands of muscular fibres connecting together the spinous processes of the vertebræ from the epistropheus downwards. Well developed in the cervical and lumbar regions, where they lie one on each side of the corresponding interspinous ligament, they are poorly developed and may be absent in the thoracic region.

Nerve-Supply.—Posterior rami of the spinal nerves.
Action.—Extension of the vertebral column.

Mm. Intertransversarii.—The **intertransversarii** are slender slips extending between the transverse processes.

In the cervical region, with certain exceptions, an anterior intertransverse muscle extends from costal element to costal element, in front of the emerging anterior ramus of the corresponding spinal nerve, and a posterior intertransverse muscle extends from transverse element to transverse element, behind the nerve. Above the atlas, the rectus capitis lateralis is in series with the posterior intertransverse muscles, but there is no representative of the anterior group. Between the atlas and the epistropheus, the posterior muscle is well developed and is situated, like the rectus capitis lateralis, lateral to the emerging nerve, but the anterior muscle in this space is frequently absent.

In the thoracic region the intertransverse muscles are absent, except in the lower three or four intervals, where their arrangement corresponds to that found in the lumbar region.

In the lumbar region lateral and medial intertransverse muscles are present. The former are in series with the posterior muscles of the cervical region and pass between the extremities of the transverse processes, while the latter connect the mamillary tubercles to the accessory tubercles of the vertebral above.

Nerve-Supply.—Anterior rami of the spinal nerves.

Actions.—Lateral movement and rotation of the vertebral column.

Mm. Rectus Capitis Lateralis.—The **rectus capitis lateralis**, extending from the transverse process of the atlas to the jugular process of the occipital bone (Fig. 370, p. 445), is homologous with the posterior of the two intertransverse muscles.

Nerve-Supply.—Anterior ramus of the first cervical (suboccipital) nerve.

Action.—Lateral movement of the head.

It should be observed that the muscles of all four groups in the back assist in extension of the vertebral column, and such as are inserted into the skull combine to raise the head. Lateral flexion of the head and of the vertebral column to one side is produced by the muscles of the same side acting alone.

Rotation of the head or of the vertebral column (the latter movement is almost entirely restricted to the thoracic region) is produced by those muscles which run obliquely, inclining either laterally or medially as they pass from origin to insertion. When the insertion is placed lateral to the origin, rotation occurs to the same side; when the insertion is placed medial to the origin, rotation occurs to the opposite side.

THE FASCIÆ AND MUSCLES OF THE HEAD AND NECK.

FASCIÆ.

The **superficial fascia** of the head and neck possesses certain features of special interest. Over the scalp it is closely adherent to the skin and subjacent galea aponeurotica and contains the superficial vessels and nerves. Beneath the skin of the eyelids it is loose and thin and contains no fat. Over the face and at the side of the neck it is separated from the deep fascia by the facial muscles and the platysma. Between the buccinator and the masseter it is continuous with a pad of fat (*corpus adiposum buccæ*) occupying the interval between those muscles.

The **deep fascia** of the head and neck presents many remarkable characters. *Over the scalp* it is represented by the **galea aponeurotica** (O.T. **epicranial aponeurosis**), the tendon of the epicranius muscle. This is a tough membrane, tightly stretched over the calvaria, from which it is separated by loose areolar tissue. It is attached posteriorly, partly through the agency of the occipitalis muscle, to the superior nuchal line of the occipital bone; anteriorly it joins the frontalis muscle and the orbicularis oculi, and has no bony attachment; laterally it extends downwards for a short distance over the temporal fascia, with which it subsequently blends. The **temporal fascia**, a stout layer of fascia attached to the temporal line and zygomatic arch, covers and gives origin to the temporal muscle. This fascia separates into two layers above the zygomatic arch, to enclose a quantity of fat along with branches of the temporal and zygomatico-orbital arteries. *On the face* deep fascia is practically non-existent anteriorly in relation to the facial muscles. Posteriorly it forms the thin **parotideo-masseteric fascia**, and is much thicker in relation to the parotid gland, for which it forms a capsule.

In the neck the deep fascia invests the muscles, and forms fascial coverings for the pharynx, trachea, œsophagus, glands, and large vessels. A superficial, or **investing**, layer encloses the sterno-mastoid muscle, and can be traced backwards over the posterior triangle to the trapezius, which it surrounds; it can be traced forwards over the anterior triangle to the median plane of the neck, where it forms a continuous membrane.

In the upper part of the neck, this layer is bound down to the body and greater cornu of the hyoid bone and blends with the thin fascial sheath of the submaxillary gland. At a higher level it becomes attached to the lower border of the mandible as far back as the angle, behind which it blends with the fascial sheath of the parotid gland. Through this intermediary the investing layer gains attachment to the zygoma, the posterior border of the petro-tympanic fissure, the styloid process, and the lower border of the tympanic plate. Posterior to the parotid gland the line of attachment of this layer follows the line of attachment to the skull of the sterno-cleido-mastoid and trapezius muscles, so reaching the external occipital protuberance. A specially thickened portion of the parotid sheath extends between the styloid process and the posterior border of the angle of the mandible, separating the lower part of the antero-medial surface of the parotid gland from the posterior part of the submaxillary gland. This is termed the **stylo-mandibular ligament.**

Below the cricoid cartilage, the investing layer separates into anterior and posterior lamellæ, which are continuous on each side with the fascial investments of the sterno-cleido-mastoid muscles. At the jugular notch, the anterior lamella is attached to the anterior surface of the manubrium sterni, but the posterior lamella, which covers the infra-hyoid muscles, is attached to the interclavicular ligament. The **suprasternal space**, which is enclosed between these two lamellæ, contains the lower ends of the anterior jugular veins and the transverse anastomosis between them.

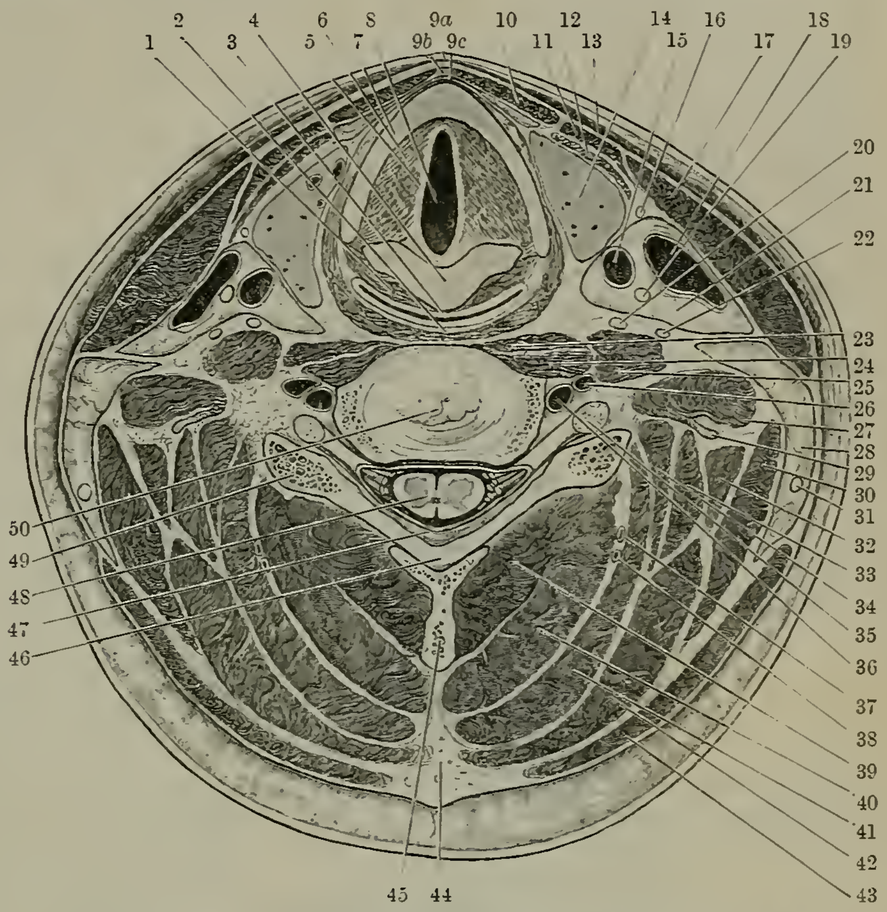

FIG. 371.—TRANSVERSE SECTION IN THE CERVICAL REGION (between the fourth and fifth cervical vertebræ).

1. Crico-arytænoideus posterior muscle.
2. Inferior constrictor muscle.
3. Pharynx.
4. Cricoid cartilage.
5. Vocal fold.
6. Vocalis and Thyreoarytænoideus muscles.
7. Thyreoid cartilage.
8. Rima Glottidis.
9. Layers of deep cervical fascia.
10. Sterno-hyoid muscle.
11. Omo-hyoid muscle.
12. Sterno-thyreoid muscle.
13. Cervical fascia.
14. Thyreoid gland.
15. Common carotid artery.
16. Descendens hypoglossi nerve.
17. Sterno-mastoid muscle.
18. Internal jugular vein.
19. Vagus nerve.
20. Sympathetic trunk.
21. Carotid sheath.
22. Phrenic nerve.
23. Longus colli muscle.
24. Longus capitis.
25. Scalenus anterior.
26. Vertebral vein.
27. Scalenus medius.
28. Posterior triangle.
29. Scalenus posterior.
30. Levator scapulæ.
31. Accessory nerve.
32. Splenius cervicis.
33. Longissimus cervicis.
34. Longissimus capitis.
35. Fifth cervical nerve.
36. Vertebral artery.
37. Profunda cervicis vein.
38. Profunda cervicis artery.
39. Multifidus.
40. Semispinalis cervicis.
41. Semispinalis capitis.
42. Splenius capitis.
43. Trapezius.
44. Ligamentum nuchæ.
45. Spine of fourth cervical vertebra.
46. Lamina of fifth cervical vertebra.
47. Dura mater.
48. Spinal medulla.
49. Transverse process.
50. Fibro-cartilage between fourth and fifth cervical vertebræ.

The **prævertebral fascia** covers the prævertebral muscles, extending upwards on the longus capitis to the basilar part of the occipital bone and downwards on the longus colli into the thorax, where it blends with the anterior longitudinal ligament. From the lateral borders of the longus capitis and the scalenus anterior it passes on to the levator scapulæ, the splenius, and the scalenus medius muscles, covering the loops of the cervical plexus and constituting a fascial floor for the posterior triangle of the neck. The subclavian artery and the trunks of the brachial plexus, as they emerge from behind the scalenus anterior, carry a strong prolongation of this fascia downwards behind the clavicle into the axilla, where it forms the axillary sheath.

In the median plane, above, the prævertebral fascia is connected to the fascial covering of the constrictor muscles by some loose areolar tissue, in which are embedded the retro-pharyngeal lymph glands.

As the phrenic nerve descends on the anterior aspect of the scalenus anterior, it is situated between the muscle and the prævertebral fascia which covers it. The dorsal scapular and the long thoracic nerves are also retro-fascial, as they lie in the floor of the posterior triangle of the neck.

The **carotid sheath** is formed by a condensation of connective tissue around and between the common carotid artery, the internal jugular vein, and the vagus nerve, and is usually regarded as a derivative of the deep fascia of the neck. Where it surrounds the artery, the sheath is very thick and the ansa hypoglossi and its constituent nerves are embedded in its anterior aspect, but over the anterior, lateral, and posterior aspects of the vein it is reduced to a very thin layer. Antero-medially, the carotid sheath blends with the sheath of the thyreoid gland (pretracheal fascia) and antero-laterally it is intimately connected to the fascia on the deep surface of the sterno-cleido-mastoid muscle. Posteriorly, it is connected to the prævertebral fascia by some loose areolar tissue in which the sympathetic trunk is embedded.

The **pretracheal fascia** is a very ill-defined layer which constitutes a sheath for the thyreoid gland. Placed deep to the sterno-thyreoid muscle, it is attached to the oblique line on the lamina of the thyreoid cartilage, where it blends with the fascial covering of the inferior constrictor muscle. It is also bound down to the cricoid cartilage, anteriorly, and, on the postero-lateral aspect of the lateral lobe of the thyreoid gland, it blends with the carotid sheath. This layer is carried downwards from the isthmus of the thyreoid gland in front of the trachea and blends with the fascial sheaths of the great vessels in the thorax.

THE MUSCLES OF THE HEAD.

The muscles of the head are divisible into three separate groups: the superficial muscles, muscles of the orbit, and muscles of mastication.

Superficial Muscles.

The superficial muscles comprise a large group, including the muscles of the scalp and face, and the platysma in the neck.

The **platysma** is a thin quadrilateral sheet extending from chest to face over the side of the neck, between the superficial and deep fasciæ. It **arises** from the deep fascia of the pectoral region.

It is directed upwards and forwards, and is partly **inserted** (by its intermediate fibres) into the inferior border of the mandible, becoming connected with the quadratus labii inferioris and triangularis muscles (Fig. 372, p. 449). The more anterior fibres pass across the median plane of the neck and decussate for a variable distance below the chin with those of the opposite side. The posterior fibres sweep over the angle of the jaw and become continuous with the risorius muscle. The platysma is the rudiment of the cervical portion of the **panniculus carnosus** of lower animals, in which it has a much more intimate connexion with the muscles of the face than is usually the case in man.

Nerve-Supply.—Cervical branch of the facial nerve.

Actions.—It depresses the mandible and laterally flexes the head. It also throws into folds the skin of the side of the neck.

The Muscles of the Scalp.

The muscles of the scalp comprise the epicranius muscle and the muscles of the auricle.

M. Epicranius.—The **epicranius** (O.T. **occipitofrontalis**) is a muscle with four bellies, two posterior and two anterior, and an intervening tendon (the galea aponeurotica) which stretches uninterruptedly across the median plane of the cranium. Each **posterior belly (occipitalis) arises** as a broad flat band from the lateral two-thirds of the superior nuchal line of the occipital bone. Each **anterior belly (frontalis)** has no bony attachments; **arising** from the galea aponeurotica about the level of the coronal suture, it passes downwards to the supra-orbital arch, where it blends with the orbicularis oculi and corrugator supercilii muscles. It extends across the full width of the forehead, and blends in the median plane with the muscle of the opposite side.

The **galea aponeurotica** (O.T. **epicranial aponeurosis**), extending between the two anterior and the two posterior fleshy bellies, has been described on p. 446.

Nerve-Supply.—The occipitalis is supplied by the posterior auricular branch of the facial nerve. The frontalis is supplied by the temporal branches of the same nerve.

Actions.—When the frontalis muscle contracts, acting from behind, the eyebrows are elevated and the skin of the forehead is thrown into horizontal folds. Acting from in front, the frontales draw the scalp forwards, and it can then be drawn backwards by the occipitales. Relatively few individuals have complete control over the movements of the scalp.

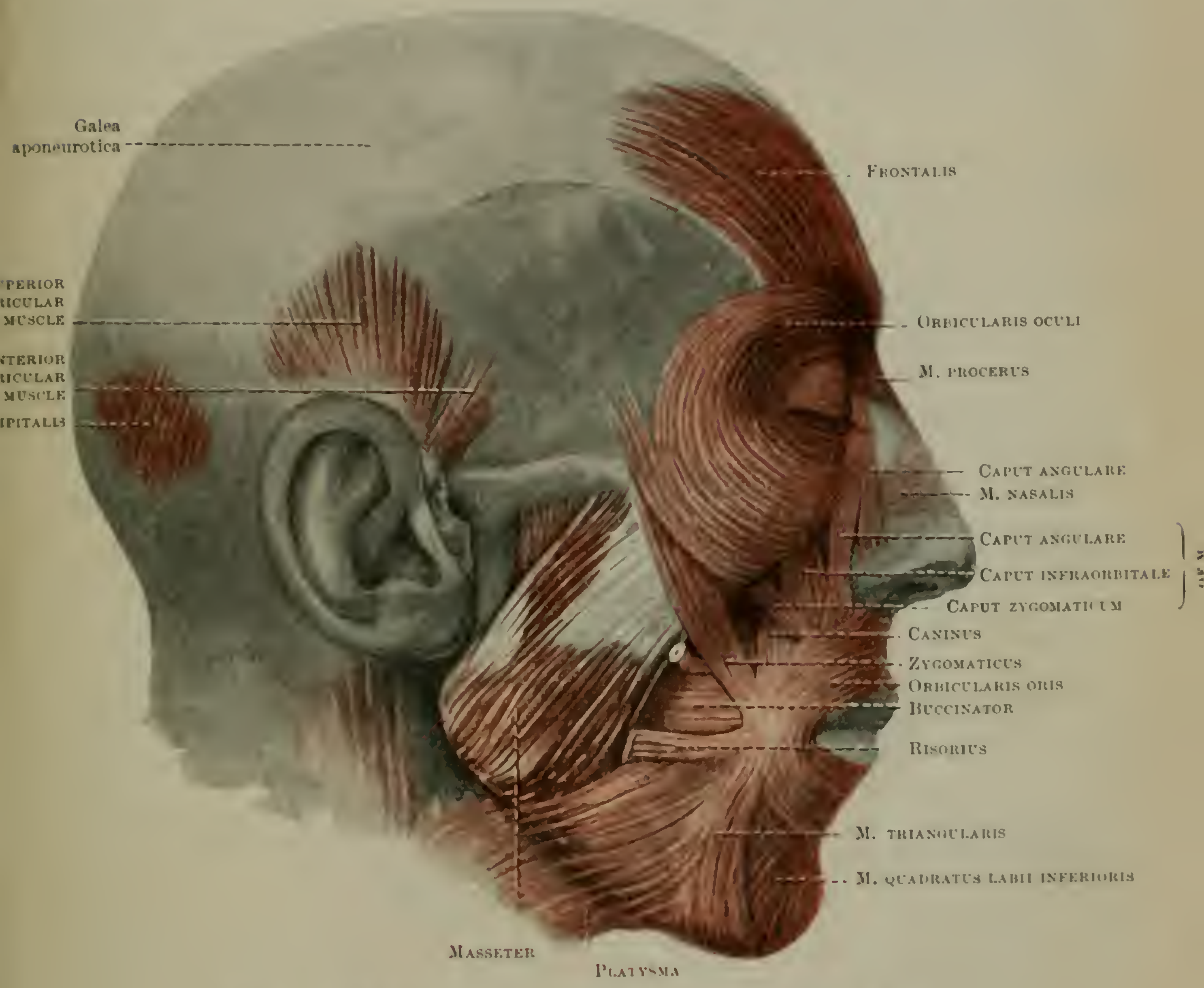

FIG. 372.—THE MUSCLES OF THE FACE AND SCALP (Muscles of Expression).

The **extrinsic muscles of the ear** are three in number: posterior, superior, and anterior. They are rudimentary and usually functionless.

The **m. auricularis posterior** is a narrow fleshy slip which **arises** from the surface of the mastoid process and is **inserted** into the cranial surface of the auricle. It bridges across the groove between the mastoid process and the auricle, and conceals the posterior auricular vessels and nerve.

The **m. auricularis superior** is a small fan-shaped muscle which **arises** from the galea aponeurotica, and descends to be **inserted** into the convex medial surface of the fossa of the antihelix.

The **m. auricularis anterior** is a similar small muscle, placed in front of the auricularis superior, and stretching obliquely between the galea aponeurotica and the anterior part of the medial surface of the helix.

The Muscles of the Face.

The facial muscles are divided into three groups, associated with the apertures of the eyes, nose, and mouth.

1. The **muscles of the eyelids** include four muscles: the levator palpebræ superioris (described with the orbital muscles (p. 453)), orbicularis oculi, lacrimal part of the orbicularis, and corrugator supercilii.

M. Orbicularis Oculi.—The **orbicularis oculi** is a transversely oval sphincter muscle surrounding and occupying the eyelids. It is divisible into an *orbital portion* (*pars orbitalis*), composed of coarse fibres, spreading on to the forehead, temple, and cheek, and a *palpebral portion* (*pars palpebralis*), composed of finer fibres, situated beneath the skin of the eyelids. At the medial commissure of the eye the muscle (by its palpebral fibres) gains an **attachment** to the medial palpebral ligament and the borders of the naso-lacrimal groove. Its fibres enclose the

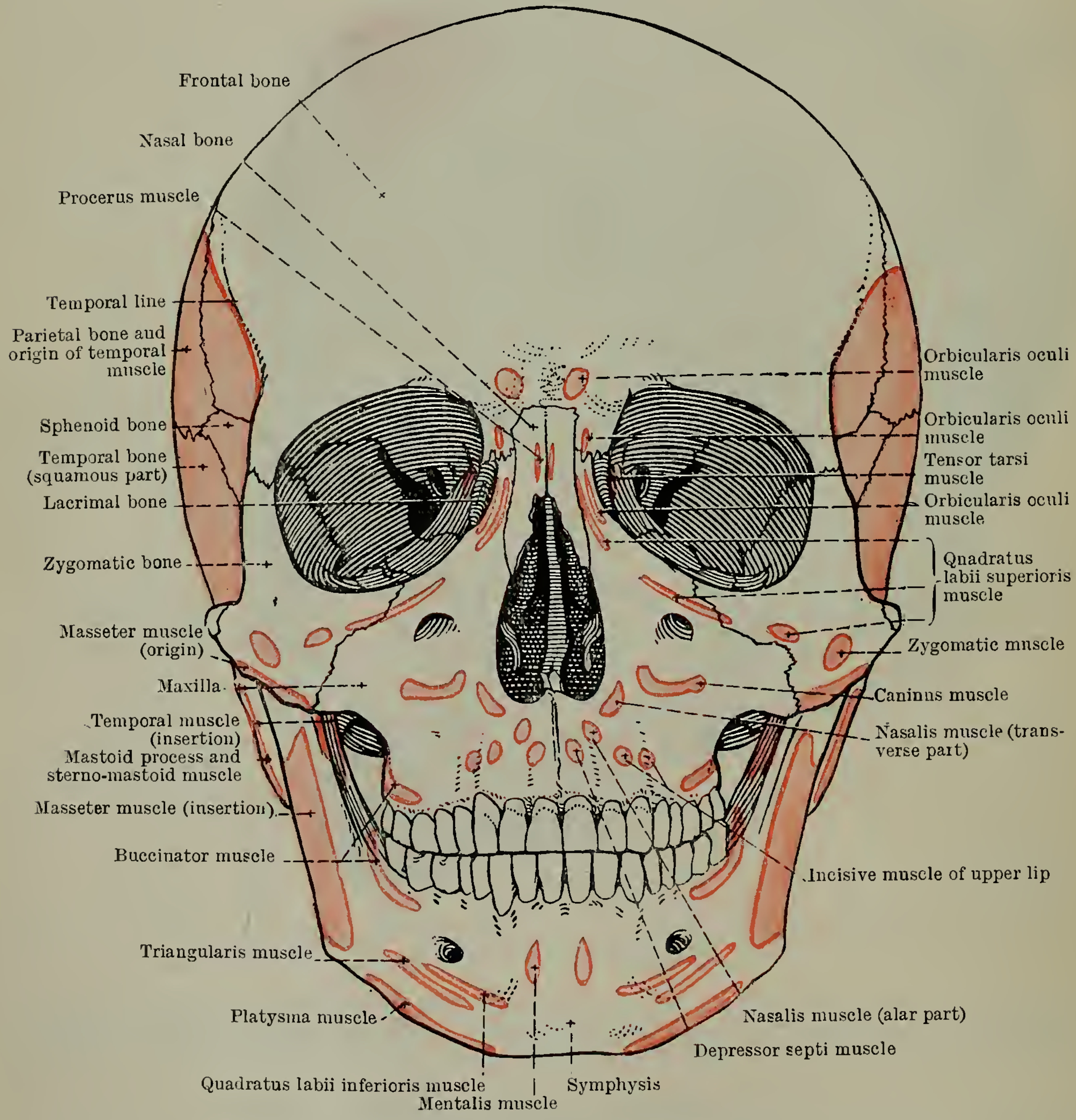

Fig. 373.—Anterior View of the Skull (Norma frontalis), showing the bones and the muscular attachments.

lacrimal sac and the canaliculi. The posterior fibres, extending between the posterior edge of the naso-lacrimal groove and the tarsal ligaments behind the lacrimal sac, constitute the **pars lacrimalis** (O.T. **tensor tarsi muscle**). A collection of very fine fibres extends along the margins of the lids and constitutes a separate **ciliary bundle.**

Laterally the orbicularis oculi has no bony attachment; so that when it contracts and closes the eyelids, both lids at the same time tend to be drawn towards the medial commissure of the eye.

M. Corrugator Supercilii.—The **corrugator supercilii arises** from the medial part of the superciliary arch, and passing laterally, its fibres intermingle with the upper fibres of the orbicularis oculi on its deep surface, but many of them reach the skin of the forehead. The contraction of this muscle throws the skin of the central part of the forehead into vertical folds, as in frowning.

2. The **muscles of the nose** comprise five small muscles proper to the nose, and one common to the nose and upper lip: the m. procerus, nasalis, dilatores naris (anterior and posterior), depressor alæ nasi, and angular head of the quadratus labii superioris. They are all small and feeble muscles.

The **m. procerus** (O.T. **pyramidalis nasi**) **arises** from a membrane stretching over the nose, which gives attachment to the musculus nasalis also; it is **inserted** into the skin over the glabella. This muscle draws down the skin of the central part of the forehead and produces transverse wrinkles at the root of the nose.

The **m. nasalis** (O.T. **compressor naris**) **arises** by a narrow origin from the maxilla, under cover of the quadratus. It passes forwards over the bridge of the nose, and ends in a membranous **insertion** common to it and the preceding muscle.

The **mm. dilatores naris** are feeble muscular slips placed on the lateral surface of the margin of the nostril, one anteriorly, the other posteriorly.

The **m. depressor alæ nasi** is a small muscle **arising** from the upper part of the incisor fossa of the maxilla; it divides into two parts as it passes upwards and medially, and is **inserted** into the ala and the septum of the nose (**depressor septi**).

The **caput angulare** (O.T. **levator labii superioris alæque nasi**) is a portion of the quadrate muscle of the upper lip, and is a narrow band **arising** from the root of the frontal process of the maxilla. It descends alongside the nose, and is **inserted**, partly into the ala of the nose and partly into the orbicularis oris muscle.

3. The **muscles of the mouth** comprise a number of muscles, of which all but one, the orbicularis oris, are bilaterally placed. The muscles are: (1) quadratus labii superioris, which includes the angular head just described, the infra-orbital head, and the zygomatic head; (2) the canine muscle; (3) zygomaticus; (4) risorius; (5) orbicularis oris; (6) triangularis; (7) quadratus labii inferioris; (8) mentalis; and (9) buccinator.

M. Orbicularis Oris.—The **orbicularis oris** is the sphincter muscle surrounding the lips. It is continuous with the other muscles converging to the mouth. It lies between the skin and mucous membrane of the lips, and is limited superiorly by the nose, inferiorly by the junction of the lower lip and chin. The deeper fibres in the upper lip are derived from the buccinator muscle, reinforced by the naso-labial and superior incisive bundles. These two little bands arise, the one from the nasal septum and the other from the incisive fossa of the maxilla, and pass laterally to the angle of the mouth. The more superficial fibres are continued upwards from the triangularis and are inserted into the skin of the central part of the lip. A similar arrangement is found in the orbicularis oris in the lower lip. The deeper fibres are derived from the buccinator, but they are reinforced by an inferior incisive bundle, which runs laterally from the incisive fossa of the mandible. The more superficial fibres are continued downwards from the caninus and are inserted into the skin of the central part of the lip.

M. Quadratus Labii Superioris.—The **quadratus labii superioris** comprises three muscles.

(1) The **caput angulare** has already been described.

(2) The **caput infra orbitale arises** from the maxilla just above the infra-orbital foramen. It passes almost vertically downwards to be inserted into the skin of the upper lip between the attachments of the caput angulare and the

caninus, but some of its fibres blend with the orbicularis oris. It conceals the infra-orbital vessels and nerve.

(3) The **caput zygomaticum arises** from the zygomatic bone, and is often continuous with the most peripheral fibres of the orbicularis oculi. It is directed obliquely downwards and forwards over the caninus, to be **inserted** along with the caput infra-orbitale into the skin of the upper lip.

M. Caninus.—The **caninus arises** from the canine fossa of the maxilla below the infra-orbital foramen and under cover of the caput zygomaticum. It is directed laterally and downwards, to be **inserted** into the orbicularis oris and the skin at the angle of the mouth.

M. Zygomaticus.—The **zygomaticus** is a narrow muscular band which **arises** from the zygomatic portion of the zygomatic arch. It passes to the angle of the mouth, to be **inserted** partly into the skin, partly into the orbicularis oris.

M. Risorius.—The **risorius** is a thin flat muscle which forms in part a continuation of the platysma on the face, in part a separate muscle, with an **origin** from the parotideo-masseteric fascia. It passes transversely forwards, to be **inserted** into the skin at the angle of the mouth.

M. Triangularis.—The **triangularis arises** from the oblique line of the mandible and is continuous with the platysma (Fig. 378, p. 456). It is triangular in form, its fibres converging to the angle of the mouth, where they are **inserted** into the orbicularis oris and the skin. Some of the fibres reach the upper lip through the orbicularis muscle.

M. Quadratus Labii Inferioris.—The **quadratus labii inferioris arises** from the lateral surface of the mandible deep and medial to the preceding muscle (Fig. 373, p. 450). It is quadrilateral in form, and is directed upwards, to be **inserted** into the orbicularis oris and the skin of the lower lip. Its lateral fibres are overlapped by the triangularis. Its medial fibres join with those of the opposite muscle.

M. Mentalis.—The **mentalis** is a small muscle which **arises** from the incisor fossa of the mandible and is **inserted** into the skin of the chin.

M. Buccinator.—The **buccinator muscle** forms the lateral wall of the mouth, and is in series posteriorly with the constrictor muscles of the pharynx. It **arises** (1) from the outer alveolar border of the maxilla in the region of the molar teeth (Fig. 373, p. 450); (2) from the pterygo-mandibular raphe; and (3) from the outer alveolar border of the mandible in the region of the molar teeth. Its fibres are directed forwards to the angle of the mouth, where they blend with the corresponding (upper and lower) portions of the orbicularis oris muscle. The *middle fibres* of the muscle decussate at the angle of the mouth, so as to pass, the lower set to the upper lip, the upper set to the lower lip. The buccinator is covered on its deep surface by the mucous membrane of the mouth. Superficially it is concealed by the muscles above mentioned, which converge to the angle of the mouth; it is separated from the masseter by the *corpus adiposum buccæ*; it is pierced by the duct of the parotid gland, and by branches of the buccinator nerve. A small gap is present in the upper and posterior part of the muscle, between the fibres arising from the tuberosity of the maxilla and those arising from the upper end of the pterygo-mandibular raphe. It is through this gap that the tendon of the tensor veli palatini passes, as it twists round the hamulus to gain the soft palate.

Nerve-Supply.—The facial and scalp muscles are all innervated by the **facial nerve.** The *posterior auricular branch* supplies the posterior auricular muscle and occipitalis; the branches into which it breaks up in the parotid gland supply the frontalis, superior and anterior auricular muscles, the several muscles associated with the apertures of the eye, nose, and mouth (including the buccinator), and the platysma.

Actions.—The almost infinite variety of facial expression is produced partly by the action of these muscles, partly by their inactivity, or by the action of antagonising muscles (antithesis). On the one hand joy, for example, is betrayed by the action of one set of muscles, while grief is accompanied by the contraction of another (opposing) set. Determination or eagerness is accompanied by a fixed expression due to a combination of muscles acting together; despair, on the other hand, is expressed by a relaxation of muscular action. For a philosophical account of the action of the facial muscles, the student should consult Darwin's *Expression of the Emotions in Man and Animals*, and Duchenne's *Mécanisme de la Physiologie humaine.*

The **platysma** retracts and depresses the angle of the mouth, and depresses the mandible. The **epicranius**, by its anterior belly, raises the eyebrows; both bellies acting together, tighten the skin of the scalp; acting along with the orbicularis oculi, it shifts the scalp backwards and forwards. The **corrugator supercilii** draws the eyebrow medially and wrinkles the skin of the forehead vertically. The **procerus** draws downwards the skin between the eyebrows as in frowning. The upper eyelid is raised by the **levator palpebræ superioris**. The closure of the lids is effected by the **orbicularis oculi**, whose fibres also assist in the lowering of the eyebrows, in the protection of the eyeball, and, by pressure on the lacrimal gland, in the secretion of tears. The **tarsal part**, acting along with the orbicularis oculi, keeps the tarsal plate in contact with the globe of the eye. The **muscles of the ear and nose** have quite rudimentary actions. Of the muscles of the mouth, the **orbicularis oris** has a complex action, depending on the degree of contraction of its component parts. It causes compression and closure of the lips in various ways, tightening the lips over the teeth, contracting them as in osculation, or causing pouting or protrusion of one or the other. The **accessory muscles of the lips** draw them upwards (zygomaticus, quadratus labii superioris), laterally (zygomaticus, risorius, platysma, triangularis, buccinator), and downwards (triangularis, quadratus labii inferioris, platysma). The **mentalis** muscle elevates the skin of the chin and protrudes the lower lip. The **buccinator** retracts the angles of the mouth, flattens the cheeks, and brings them in contact with the teeth.

The Fasciæ and Muscles of the Orbit.

The eyeball, with its muscles, vessels, and nerves, is lodged in a mass of soft and yielding fat which entirely fills up the cavity of the orbit. Surrounding the posterior part of the eyeball is the **fascia bulbi** (O.T. **capsule of Tenon**), which constitutes a large lymph space or synovial bursa in relation to the posterior part of the eyeball. Anteriorly the capsule is in contact with the conjunctiva, and intervenes between the latter and the eyeball; posteriorly it is pierced by and prolonged along the optic nerve. It is a smooth membrane connected to the globe of the eye by loose areolar tissue. It is pierced by the tendons of the ocular muscles, along which it sends prolongations continuous with the muscular sheaths.

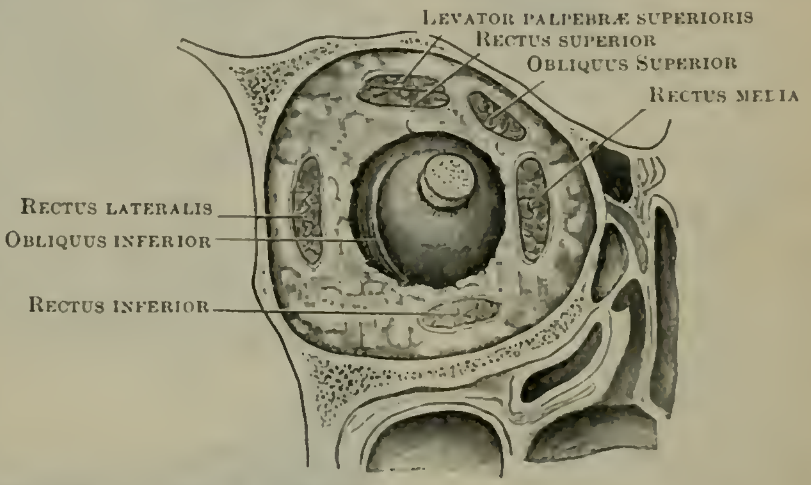

Fig. 374.—Transverse Vertical Section through the Left Orbit behind the Eyeball to show the Arrangement of Muscles.

The **muscles of the orbit** are seven in number: one, the levator palpebræ superioris, belongs to the upper eyelid; the other six are muscles of the eyeball.

M. Levator Palpebræ Superioris.—The **levator palpebræ superioris** lies immediately beneath the orbital periosteum and covers the superior rectus muscle. It has a narrow **origin** above that muscle from the roof of the orbit in front of the optic foramen.

It expands as it passes forwards, to end, in relation to the upper lid, in a membranous expansion which is **inserted** in a fourfold manner; (1) into the orbicularis oculi and skin of the upper lid, (2) mainly into the superior border of the superior tarsus, and (3) by its edges into the upper border of the margin of the orbital opening.

In addition the muscle is connected to the superior fornix conjunctivæ through the medium of its fascial sheath, which becomes considerably thickened in the forepart of the orbit and blends with the sheath of the superior rectus and the conjunctiva.

Nerve-Supply.—The muscle is supplied by the superior division of the oculo-motor nerve.

Actions.—It elevates the upper eyelid and antagonises the action of the palpebral part of the orbicularis oculi muscle.

Mm. Recti.—The **recti muscles** are four in number—**superior, inferior, medial,** and **lateral.** They all **arise** from a membranous ring surrounding the optic foramen, which is separable into two parts—a *superior common tendon,* giving origin to the superior and medial recti and the superior head of the lateral rectus; and an *inferior common tendon,* giving origin to the medial and inferior recti and the inferior head of the lateral rectus. The two origins of the lateral rectus muscle are separated by the passage into the orbit of the oculo-motor, naso-ciliary, and abducent nerves. Forming flattened bands which lie in the fat of the orbit around the optic nerve and eyeball, the four muscles end in tendons which pierce the fascia bulbi, and are **inserted** into the sclera about eight millimetres (three to four lines) behind the margin of the cornea.

The **superior** and **inferior recti** are inserted in the vertical plane slightly medial to the axis of the eyeball; the **lateral** and **medial recti** in the transverse plane of the eyeball; and all are attached in front of the equator of the eyeball.

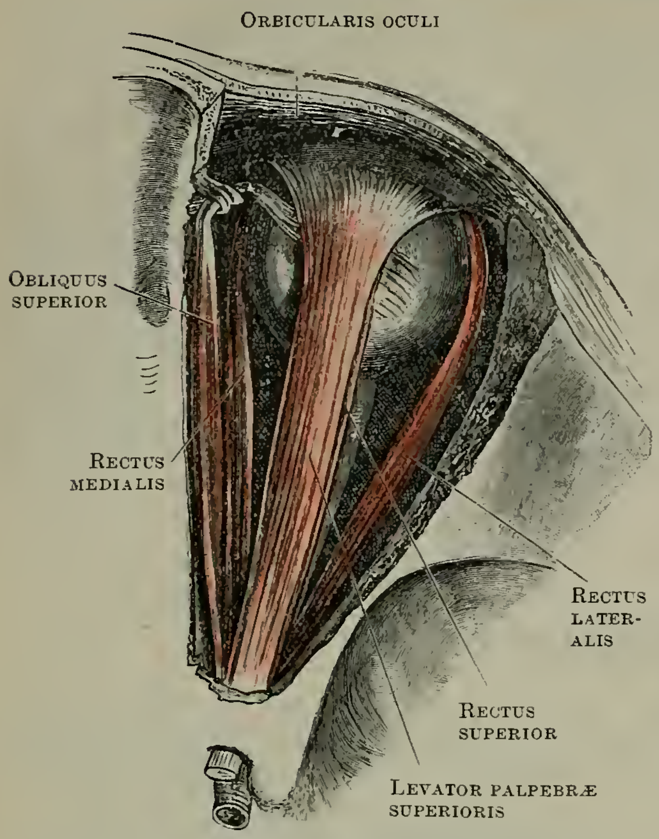

Fig. 375.—Muscles of the Right Orbit (from above).

M. Obliquus Superior.—The **obliquus superior arises** from the margin of the optic foramen between the rectus superior and rectus medialis. It passes forwards, as a narrow muscular band, medial to the rectus superior, and at the anterior margin of the orbit forms a narrow tendon which passes through a special fibrous pulley (trochlea) attached to the roof of the orbit.

Its direction is then altered, and passing laterally, between the tendon of the superior rectus and the eyeball, it is **inserted** into the sclera between the superior and lateral recti, midway between the margin of the cornea and the entrance of the optic nerve.

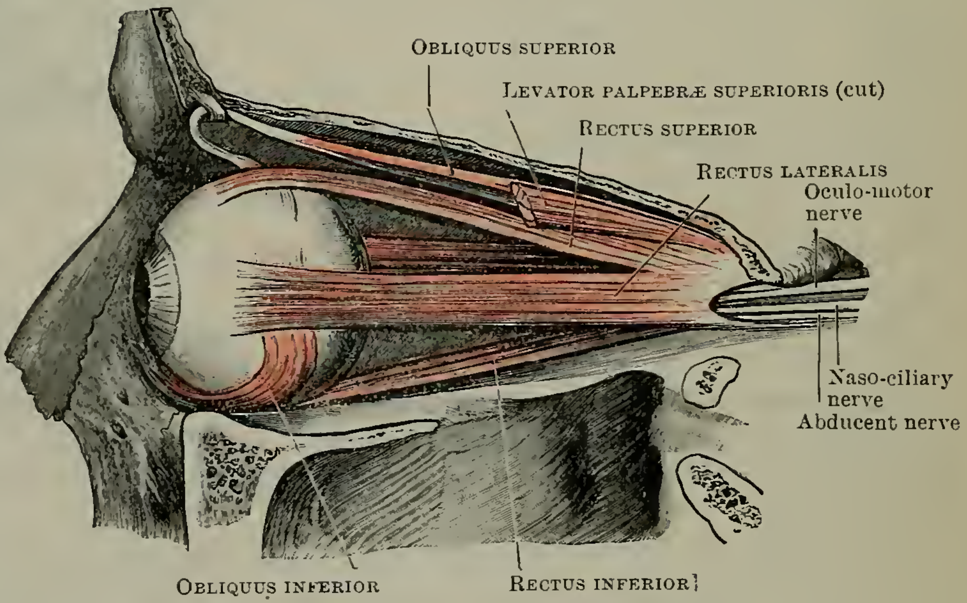

Fig. 376.—Muscles of the Left Orbit (from lateral aspect).

M. Obliquus Inferior.—The **obliquus inferior arises** from the medial side of the floor of the orbit just behind its anterior margin, and lateral to the naso-lacrimal groove.

It forms a slender rounded slip, which curls round the inferior rectus tendon, and passes between the lateral rectus and the eyeball, to be **inserted** into the sclera between the superior and lateral recti, and farther back than the superior oblique muscle.

M. Orbitalis is a rudimentary bundle of non-striated muscular fibres bridging across the inferior orbital fissure and infra-orbital groove. It is supplied by fibres from the sympathetic, and may have a slight influence in the protrusion of the eyeball.

Nerve-Supply.—The muscles of the eyeball are supplied by the third, fourth, and sixth cerebral nerves. The trochlear **(fourth nerve)** supplies the obliquus superior; the abducent **(sixth)** supplies the rectus lateralis; the oculo-motor **(third nerve)** supplies the others—recti, superior, inferior, and medialis, and obliquus inferior.

Actions.—The lateral and medial recti, by virtue of their insertions in front of the coronal equator, rotate the eyeball so as to make the pupil look laterally or medially, respectively. As their insertions extend equally on to the upper and lower quadrants of the sclera, they produce no rotation around the transverse axis of the eyeball.

The superior and inferior recti rotate the eyeball so as to make the pupil look upwards and downwards, respectively, but as the line of pull of each muscle passes to the medial side of the vertical axis of the eyeball, a slight degree of medial rotation accompanies the primary movement.

The superior and inferior oblique muscles, by virtue of their insertion behind the coronal equator of the eyeball and because their pull is exerted from the forepart of the orbit, rotate the eyeball so as to make the pupil look downwards and upwards, respectively. As in the case of the superior and inferior recti, the lines of pull pass to the medial side of the vertical axis of the eyeball, but, as the pull is exerted from in front instead of from behind, the opposite effect, viz.:—lateral rotation, is added to the primary movement.

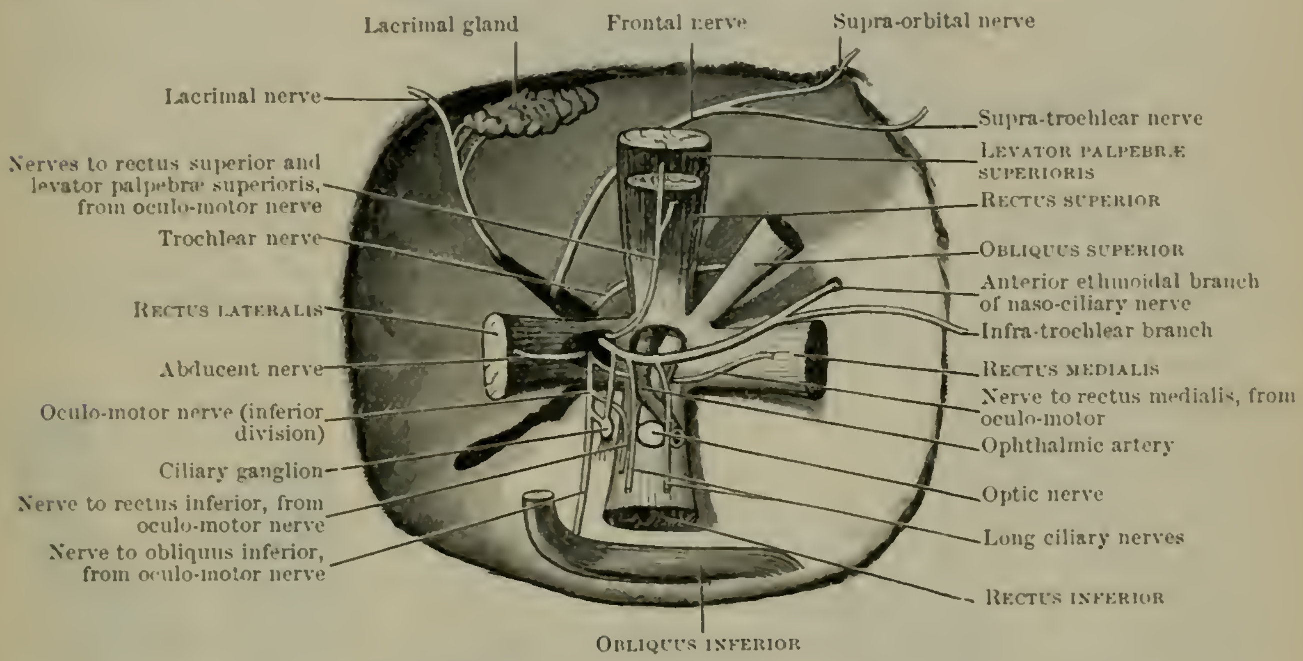
Lacrimal gland
Frontal nerve
Supra-orbital nerve
Lacrimal nerve
Supra-trochlear nerve
Nerves to rectus superior and levator palpebræ superioris, from oculo-motor nerve
LEVATOR PALPEBRÆ SUPERIORIS
RECTUS SUPERIOR
Trochlear nerve
OBLIQUUS SUPERIOR
Anterior ethmoidal branch of naso-ciliary nerve
RECTUS LATERALIS
Infra-trochlear branch
Abducent nerve
RECTUS MEDIALIS
Nerve to rectus medialis, from oculo-motor
Oculo-motor nerve (inferior division)
Ophthalmic artery
Ciliary ganglion
Optic nerve
Nerve to rectus inferior, from oculo-motor nerve
Long ciliary nerves
Nerve to obliquus inferior, from oculo-motor nerve
RECTUS INFERIOR
OBLIQUUS INFERIOR

FIG. 377.—SCHEMATIC REPRESENTATION OF THE NERVES WHICH TRAVERSE THE CAVITY OF THE RIGHT ORBIT.

When the eyeball is rotated so as to make the pupil look directly downwards, the superior oblique and the inferior rectus act together and the lateral rotation of the former is counteracted by the medial rotation of the latter. In a similar way the inferior oblique and the superior rectus act together to produce a pure upward direction of the pupils.

Combinations of rotation around the vertical and transverse axes of the eyeball are brought about by the combined actions of the superior oblique with the inferior and medial, or with the inferior and lateral recti, or by the combined actions of the inferior oblique with the superior and medial, or superior and lateral recti.

Muscles of Mastication.

The muscles of mastication comprise the masseter, temporal, external and internal pterygoids, and buccinator (described above).

M. Masseter.—The **masseter** is the most superficial. Covered by the parotid gland on the side of the face, it has an **origin** which is partly tendinous and partly fleshy. It arises in two parts: (1) superficially from the inferior border of the zygomatic arch in its anterior two-thirds, and (2) more deeply from the deep surface of the zygomatic arch in its whole length. The superficial fibres are directed downwards and backwards towards the angle of the mandible; the deeper fibres are directed vertically downwards.

The muscle is **inserted** by fleshy and tendinous fibres into the lateral surface of the ramus and angle of the mandible and the coronoid process (Fig. 378). The deepest fibres blend with the fibres of the subjacent temporal muscle.

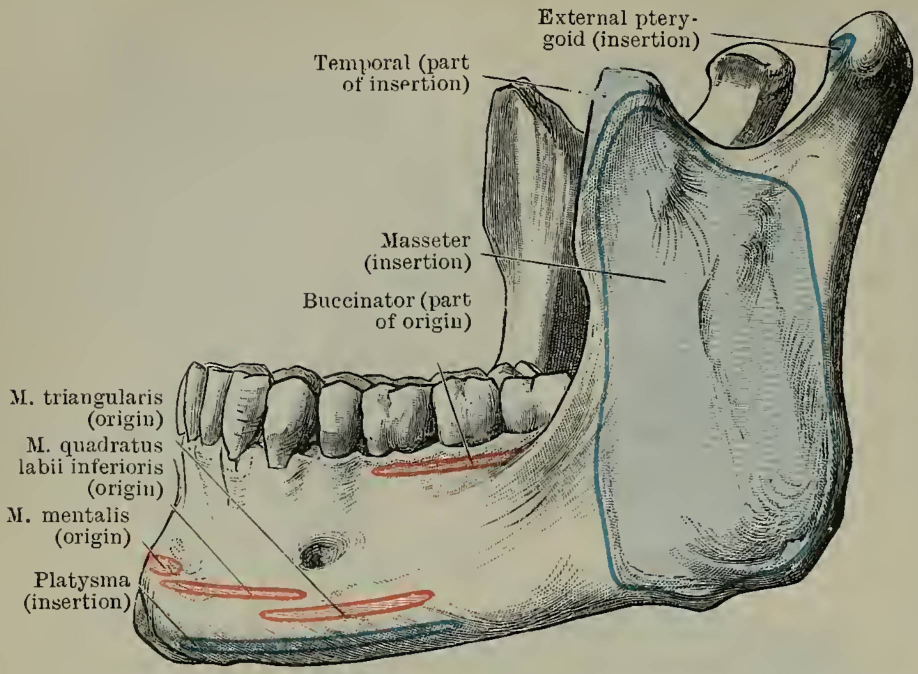
External pterygoid (insertion)
Temporal (part of insertion)
Masseter (insertion)
Buccinator (part of origin)
M. triangularis (origin)
M. quadratus labii inferioris (origin)
M. mentalis (origin)
Platysma (insertion)

Fig. 378.—Muscle-Attachments to the Lateral Aspect of the Mandible.

The muscle is partially concealed on the face by the parotid gland, accessory parotid gland, and parotid duct; by the anterior facial vein; the branches of the facial nerve; and by the zygomatic and platysma muscles. It conceals the ramus of the mandible, and, at its anterior border, is separated from the buccinator muscle by the *corpus adiposum buccæ*.

M. Temporalis.—The **temporal muscle** is a fan-shaped muscle **arising** from the whole area of the temporal fossa, as well as from the temporal fascia which covers it. Its converging fibres pass medial to the zygomatic arch.

The muscle is **inserted** into the deep surface and apex of the coronoid process, and into the anterior border of the ramus of the mandible (Figs. 378 and 379).

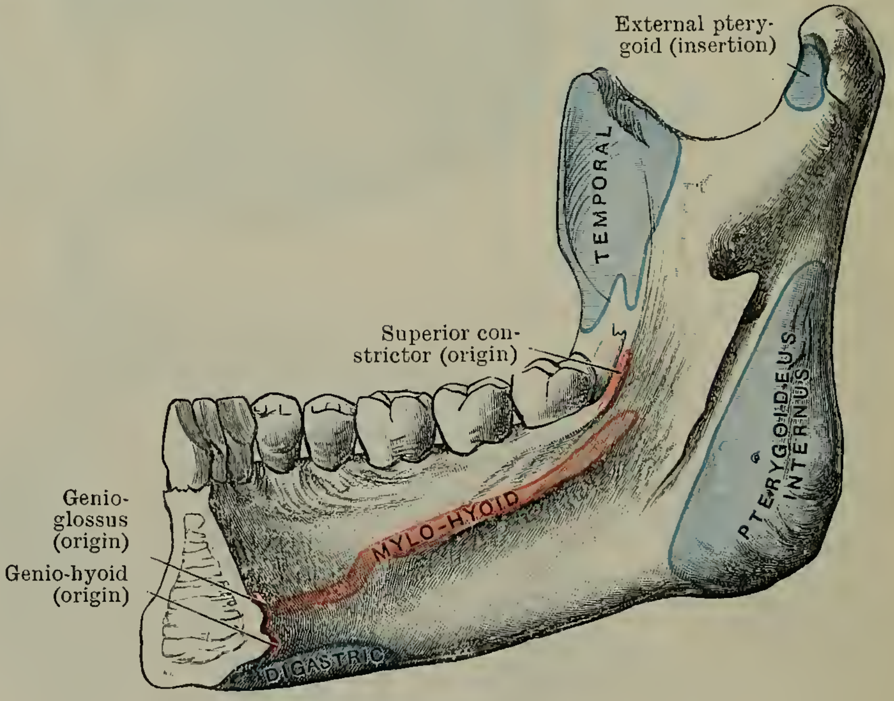

Fig. 379.—Muscle-Attachments on the Medial Side of the Mandible.

The origin of the muscle is concealed by the temporal fascia. As it passes to its insertion the muscle is concealed by the zygomatic arch, the masseter muscle, and the coronoid process of the mandible. It is separated from the external pterygoid in a majority of cases by the internal maxillary artery. The masseteric nerve and vessels appear at its posterior border; the buccinator nerve and vessels at its anterior border.

M. Pterygoideus Externus.—The **external pterygoid muscle** is deeply placed under cover of the temporal muscle, in the infra-temporal fossa. It arises by two heads, superior and inferior. The *superior* head is attached to the infra-temporal surface of the great wing of the sphenoid; the *inferior* head takes origin from the lateral surface of the lateral pterygoid lamina of the pterygoid process.

The muscle is directed laterally and backwards, to be **inserted** into (1) the fovea pterygoidea on the anterior aspect of the neck of the mandible (Figs. 378 and 379), and (2) the articular disc and capsule of the mandibular articulation.

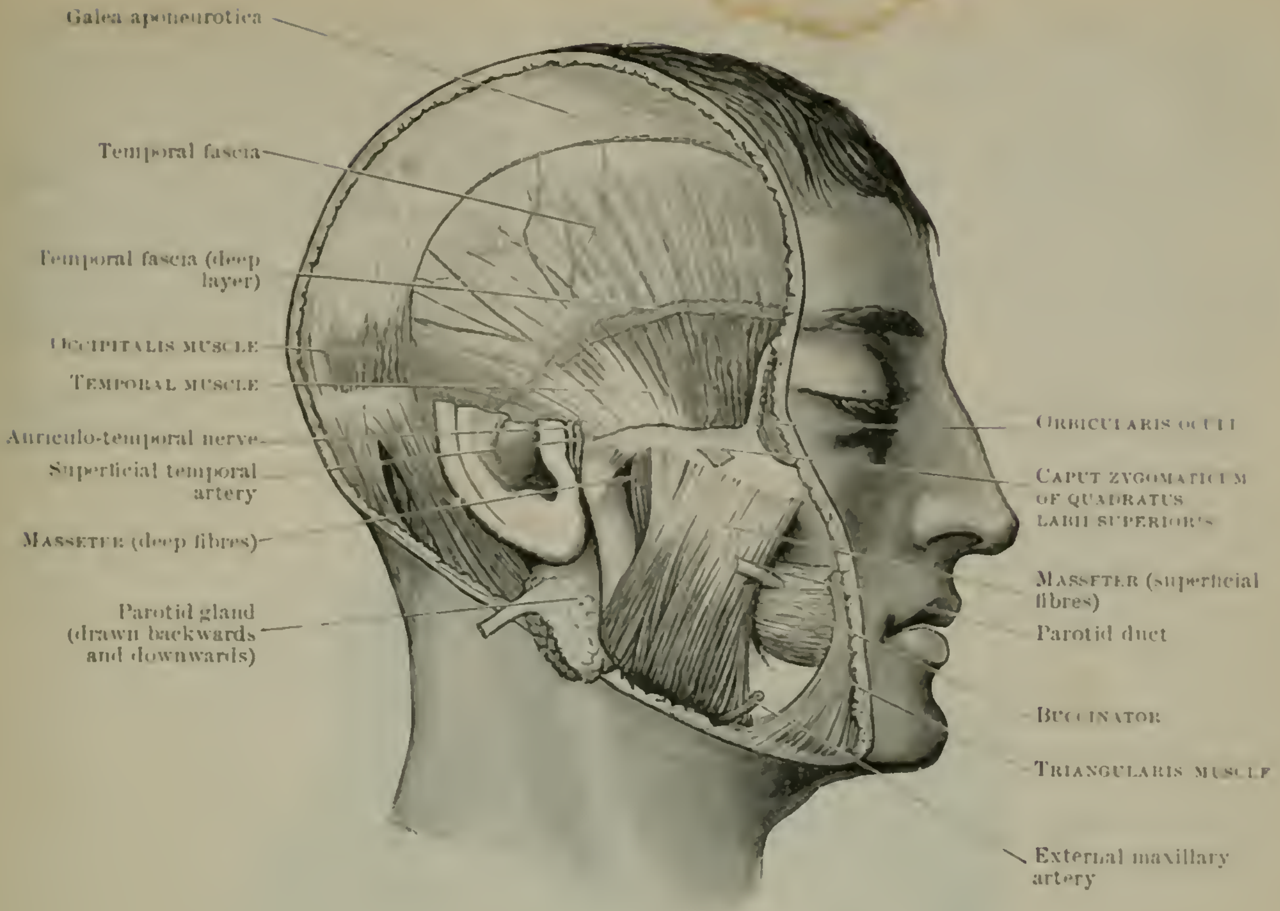
Galea aponeurotica
Temporal fascia
Temporal fascia (deep layer)
OCCIPITALIS MUSCLE
TEMPORAL MUSCLE
Auriculo-temporal nerve
Superficial temporal artery
MASSETER (deep fibres)
Parotid gland (drawn backwards and downwards)
ORBICULARIS OCULI
CAPUT ZYGOMATICUM OF QUADRATUS LABII SUPERIORIS
MASSETER (superficial fibres)
Parotid duct
BUCCINATOR
TRIANGULARIS MUSCLE
External maxillary artery

FIG. 380.—MUSCLES OF MASTICATION (superficial view).

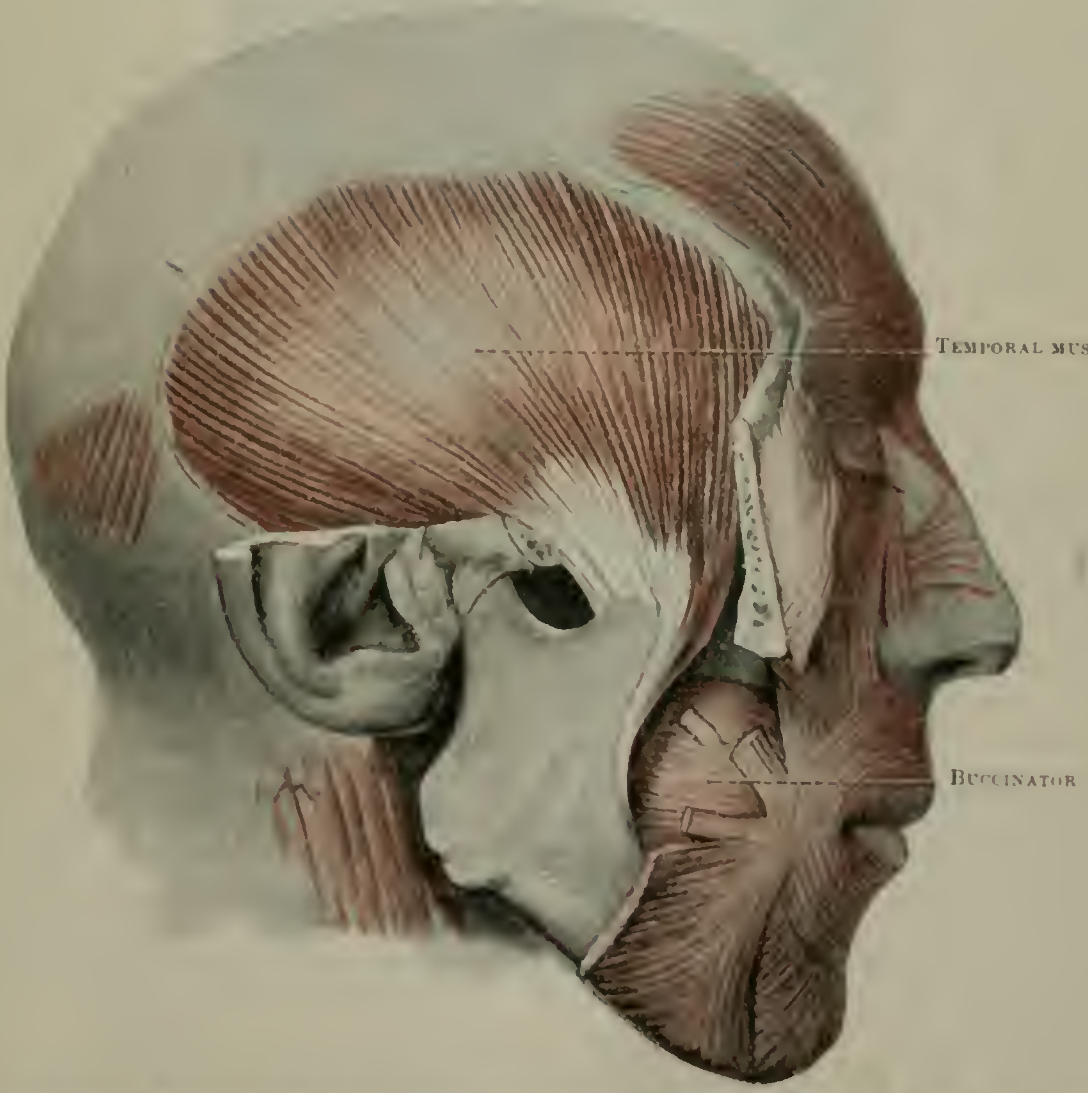

FIG. 381.—THE RIGHT TEMPORAL MUSCLE. (The Zygomatic Arch and the Masseter Muscle have been removed.)

This muscle is covered by the insertion of the temporal muscle and the coronoid process of the mandible, and its inferior head is usually crossed by the internal maxillary artery. It conceals the mandibular branch of the trigeminal nerve, and the pterygoid origin of the internal pterygoid muscle.

M. Pterygoideus Internus.—The **internal pterygoid muscle**, placed beneath the external pterygoid muscle and the ramus of the mandible, has likewise a double **origin**—(1) from the medial surface of the lateral pterygoid lamina and the pyramidal process of the palate bone, and (2) by a stout tendon from the tuberosity of the maxilla. Its two heads of origin embrace the inferior fibres of the external pterygoid muscle.

It is quadrilateral in form, and is directed downwards, laterally, and backwards lateral to the auditory tube and the tensor and levator muscles of the palate, to be **inserted** into a triangular impression on the medial surface of the mandible, between the mylo-hyoid groove and the angle of the bone (Fig. 379, p. 456).

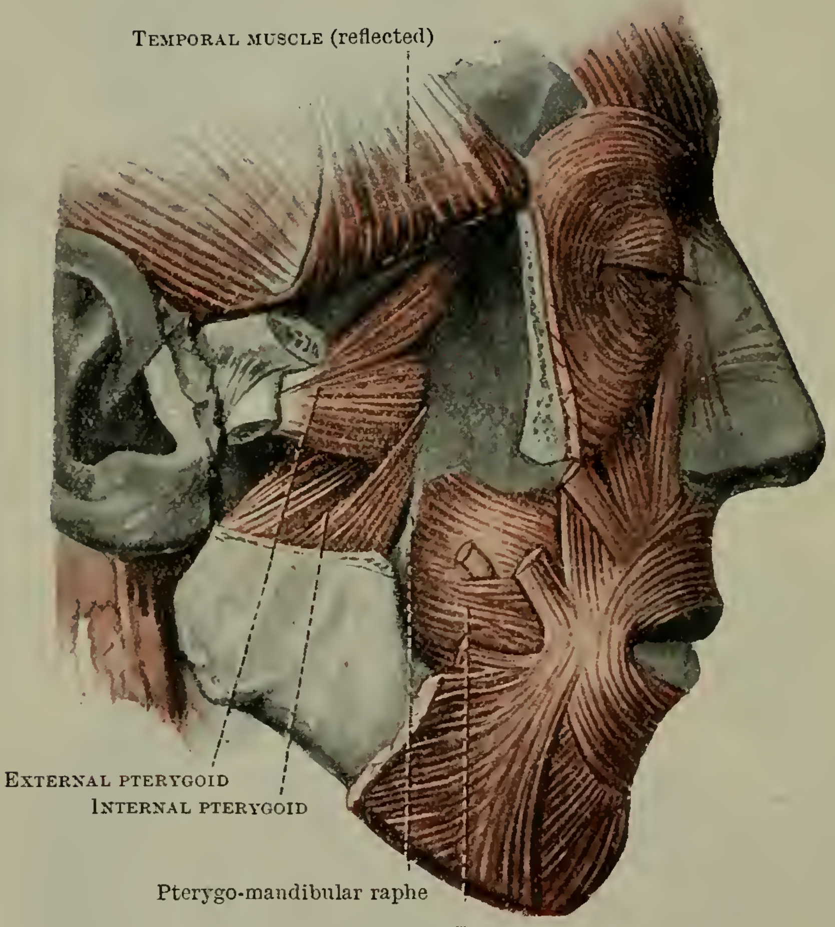

Fig. 382.—The Pterygoid Muscles of the Right Side.

This muscle is covered by the ramus of the mandible and temporal muscle, and partially by the external pterygoid muscle. In contact with its superficial surface are the spheno-mandibular ligament, and the inferior alveolar and lingual nerves and their accompanying vessels. The muscle conceals the tensor veli palatini and the wall of the pharynx (superior constrictor).

Nerve-Supply.—The **mandibular division of the trigeminal nerve** supplies all the muscles of mastication except the buccinator, which is supplied by the **facial nerve**. The internal pterygoid muscle is supplied by the nerve before its division into anterior and posterior parts; the other muscles are innervated by the anterior trunk.

Actions.—The masseter, temporal, and internal pterygoid muscles all take part in the movements of closing the mouth and clenching the teeth, and in this movement the mandible functions as a lever of the third order. It should be observed that when the protruded mandible is elevated, the power of the movement is much reduced and the temporal muscle takes no part in its production.

Protrusion of the mandible results from the combined action of all four pterygoid muscles, and the subsequent retraction of the bone is brought about by the temporal muscles (posterior fibres) and the genio-hyoids.

The side-to-side movement of the mandible, which constitutes the important chewing action, is a combination of unilateral protrusion and the resulting rotation. The external and internal pterygoid muscles of the right side draw the right ramus forwards and medially so that the molar teeth of the mandible pass forwards and to the left across the molar teeth of the maxilla. When the mandible has been twisted over to the left by the right pterygoid muscles, the left pterygoids contract to restore the bone to its resting position and then twist it over to the right. The chewing movement is brought about, therefore, by the right and left pterygoid muscles acting alternately.

Depression of the mandible is usually assisted by gravity and requires little force. The digastric and the mylo-hyoid muscles are the prime movers, and the external pterygoids assist by drawing the condyles forwards.

THE MUSCLES OF THE NECK.

In addition to those included among the muscles of the back (p. 437), the following series of muscles occur in the neck: (1) sterno-cleido-mastoid; (2) the muscles of the hyoid bone (supra-hyoid and infra-hyoid); (3) the muscles of the tongue (extrinsic and intrinsic); (4) the muscles of the pharynx and soft palate; and (5) the prævertebral muscles.

M. Sternocleidomastoideus.—The **sterno-mastoid muscle** is the prominent muscle projecting on the side of the neck, and separating the anterior from the posterior triangle. It **arises** by two heads—(1) a narrow, tendinous, *sternal* head, from the anterior surface of the manubrium sterni (Fig. 126, p. 114), and (2) a broader *clavicular* origin, partly tendinous, partly fleshy, from the superior surface of the clavicle in its medial third (Fig. 193, p. 224). The muscle is **inserted** into the lateral surface of the mastoid portion of the temporal bone and into the superior nuchal line of the occipital bone (Fig. 370, p. 445).

The muscle passes obliquely over the side of the neck, separating the anterior from the posterior triangle. It is almost superficial in its whole extent, but is overlapped superiorly by the parotid gland and is covered in its inferior part by the platysma. It is crossed by the external jugular vein, and by superficial branches of the cervical plexus. Its deep surface is in contact with: (*a*) in its lower third, the infra-hyoid muscles, which separate it from the common carotid artery, and the subclavian artery and the internal jugular vein; (*b*) in its middle third, with the internal jugular vein, the external and internal carotid arteries, and the cervical plexus; and (*c*) in its superior third, with the levator scapulæ muscle, and the accessory nerve, which there pierces the deep surface of the muscle. Near its insertion the muscle is related to the splenius capitis, longissimus capitis, the posterior belly of the digastric, and the occipital artery.

The sterno-cleido-mastoid muscle is properly divisible into three parts: (1) **sterno-mastoid,** placed superficially, and passing obliquely from the sternum to the mastoid process; (2) **cleido-mastoid,** placed more deeply, and directed vertically upwards from the clavicle to the mastoid process; and (3) **cleido-occipitalis,** passing obliquely upwards and backwards behind the cleido-mastoid to the superior nuchal line of the occipital bone.

Nerve-Supply.—The sterno-mastoid muscle is innervated by the accessory nerve, joined by a branch from the cervical plexus (C. 2.).

Actions.—When one muscle acts alone, it flexes the head laterally, and rotates it to the opposite side. The two muscles acting together (1) flex the head in a forward direction, and (2) act as extraordinary muscles of inspiration, by raising the sternum and clavicles.

The Muscles of the Hyoid Bone.

The muscles attached to the hyoid bone are in three series: (1) infra-hyoid muscles, connecting the hyoid bone to the scapula, the wall of the thorax, and thyreoid cartilage; (2) supra-hyoid muscles, connecting it to the mandible, cranium, and tongue; and (3) the middle constrictor muscle of the pharynx.

The **infra-hyoid muscles** comprise the omo-hyoid, sterno-hyoid, sterno-thyreoid, and thyreo-hyoid muscles.

M. Omohyoideus.—The **omo-hyoid** is a muscle with two bellies, anterior and posterior. The *posterior* belly **arises** from the superior margin of the scapula and the superior transverse scapular ligament (Fig. 190, p. 220). It forms a narrow muscular band, which passes obliquely forwards and upwards, and ends in an intermediate tendon beneath the sterno-mastoid muscle.

From this tendon the anterior belly proceeds upwards, to be **inserted** into the lateral part of the inferior border of the body of the hyoid bone.

The posterior belly of the muscle separates the posterior triangle into occipital and subclavian parts; the anterior belly crosses the carotid sheath at the level of the cricoid cartilage, and in the anterior triangle lies on the lateral side of the sterno-hyoid. A process of the deep cervical fascia binds down the tendon and the posterior belly to the clavicle and the first rib.

M. Sternohyoideus.—The **sterno-hyoid muscle arises** from the posterior surface of the manubrium and from the posterior sterno-clavicular ligament, or from the latter and the adjoining part of the clavicle. Sometimes it obtains partial origin from the first costal cartilage.

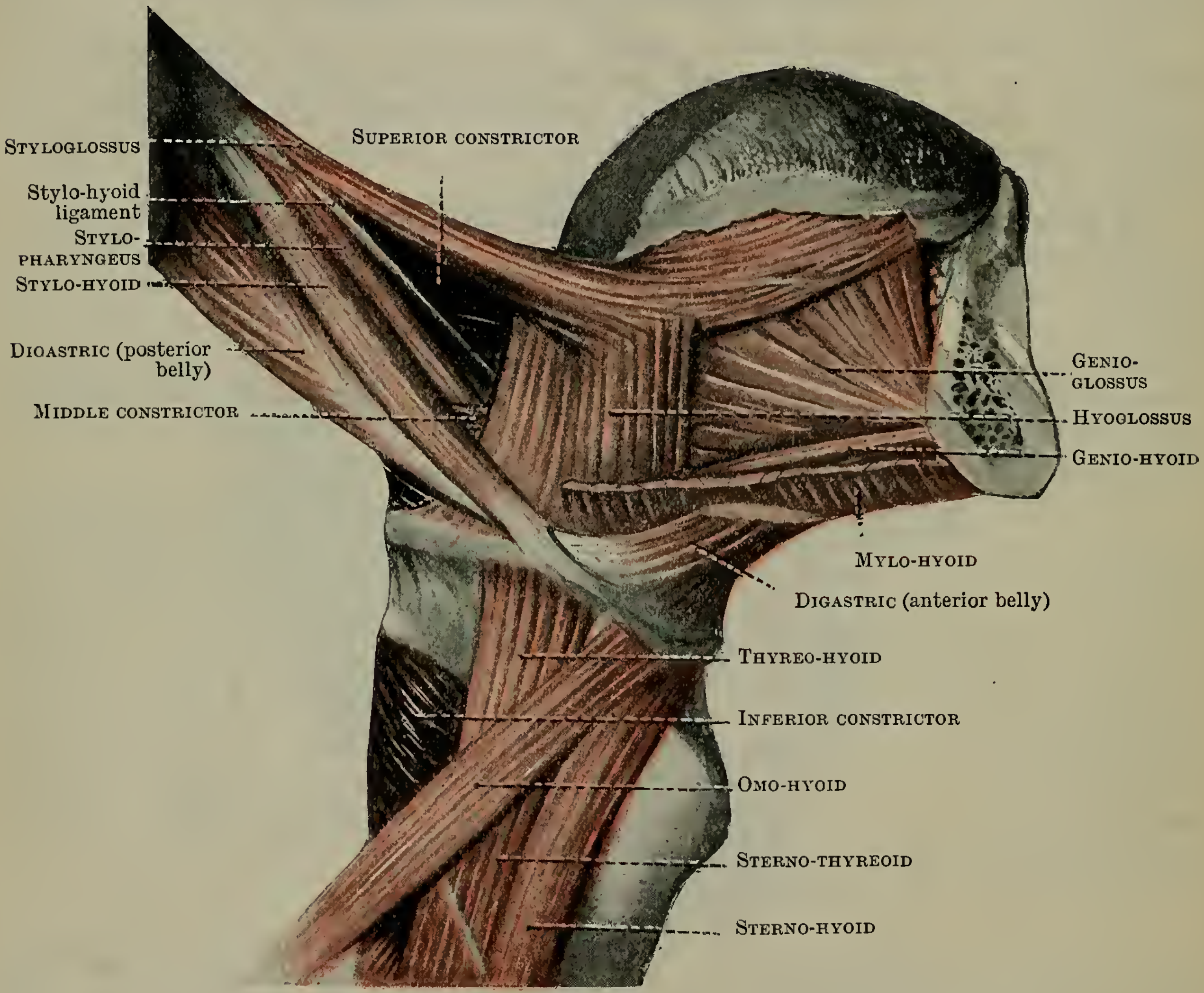

FIG. 383.—THE MUSCLES OF THE TONGUE AND HYOID BONE (right side).

It passes vertically upwards in the neck, medial to the omo-hyoid and anterior to the sterno-thyreoid muscle, to be **inserted** into the medial part of the body of the hyoid bone. Except near its origin, which is covered by the sternum, clavicle, and sternal head of the sterno-mastoid, the muscle is superficially placed.

M. Sternothyreoideus.—The **sterno-thyreoid muscle arises** beneath the sterno-hyoid from the back of the manubrium and first costal cartilage.

Broader than the preceding muscle, it passes upwards, and slightly in a lateral direction in the neck, in front of the trachea and thyreoid gland, and deep to the sterno-mastoid, omo-hyoid, and sterno-hyoid muscles. It is **inserted** into the oblique line of the thyreoid cartilage. The muscle is marked by an oblique tendinous intersection in the middle of its length.

M. Thyreohyoideus.—The **thyreo-hyoid muscle** continues the line of the preceding muscle to the hyoid bone. Short and quadrilateral, it **arises** from the oblique line of the thyreoid cartilage.

Passing over the thyreo-hyoid membrane, deep to the omo-hyoid and sterno-hyoid, it is **inserted** into the body and great cornu of the hyoid bone.

The **levator glandulæ thyreoideæ** is an occasional slip stretching between the hyoid bone and the isthmus or pyramid of the thyreoid gland.

Nerve-Supply.—The sterno-hyoid, sterno-thyreoid, and omo-hyoid are supplied by the *ansa hypoglossi*; the thyreo-hyoid, by a special branch from the hypoglossal nerve. Through the ansa hypoglossi the muscles are innervated by nerves which are ultimately derived from the first three cervical nerves. The descendens hypoglossi is derived from the loop between the first two cervical nerves, and the descendens cervicis springs from the second and third. These two trunks combine to form the ansa. The thyreo-hyoid muscle is innervated (through the hypoglossal) from the loop between the first and second cervical nerves.

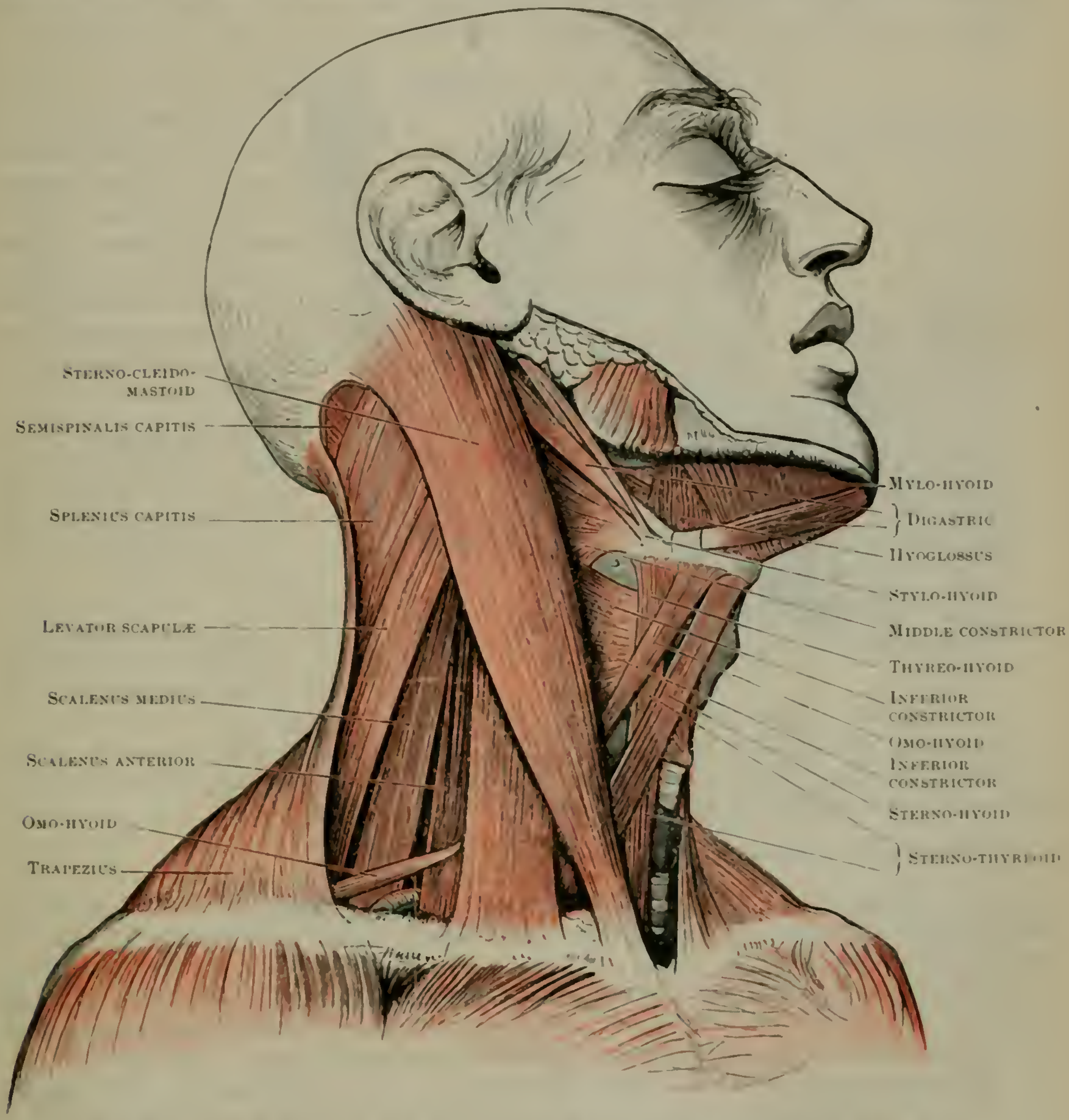

Fig. 384.—The Muscles of the Side of the Neck (anterior and posterior triangles).

Actions.—The sterno-hyoid, sterno-thyreoid, and omo-hyoid are depressors of the hyoid bone. The omo-hyoid is a feeble elevator of the scapula. The thyreo-hyoid is, on the one hand, an elevator of the thyreoid cartilage, and acting with the previous muscles, on the other hand, it is a depressor of the hyoid bone.

The **supra-hyoid muscles** comprise the digastric, stylo-hyoid, mylo-hyoid, and genio-hyoid muscles; and also two muscles, the genioglossus and hyoglossus, which will be described along with the extrinsic muscles of the tongue.

M. Digastricus.—The **digastric muscle**, as its name implies, possesses two bellies—anterior and posterior.

The *posterior belly* **arises**, under cover of the sterno-mastoid muscle, from the mastoid notch medial to the mastoid process. It is directed forwards and downwards, in company with the stylo-hyoid muscle, to end in an intermediate tendon, which is connected by a pulley-like band of cervical fascia to the body of the hyoid bone.

The *anterior belly* of the muscle is directed forwards and slightly upwards, over the mylo-hyoid muscle, to the chin, and is **inserted** into the oval digastric fossa on the inferior border of the mandible close to the symphysis (Fig. 385).

The muscle forms the inferior boundary of the submaxillary division of the anterior triangle, containing the submaxillary gland. The posterior belly in company with the stylo-hyoid crosses the carotid arteries and internal jugular vein. The occipital artery extends posteriorly along its inferior margin, and the parotid gland covers its superior border. The hypoglossal nerve emerges from under cover of the muscle. The anterior belly, as it passes to its insertion, lies upon the mylo-hyoid muscle.

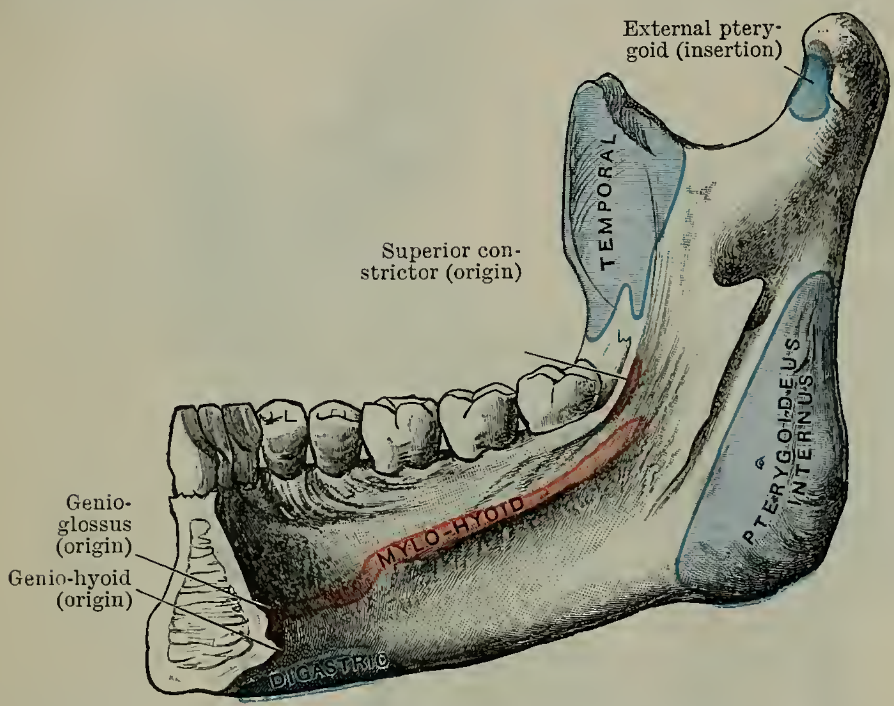

Fig. 385.—Muscle-Attachments on the Medial Side of the Mandible.

Nerve-Supply.—The posterior belly is supplied by the facial nerve; the anterior belly by the nerve to the mylo-hyoid, a branch of the inferior alveolar nerve.

M. Stylohyoideus.—The **stylo-hyoid muscle arises** from the posterior border of the styloid process of the temporal bone.

Crossing the anterior triangle obliquely, along with the posterior belly of the digastric muscle, it is **inserted** into the body of the hyoid bone, by two slips which enclose the tendon of the digastric muscle.

Nerve-Supply.—Facial nerve.

M. Mylohyoideus.—The **mylo-hyoid muscle** forms with its fellow a diaphragm in the floor of the mouth. It **arises** from the mylo-hyoid ridge of the mandible (Fig. 385).

It is directed downwards and medially, to be **inserted** into (1) the superior border of the body of the hyoid bone, and more anteriorly (along with the opposite muscle) into (2) a median raphe extending from the hyoid bone nearly to the chin.

The muscle is in contact, on its superficial or lateral surface, with the digastric muscle, the submaxillary gland, and the mandible. Its deep or medial surface is partially covered by the mucous membrane of the floor of the mouth, and is separated from the muscles of the tongue by the deep part of the submaxillary gland, the sublingual gland, the submaxillary duct, and the lingual and hypoglossal nerves.

Nerve-Supply.—The muscle is supplied by the nerve to the mylo-hyoid, a branch of the inferior alveolar nerve.

M. Geniohyoideus.—The **genio-hyoid muscle arises** from the inferior of the two mental spines on the posterior surface of the symphysis of the mandible (Fig. 385).

It is directed backwards and slightly downwards, along the inferior border of the genioglossus, to be **inserted** into the anterior surface of the body of the hyoid bone. The muscles of opposite sides are often fused together.

The muscle is placed deep to the mylo-hyoid, and is in contact with the inferior border of the genioglossus muscle.

Nerve-Supply.—It is supplied by the hypoglossal nerve, but its nerve can be traced back to an origin from the communication between that nerve and the first and second cervical nerves.

Actions.—The digastric, stylo-hyoid, mylo-hyoid, and genio-hyoid muscles are all elevators of the hyoid bone. The posterior belly of the digastric and stylo-hyoid draw it upwards and backwards, while the anterior belly of the digastric and the genio-hyoid draw it upwards and forwards. The anterior belly of the digastric, mylo-hyoid, and genio-hyoid also assist in opening the mouth.

The Muscles of the Tongue.

The muscular substance of the tongue consists of two symmetrical series of muscles placed on either side of a membranous raphe in the median plane. The series comprise (1) **extrinsic muscles** arising from the soft palate, styloid process, hyoid bone and mandible, and (2) **intrinsic muscles** proper to the tongue itself. Each set consists of four series of muscles.

A. The **extrinsic muscles** are four in number: (1) genioglossus, (2) hyoglossus, (3) styloglossus, and (4) glossopalatinus.

M. Genioglossus.—The **genioglossus muscle** (O.T. **geniohyoglossus**) (Fig. 383, p. 460) is an extrinsic muscle of the tongue as well as a supra-hyoid muscle.

It is a fan-shaped muscle **arising** by its apex from the superior of the two mental spines, behind the symphysis of the mandible (Fig. 385, p. 462).

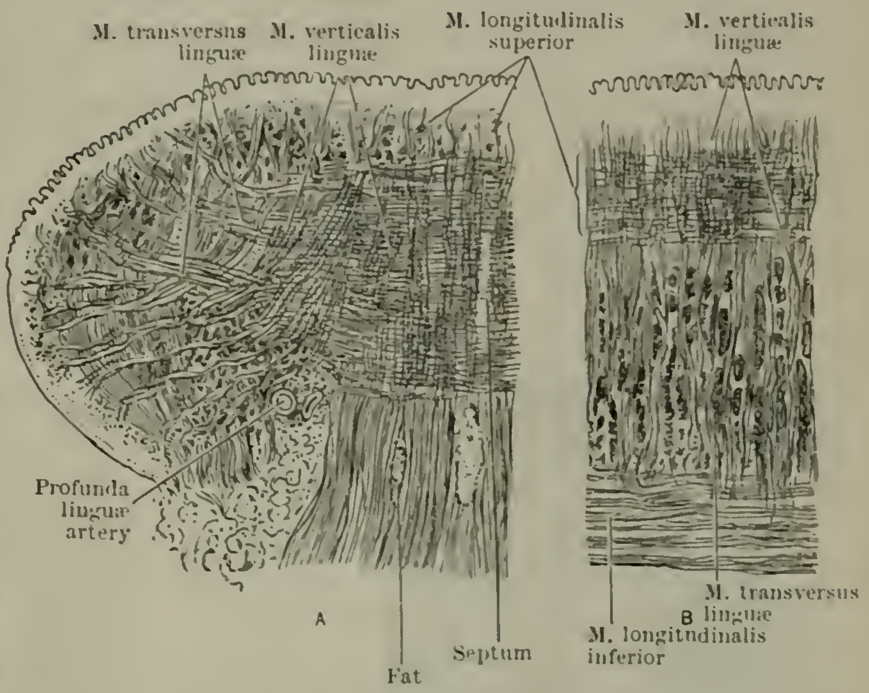

FIG. 386.—A, TRANSVERSE, AND B, LONGITUDINAL VERTICAL SECTIONS THROUGH THE TONGUE (Krause).

From that origin the muscular fibres diverge; the lowest fibres are directed downwards and backwards, to be **inserted** into the body of the hyoid bone; the highest fibres curve forwards, to be attached to the tip of the tongue; the intermediate fibres are attached to the substance of the tongue in its whole length between the base and tip.

The muscles of opposite sides are separated by the median raphe of the tongue. On the lateral aspect, of each, are the hyoglossus, the lingual artery, and the sublingual gland.

M. Hyoglossus.—The **hyoglossus muscle** is also an extrinsic muscle of the tongue as well as a supra-hyoid muscle.

It **arises** from the body and greater cornu of the hyoid bone.

It is directed upwards and forwards, to be **inserted** into the side of the tongue, its fibres interlacing with the fibres of the styloglossus (Fig. 383, p. 460).

The muscle is quadrilateral in shape, and, with the exception of its lower and posterior portion, it is entirely hidden by the mylo-hyoid. Numerous structures intervene between the two muscles. A little above the greater cornu of the hyoid bone the hypoglossal nerve and its accompanying vein are found in this intermuscular interval, and, at a higher level, the deep part of the submaxillary gland, the submaxillary duct, the lingual nerve, the submaxillary ganglion, and the posterior part of the sublingual gland separate the two muscles from one another. The insertion of the hyoglossus is separated from the origin of the mylo-hyoid by the mucous membrane of the floor of the mouth. The postero-inferior part of the muscle is in contact with the hypoglossal nerve and the common tendon of the digastric muscle.

The deep surface of the hyoglossus is in contact with the genioglossus in front, and the middle constrictor of the pharynx behind, but the lingual artery intervenes between them.

The **chondroglossus** is a small separated slip of the hyoglossus, not always present. It arises from the lesser cornu of the hyoid bone.

M. Styloglossus.—The **styloglossus muscle arises** from the anterior border of the styloid process near its tip, and from the stylo-hyoid ligament.

It sweeps forwards and medially, at first, on the stylo-pharyngeus, and subsequently on the lower and anterior part of the superior constrictor muscle of the pharynx, by which it is separated from the palatine tonsil. It is **inserted** into the side and inferior surface of the tongue, its fibres spreading out to decussate with those of the glossopalatinus and hyoglossus muscles beneath the submaxillary gland and the mucous membrane of the tongue.

M. Glossopalatinus.—The **glossopalatinus** is a thin sheet of muscular fibres **arising** from the inferior surface of the soft palate, where it is continuous with fibres of the opposite muscle.

It passes downwards, in the glosso-palatine arch, and spreads out, to be **inserted** into the sides of the tongue, blending with the styloglossus and the deep transverse fibres of the tongue.

The muscle is placed directly beneath the mucous membrane of the soft palate and tongue.

B. **Intrinsic Muscles of the Tongue.**—Besides receiving the fibres of insertion of the extrinsic muscles, the substance of the tongue is composed of four intrinsic muscles on either side—two in the sagittal plane, the superior and inferior longitudinal muscles; two in the frontal plane, the transverse and vertical muscles.

M. Longitudinalis Superior.—The **superior longitudinal muscle** extends from base to tip of the tongue. It is placed on its dorsum immediately under the mucous membrane, into which many of its fibres are inserted.

M. Longitudinalis Inferior.—The **inferior longitudinal muscle** is a cylindrical band of muscular fibres occupying the inferior part of the organ on each side, in the interval between the genioglossus and the hyoglossus muscles. Posteriorly some of its fibres extend to the hyoid bone.

M. Transversus Linguæ.—The **transversus linguæ** arises from the median raphe, and radiates outwards to the dorsum and sides of the tongue, intermingling with the extrinsic muscles and the fibres of the vertical muscle. It occupies the substance of the tongue between the superior and inferior longitudinal muscles.

M. Verticalis Linguæ.—The **verticalis linguæ** arises from the dorsal surface of the tongue, and sweeps downwards and laterally to its sides, intermingled with the fibres of the preceding muscle and the insertions of the extrinsic muscles. The transverse and vertical muscles form a very considerable part of the total muscular substance of the organ.

Nerve-Supply.—All these muscles except the glossopalatinus are supplied by the hypoglossal nerve. The glossopalatinus is supplied by the accessory nerve through the pharyngeal plexus.

Actions.—For the most part, the extrinsic muscles produce alterations in the position of the tongue, while the intrinsic muscles are responsible for changes in its shape. The tongue is protruded by the action of the posterior fibres of the genioglossus, retracted by the anterior fibres aided by the styloglossus. The styloglossus and glossopalatinus are elevators, while the genioglossus and hyoglossus are depressors of the tongue.

The Muscles of the Pharynx.

The muscular envelope of the pharynx is composed of two strata. The *external* or *circular layer* consists of the three fan-shaped constrictor muscles; the *internal* or *longitudinal layer* consists of the fibres of the stylopharyngeus and pharyngopalatinus muscles.

M. Constrictor Pharyngis Superior.—The **superior constrictor muscle arises** successively from the inferior half of the posterior border of the medial lamina of the pterygoid process **(pterygopharyngeus)**, from the pterygomandibular raphe **(buccopharyngeus)**, from the mylo-hyoid line of the mandible **(mylopharyngeus)** (Fig. 375, p. 456), and from the side of the tongue **(glossopharyngeus)**.

The muscular fibres radiate backwards and medially, and are **inserted**, for the most part, into a raphe extending down the posterior wall of the pharynx in the median plane. The highest fibres are attached to the pharyngeal tubercle of the occipital bone (Fig. 370, p. 445), and the lowest fibres are overlapped by the middle constrictor. A crescentic interval occurs above the muscle, below the base of the skull, in which the auditory tube and the levator and tensor veli palatini muscles appear. Its lower border is separated from the middle constrictor by the stylopharyngeus muscle.

M. Constrictor Pharyngis Medius.—The **middle constrictor muscle arises** from the stylo-hyoid ligament and from both cornua of the hyoid bone **(chondropharyngeus, ceratopharyngeus)**.

From its origin the muscular fibres radiate backwards and medially, to be **inserted** into the median raphe on the posterior aspect of the pharynx.

The superior fibres overlap the inferior part of the superior constrictor; the inferior fibres are concealed from view by the inferior constrictor muscle. In the interval between the middle and inferior constrictors are found the superior laryngeal artery and internal laryngeal nerve.

M. Constrictor Pharyngis Inferior.—The **inferior constrictor muscle arises** from the oblique line of the thyreoid cartilage **(thyreopharyngeus)**, and from the side of the cricoid cartilage **(cricopharyngeus)**.

Its fibres radiate backwards and medially, to be **inserted** into the median *raphe* on the posterior wall of the pharynx, the superior fibres overlapping the inferior part of the middle constrictor, the inferior fibres blending with the muscular fibres of the œsophagus. Below the inferior border of the muscle the inferior laryngeal artery and nerve enter into relation with the larynx.

Nerve-Supply.—The constrictors of the pharynx receive their nerve-supply through the pharyngeal plexus from the accessory nerve. The inferior constrictor is supplied also by the external laryngeal and recurrent branches of the vagus nerve.

The deeper longitudinal stratum of muscles in the pharyngeal wall is composed of the insertions of the stylopharyngeus and pharyngopalatinus muscles.

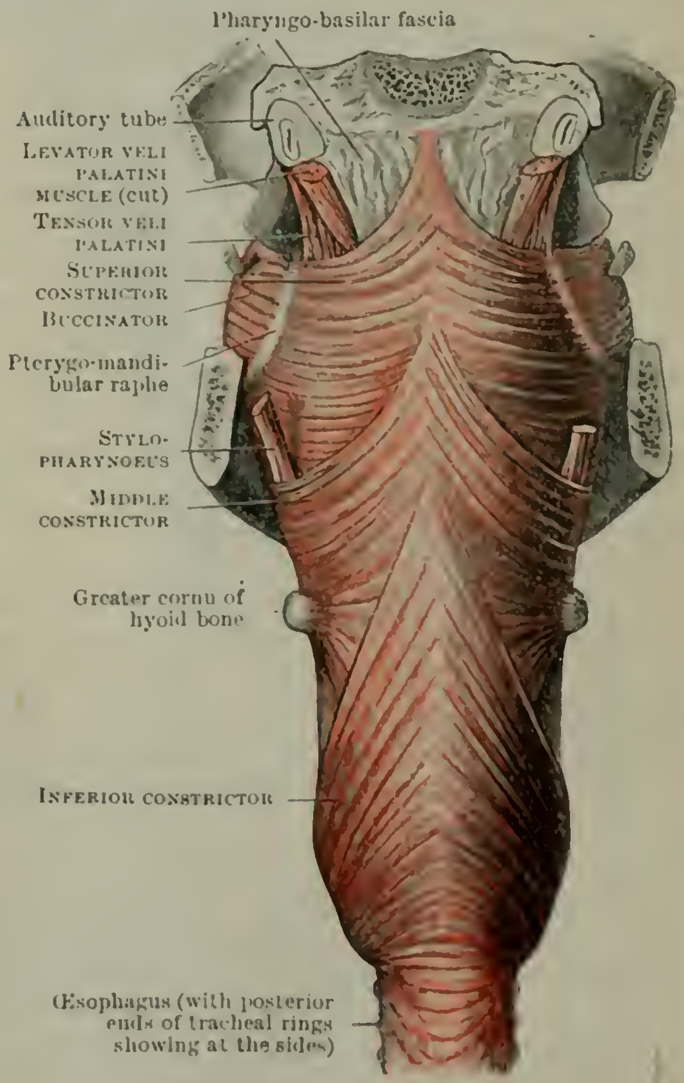

Fig. 387.—Posterior View of the Pharynx and Constrictor Muscles.

M. Stylopharyngeus.—The **stylopharyngeus arises** from the root of the styloid process on its medial side, and passes downwards between the external and internal carotid arteries. It enters the wall of the pharynx in the interval between the superior and middle constrictor muscles.

Spreading out beneath the middle constrictor muscle, the greater cornu of the hyoid bone, and the thyreo-hyoid membrane, it is **inserted** into the superior and posterior borders of the thyreoid cartilage and into the wall of the pharynx itself, becoming continuous posteriorly with the palatopharyngeus. In the neck the glossopharyngeal nerve winds round it on its way to the tongue.

Nerve-Supply.—Glossopharyngeal nerve.

M. Pharyngopalatinus.—The **pharyngopalatinus** (O.T. **palatopharyngeus**) occupies the soft palate and the pharyngeal wall. In the substance of the soft palate it consists of *two layers,* a postero-superior layer, thin, and continuous across the median plane with the corresponding layer on the opposite side, and an antero-inferior layer, which is thicker, and is attached to the posterior border of the hard palate. The levator veli palatini and the musculus uvulæ are enclosed between the two layers, which unite at the posterior edge of the palate, receiving at the same time additional fibres arising from the auditory tube (**salpingopharyngeus**). The muscle descends to the pharynx in the pharyngopalatine arch.

Its fibres spread out in the form of a thin sheet in the wall of the pharynx, in continuity anteriorly with the stylopharyngeus, and are **inserted** into the posterior border of the thyreoid cartilage, and behind that into the aponeurosis of the pharynx, reaching down as far as the inferior border of the inferior constrictor. The muscle is placed beneath the middle and inferior constrictors, and the fibres of the muscles of opposite sides decussate in the median plane, in the inferior part of the pharyngeal wall.

Nerve-Supply.—The muscle is innervated through the pharyngeal plexus, by the accessory nerve.

The Muscles of the Soft Palate.

The soft palate and uvula form a muscular fold, covered on each surface by mucous membrane, projecting backwards into the pharynx, and forming the posterior parts of the floor of the nasal cavities and the roof of the mouth.

The muscular fold is composed of five pairs of muscles—the pharyngopalatinus, m. uvulæ, levator veli palatini, tensor veli palatini, and glossopalatinus. In its anterior part the fold contains the **palatal aponeurosis**, which is attached in front to the posterior border of the hard palate and on either side to the pharyngeal aponeurosis. Posteriorly it rapidly diminishes in breadth, and the posterior part of the soft palate is entirely muscular. The palatal aponeurosis gives origin to the pharyngopalatinus and the m. uvulæ, and receives fibres of insertion from the levator and the tensor veli palatini.

The **pharyngopalatinus** muscle has been already described (see above).

The **m. uvulæ** consists of two narrow bundles enclosed along with the insertion of the levator veli palatini, between the layers of the pharyngopalatinus. The slips **arise** from the posterior nasal spine and the aponeurosis of the soft palate, and unite as they proceed backwards to end in the uvula.

M. Levator Veli Palatini.—The **levator veli palatini** has a double **origin**: (1) from the inferior surface of the apex of the petrous portion of the temporal bone, and (2) from the inferior part of the cartilaginous part of the auditory tube. It passes obliquely downwards and medially, across the medial aspect of the superior border of the superior constrictor muscle, and enters the soft palate between the two layers of the pharyngopalatinus muscle.

It is **inserted** into the aponeurosis of the soft palate, and some of its fibres become continuous with those of the opposite muscle.

It is separated from the tensor veli palatini muscle (1) by the auditory tube, (2) by the upper fibres of the superior constrictor, and (3) by the deeper layer of the pharyngopalatinus muscle.

M. Tensor Veli Palatini.—The **tensor veli palatini** **arises** (1) from the scaphoid fossa and the angular spine of the sphenoid bone, and (2) from the lateral side of the cartilaginous part of the auditory tube.

It descends, between the internal pterygoid muscle and the medial pterygoid lamina, and ends in a tendon which hooks round the pterygoid hamulus and passes through a gap in the origin of the buccinator muscle (p. 452) to enter the soft palate. The tendon is **inserted**, beneath the levator veli palatini, into the posterior border of the hard palate, and into the aponeurosis of the soft palate.

M. Glossopalatinus.—The **glossopalatinus**, occupying the inferior surface of the soft palate and the glosso-palatine arch, has already been described with the muscles of the tongue (p. 464).

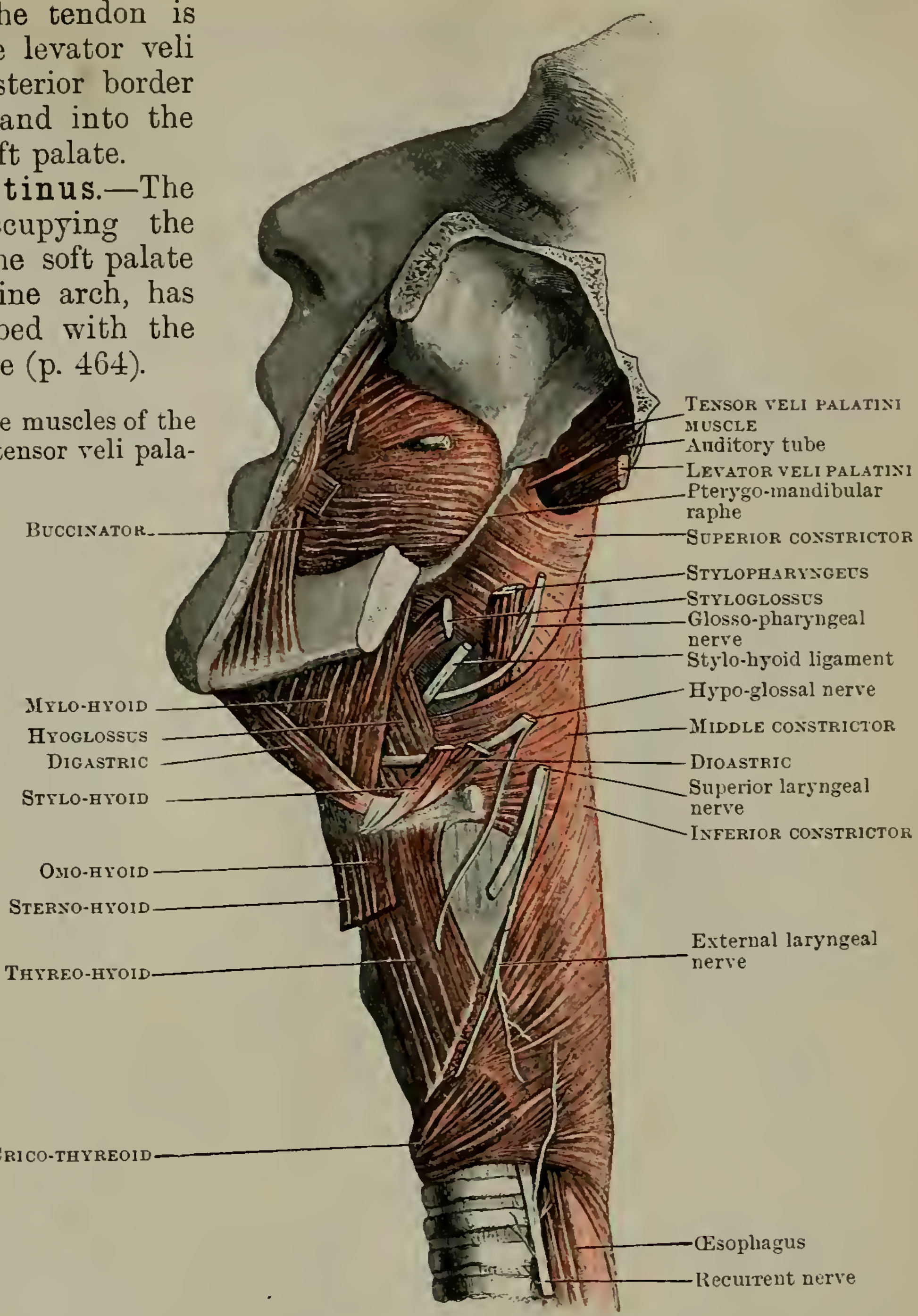

Fig. 388.—Lateral View of the Wall of the Pharynx.

Nerve-Supply.—The muscles of the soft palate (except the tensor veli palatini, which is innervated through the otic ganglion by the trigeminal nerve) are supplied through the pharyngeal plexus by the accessory nerve.

Actions of the Muscles of the Pharynx and Soft Palate.—The muscles of the pharynx and soft palate are chiefly brought into action in **the act of swallowing.** This act is divided into a *voluntary stage*, in which the bolus lies anterior to the arches of the fauces, and an *involuntary stage*, during which the food passes from the mouth through the pharynx. The movements occurring during the passage of food through the mouth are as follows: the cheeks are compressed by the action of the buccinator muscles; the tongue, hyoid bone, and thyreoid cartilage are successively raised upwards by the action of the muscles which close the mouth and elevate the hyoid bone. By these means the food is pushed backwards between the palatine arches.

At the same time, by the contraction of the glossopalatinus and pharyngopalatinus, the palatine arches of the fauces are narrowed, while the muscles of the soft palate, contracting, tighten the soft palate, and by bringing it in contact with the posterior wall of the pharynx, shut off the nasal portion of the cavity. The elevation of the tongue, hyoid bone, and larynx simultaneously causes the elevation of the epiglottis and the superior aperture of the larynx, which is closed by the approximation of the arytænoid cartilages and the combined action of laryngeal muscles (arytænoideus, thyreoarytænoideus, and thyreoepiglotticus). The food thus slips over the posterior surface of the epiglottis and the closed superior aperture of the larynx, and between the palatine arches on either side, into the pharynx. It is now clasped by the constrictor muscles, which, by their contractions, force it down into the œsophagus. The contraction of the constrictor muscles results in a flattening of the pharynx and elevation of its anterior attachments.

During the act of swallowing, it is generally thought that the auditory tube is opened by the contraction of the tensor veli palatini muscle, which arises from it. It has been held, on the other hand, that the auditory tube is closed during swallowing by the compression of its wall by the contraction of the levator veli palatini.

Deep Lateral and Prævertebral Muscles of the Neck.

Three series of muscles are comprised in this group: (1) vertebro-costal (scaleni, anterior, medius, and posterior), (2) vertebro-cranial (longus capitis and rectus capitis anterior, and lateralis), and (3) vertebral (longus colli). They clothe the anterior surface of the cervical portion of the vertebral column for the most part, and are in relation anteriorly with the pharynx and œsophagus, and the large vessels and nerves of the neck.

M. Scalenus Anterior.—The **scalenus anterior arises** from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ.

It runs downwards and laterally to be **inserted** into the scalene tubercle and ridge on the first rib (Fig. 389).

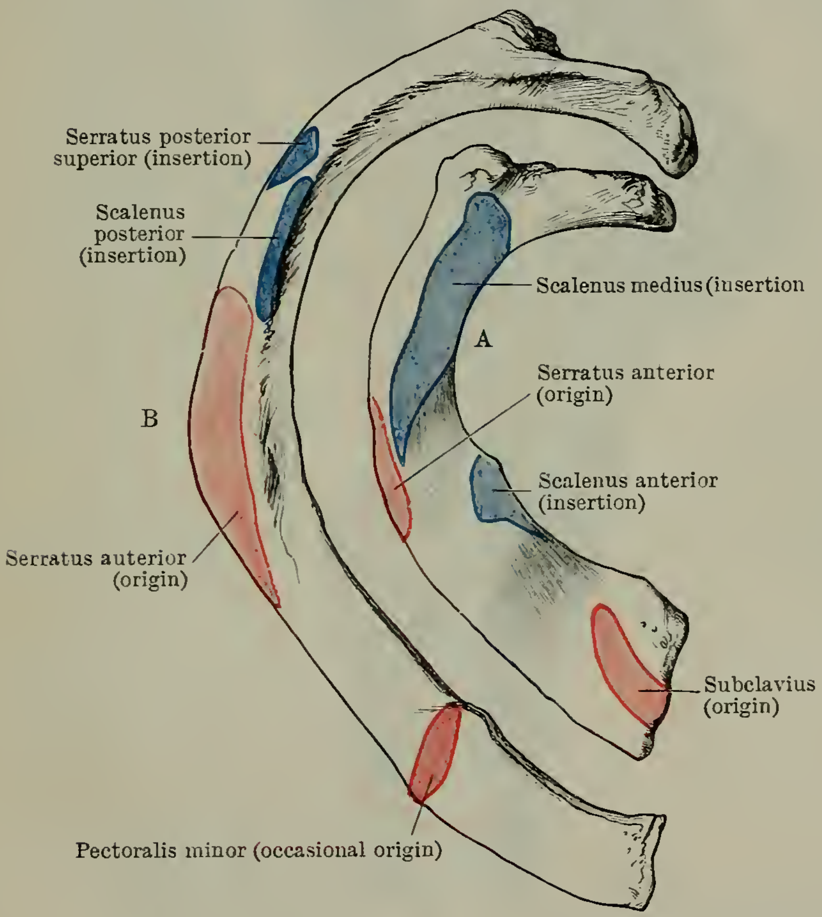
Serratus posterior superior (insertion)
Scalenus posterior (insertion)
Scalenus medius (insertion
A
B
Serratus anterior (origin)
Scalenus anterior (insertion)
Serratus anterior (origin)
Subclavius (origin)
Pectoralis minor (occasional origin)

Fig. 389.—Muscle-Attachments to the Superior Surface of the First Rib, and the External Surface of the Second Rib (Right Side). A, First rib; B, Second rib.

The phrenic nerve is formed at the upper part of the lateral border of the scalenus anterior and runs vertically downwards on its anterior surface, leaving its medial border a little above its insertion. The prævertebral fascia covers the muscle and binds down the phrenic nerve to its surface. With the exception of its insertion, which lies behind the clavicle, the muscle is completely covered by the sterno-cleido-mastoid, but the anterior belly of the omo-hyoid, the internal jugular vein, and the subclavian vein intervene between them.

It is separated posteriorly from the scalenus medius by the roots of the brachial plexus, the subclavian artery, and the pleura.

M. Scalenus Medius.—The **scalenus medius arises** from the posterior tubercles of the transverse processes of the cervical vertebræ, from the second to the sixth inclusive.

It descends in the posterior triangle, behind the subclavian artery and the roots of the brachial plexus, to be **inserted** into the rough impression on the first rib behind the subclavian groove (Fig. 389). The muscle is pierced by the dorsal scapular and long thoracic nerves, which descend on its lateral aspect, under cover of the prævertebral fascia.

It is separated from the scalenus anterior by the subclavian artery and the roots of the brachial plexus.

M. Scalenus Posterior.—The **scalenus posterior arises**, behind the scalenus medius, from the posterior tubercles of the fourth, fifth, and sixth cervical transverse processes. It is **inserted** into an impression on the outer side of the second rib.

At first completely hidden by the scalenus medius, the scalenus posterior appears in the lowest part of the floor of the posterior triangle in the angle between the scalenus medius and the levator scapulæ muscles.

Nerve-Supply.—The scalene muscles are supplied by branches which arise directly from the anterior rami of the lowest four or five cervical nerves.

Actions.—The actions of those muscles are twofold. They are lateral flexors of the vertebral column, and are also important muscles of respiration, as elevators of the first and second ribs.

M. Longus Capitis.—The **longus capitis** (O.T. **rectus capitis anticus major**) **arises** from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ.

It forms a flat triangular muscle, which is directed upwards, overlapping the upper oblique part of the longus colli muscle and lying behind the carotid sheath, to be **inserted** into an impression on the inferior surface of the basilar part of the occipital bone, anterior and lateral to the pharyngeal tubercle (Fig. 370, p. 445).

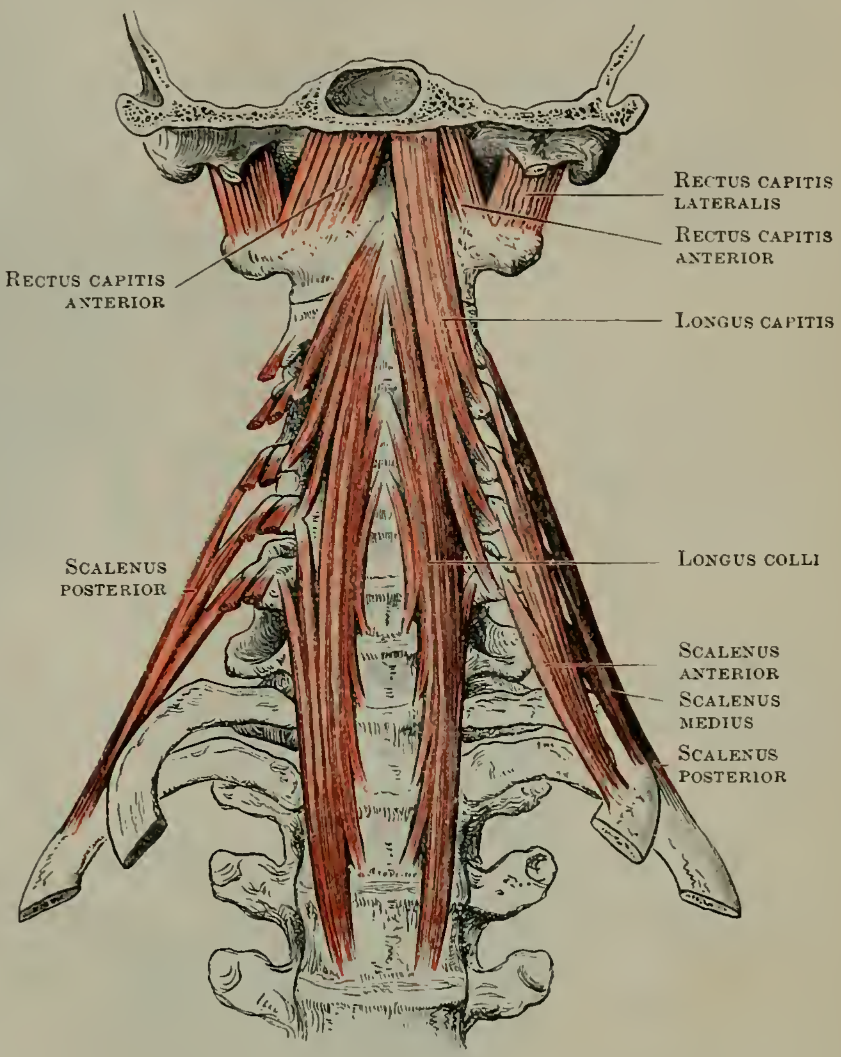

Fig. 390.—The Prævertebral Muscles of the Neck.

Nerve-Supply.—The muscle receives nerves directly from the anterior rami of the first four cervical nerves.

Action.—Flexion of the head and cervical vertebræ.

M. Rectus Capitis Anterior.—The **rectus capitis anterior** (O.T. **rectus capitis anticus minor**) arises, under cover of the preceding muscle, from the lateral mass of the atlas. It is **inserted** into the basilar part of occipital bone between the preceding muscle and the occipital condyle (Fig. 370, p. 445).

Nerve-Supply.—The muscle is innervated by the loop between the first two cervical nerves (anterior rami).

Action.—Flexion of the head on the vertebral column.

M. Longus Colli.—The **longus colli** is a flattened muscular band extending from the third thoracic vertebra to the atlas. It is divisible into three portions—a vertical, an inferior oblique, and a superior oblique portion.

The **vertical portion** of the muscle **arises** from the bodies of the first three thoracic and the last three cervical vertebræ.

Passing vertically upwards, it is **inserted** into the bodies of the second, third, and fourth cervical vertebræ.

The **inferior oblique portion arises** from the bodies of the first three thoracic vertebræ.

It is **inserted** into the anterior tubercles of the fifth and sixth cervical vertebræ.

The **superior oblique portion arises** from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebræ.

It is directed upwards, to be **inserted** into the anterior tubercle of the atlas.

Nerve-Supply.—It is supplied by the anterior rami of the cervical nerves.

Action.—A flexor of the vertebral column. In addition, the oblique portions act as lateral flexors and the lower oblique part may produce a slight degree of rotation to the opposite side.

M. Rectus Capitis Lateralis.—The **rectus capitis lateralis**, in series with the posterior inter-transverse muscles in the neck, **arises** from the transverse process of the atlas.

It is **inserted** into the inferior surface of the jugular process of the occipital bone. It is placed alongside the rectus capitis anterior, separated from it by the anterior ramus of the first cervical nerve, and is covered anteriorly by the internal jugular vein.

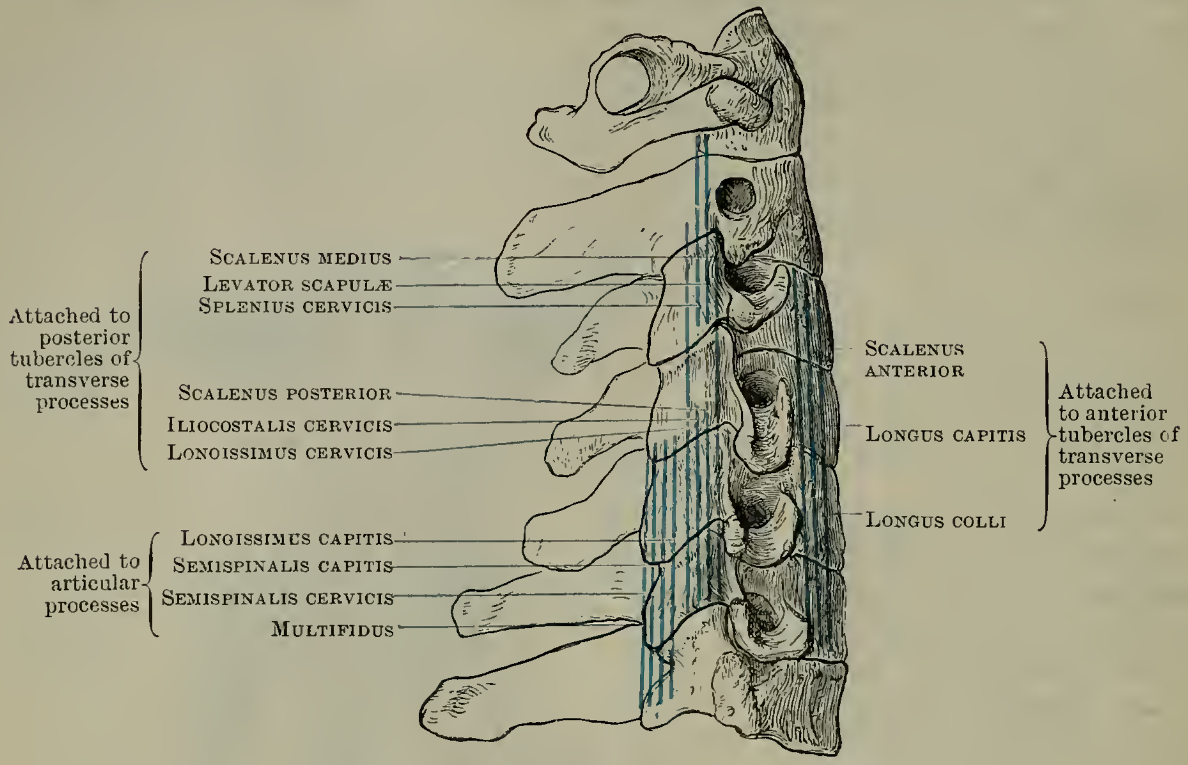

Fig. 391.—Scheme of Muscular Attachments to Cervical Vertebræ.

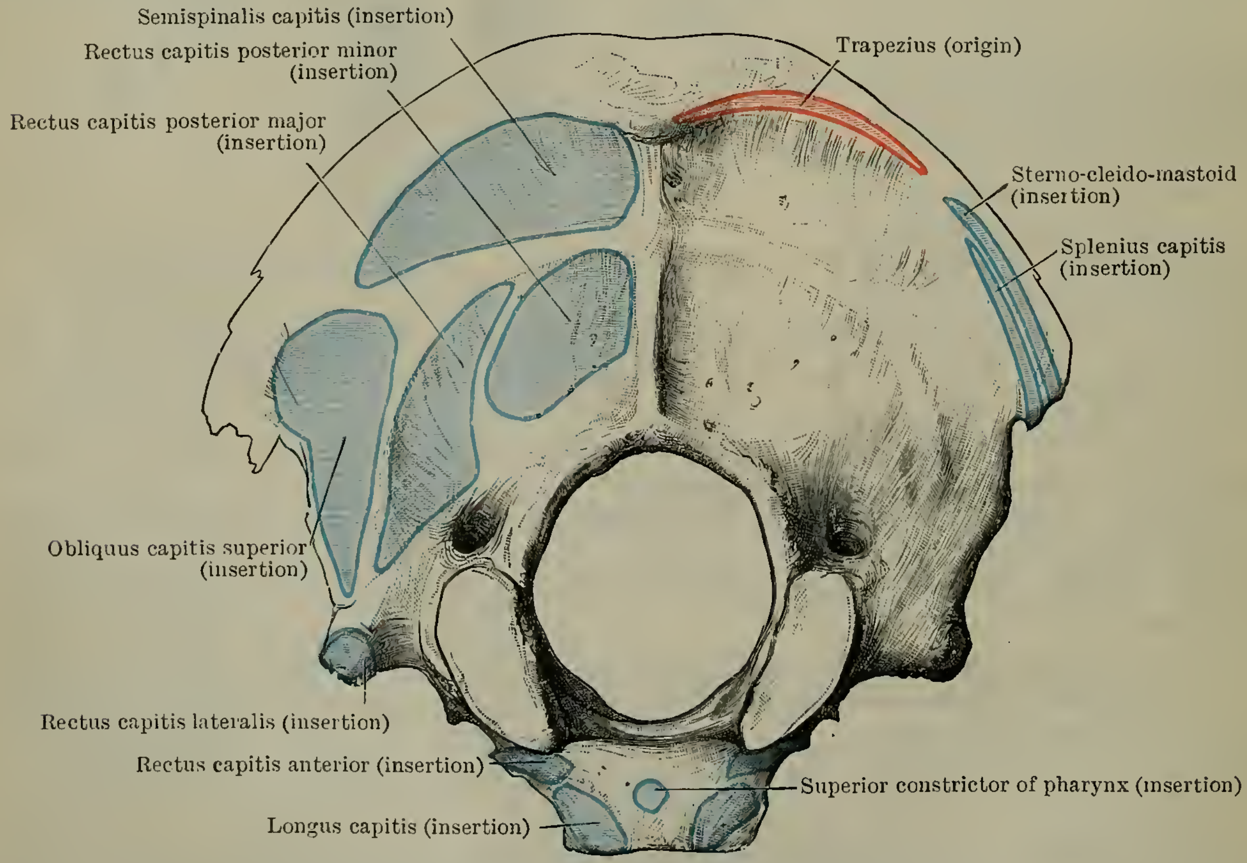
Semispinalis capitis (insertion)
Rectus capitis posterior minor (insertion)
Rectus capitis posterior major (insertion)
Trapezius (origin)
Sterno-cleido-mastoid (insertion)
Splenius capitis (insertion)
Obliquus capitis superior (insertion)
Rectus capitis lateralis (insertion)
Rectus capitis anterior (insertion)
Superior constrictor of pharynx (insertion)
Longus capitis (insertion)

Fig. 392.—Muscle-Attachments to the Occipital Bone.

Nerve-Supply.—The anterior ramus of the first cervical nerve.
Action.—A lateral flexor of the head.

THE MUSCLES OF THE THORAX.

Muscles of Respiration.

The muscles which complete the boundaries of the thorax are the diaphragm and intercostal muscles (external and internal), along with three series of smaller muscles—the transversus thoracis, the levatores costarum, and the subcostal muscles.

Mm. Intercostales.—The **intercostal muscles** are arranged in eleven pairs, which occupy the intercostal spaces.

Each **external muscle** arises from the sharp lower border of a rib, and is directed inferiorly and anteriorly, to be **inserted** into the external edge of the superior border of the rib below. It extends from the tubercle of the rib posteriorly nearly to the costal cartilage anteriorly. The *anterior intercostal aponeurosis* is continuous with it anteriorly, and extends forwards to the side of the sternum.

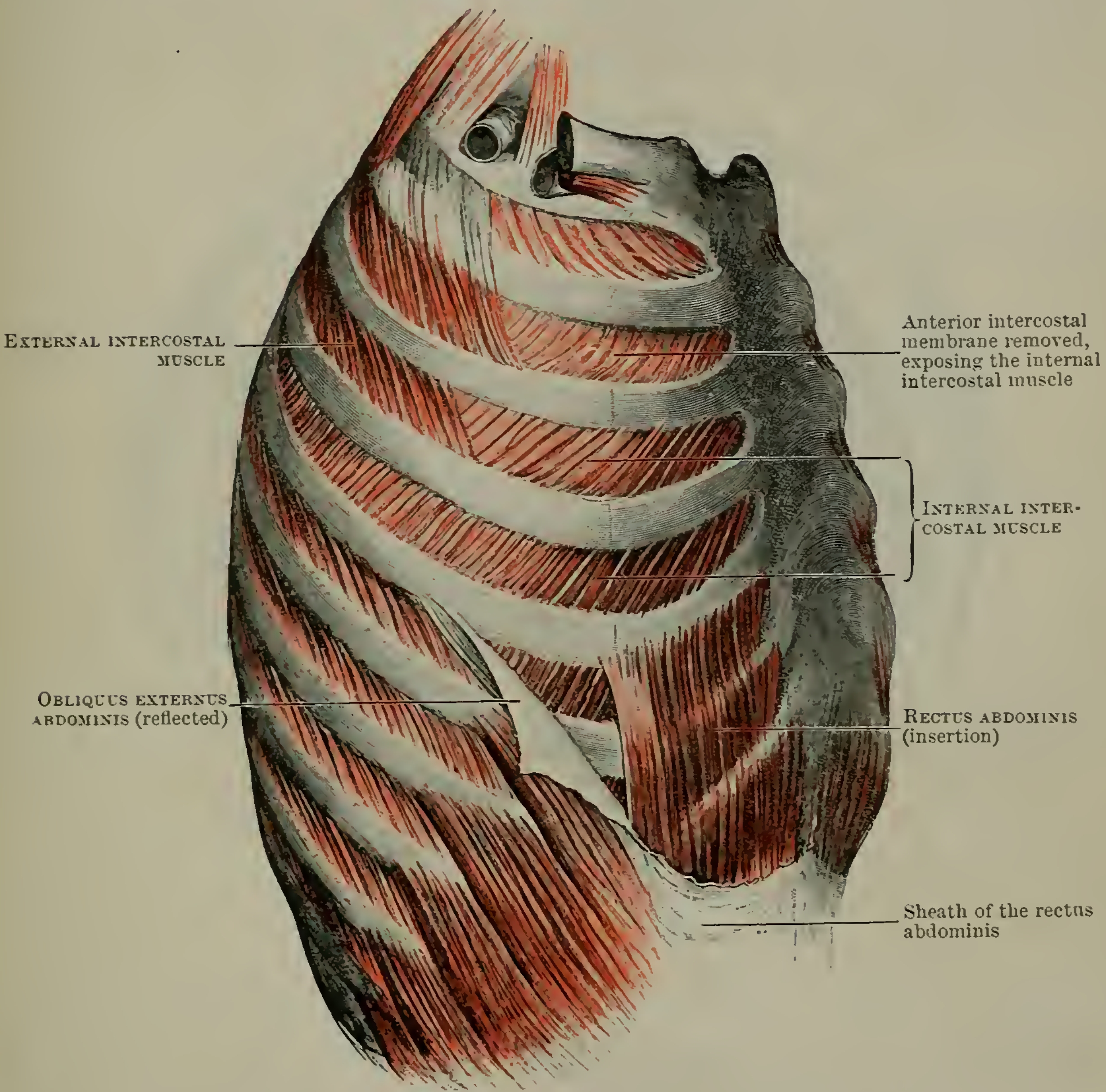
External intercostal muscle
Anterior intercostal membrane removed, exposing the internal intercostal muscle
Internal intercostal muscle
Obliquus externus abdominis (reflected)
Rectus abdominis (insertion)
Sheath of the rectus abdominis

Fig. 393.—The Muscles of the Right Side of the Thoracic Wall.

Each **internal muscle arises** from the costal cartilage and the internal or superior edge of the costal groove, and is directed inferiorly and posteriorly, to be **inserted** into the internal edge of the superior border of the rib and costal cartilage below. It extends from the side of the sternum anteriorly to the angle of the rib posteriorly, where it is replaced by the *posterior intercostal aponeurosis* extending to the tubercle of the rib.

The superficial surface of the external muscle is covered by the muscles of the chest, axilla, abdomen, and back. The deep surface of the internal muscle is in contact with the pleura.

Mm. Levatores Costarum.—The **levatores costarum** are in series with the external intercostal muscles. They are twelve small slips **arising** from the transverse processes of the seventh cervical and upper eleven thoracic vertebræ. Each spreads out in a fan-like manner as it descends to the external surface of the rib immediately below, into which it is **inserted** medial to the angle.

Mm. Subcostales.—The **subcostal muscles** are slips of muscles found on the internal surface of the lower ribs near their angles. They are in series with the internal intercostal muscles, but pass over the deep surfaces of several ribs.

M. Transversus Thoracis.—The **transversus thoracis** occupies the posterior aspect of the anterior thoracic wall, and is separated from the costal cartilages by the internal mammary vessels. It **arises** from the posterior surface of the xiphoid process and body of the sternum as high as the level of the third costal cartilage.

From that origin its fibres radiate laterally, the lower horizontally, the upper fibres obliquely upwards, to be **inserted** into the second, third, fourth, fifth, and sixth costal cartilages. The muscle is continuous below with the transversus abdominis.

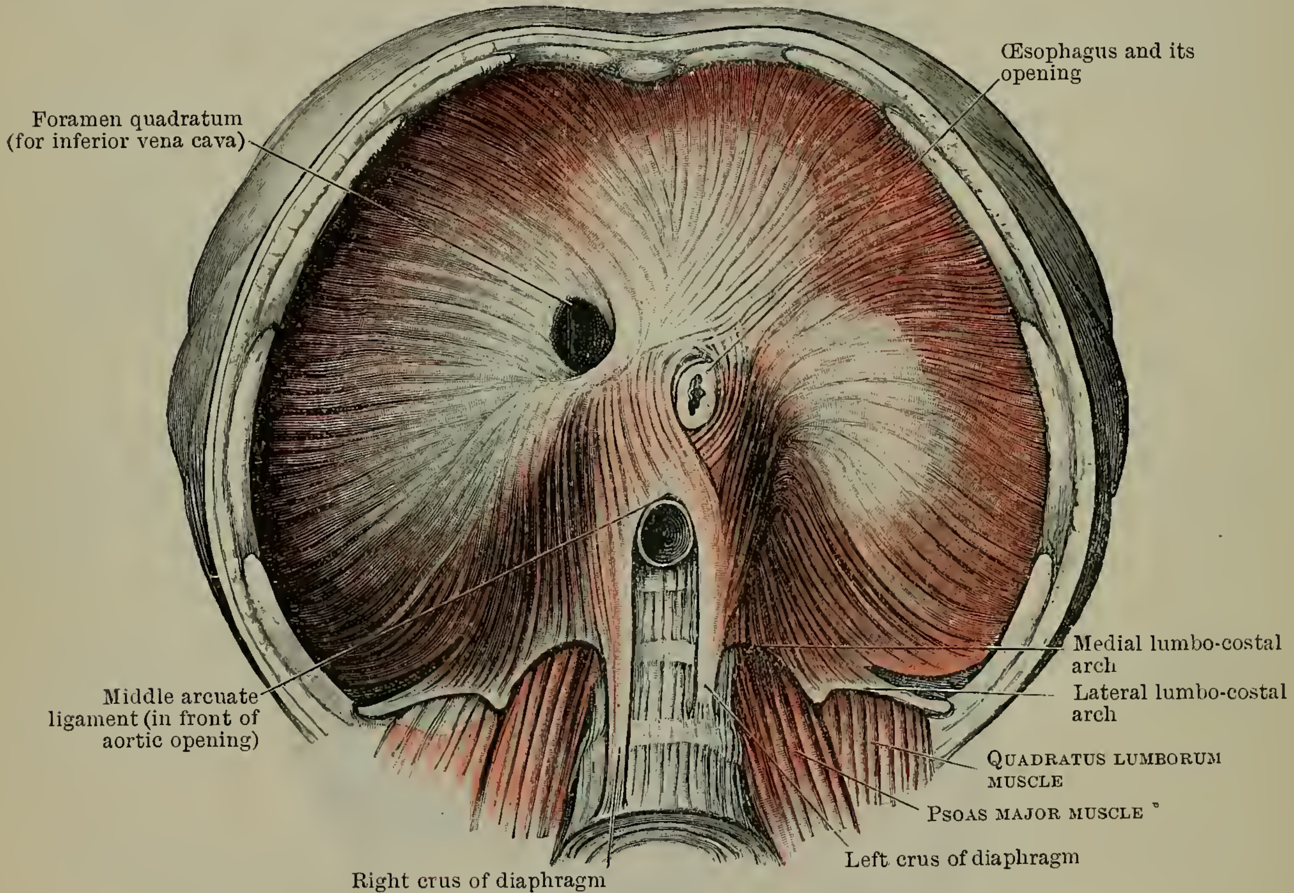
Œsophagus and its opening
Foramen quadratum (for inferior vena cava)
Medial lumbo-costal arch
Lateral lumbo-costal arch
Middle arcuate ligament (in front of aortic opening)
QUADRATUS LUMBORUM MUSCLE
PSOAS MAJOR MUSCLE
Left crus of diaphragm
Right crus of diaphragm

FIG. 394.—THE DIAPHRAGM (from below).

Diaphragma.—The **diaphragm** is the great membranous and muscular partition separating the cavities of the thorax and abdomen. It forms a thin lamella arching over the abdominal cavity, and clothed on that surface, for the most part, by peritoneum. It is related, on its inferior concave surface, to the liver, stomach, and spleen, the kidneys and suprarenal glands, and the vena cava inferior. Its superior convex surface projects into the thoracic cavity, rising higher on the right than on the left side, and is related to the pericardium and pleuræ, and along its margin to the chest wall. The œsophagus and thoracic aorta are in contact with this surface posteriorly.

It possesses a peripheral origin from the sternum, ribs, and vertebral column, and an insertion into a central tendon. It **arises** (1) *anteriorly* (**pars sternalis**), from the posterior surface of the xiphoid process by two slender fleshy slips, directed backwards; (2) *laterally* (**pars costalis**), from the deep surface of the lower six costal cartilages on each side by fleshy bands which interdigitate with those of the transversus abdominis; (3) *posteriorly* (**pars lumbalis**), from the lumbar vertebræ, by the crura, and the medial and lateral lumbo-costal arches. The **crura** are two elongated fibro-muscular bundles which arise, on each side of the aorta, from the anterior surfaces of the bodies of the lumbar vertebræ, on the right side from the first three, on the left side from the first two lumbar vertebræ, as a general rule. They are separated from the vertebral bodies by the upper lumbar arteries, but are firmly attached to their margins and to the invertebral fibro-cartilages. The crura are directed upwards and decussate across the median plane in front of the aorta, the fibres of the right crus passing anterior to those of the left crus. The fibres then encircle the œsophagus, forming an elliptical opening for its passage, and finally join the central tendon, after a second decussation anterior to the gullet.

The medial part of each crus is wholly tendinous and is sometimes called the *crus mediale*; it is connected with its fellow of the opposite side by a tendinous band called the **middle arcuate ligament**, which arches between them, in front of the aorta, and gives origin to fibres which join the crura as they decussate to encircle the gullet. The most outlying part of the crus is sometimes called the *crus laterale*; it arises below from the medial lumbo-costal arch. The intermediate part of the crus is the *crus intermedium*; the splanchnic nerves pierce the diaphragm between it and the medial crus. The sympathetic trunk sometimes pierces the diaphragm between the intermediate and lateral crura.

The **arcus lumbocostalis medialis** is an oblique, linear thickening. Medially, it is attached to the side of the body of the second (sometimes first), laterally to the tip of the transverse process of the first lumbar vertebra. Stretching across the superior end of the psoas muscle, the ligament gives origin to muscular fibres which join the fibres of the crus.

The **arcus lumbocostalis lateralis** is the thickened superior border of the fascia over the quadratus lumborum muscle and is attached medially to the transverse process of the first lumbar vertebra, and laterally to the last rib. It gives origin to a broad band of muscular fibres, which sweep upwards to the central tendon. Not infrequently an interval separates these fibres from those which arise from the medial lumbo-costal arch. In these cases the kidney and the lower limit of the pleura are intimately related.

From this extensive origin the muscular fibres of the diaphragm converge to an **insertion** into a large trilobed **central tendon** called the **centrum tendineum**. Of its lobes the right one is the largest, the middle or anterior is intermediate in size, and the left is the smallest. It does not occupy the centre of the muscle, being placed nearer the front than the back. The fibres of the crura are consequently the longest; those from the xiphoid process are the shortest.

The diaphragm is pierced by numerous structures. The superior epigastric artery enters the sheath of the rectus abdominis between its sternal and costal origins; the musculo-phrenic artery passes between its attachments to the seventh and eighth ribs. The splanchnic nerves pierce the crura and the sympathetic trunk descends behind the medial end of the medial lumbo-costal arch. The last thoracic nerve and the subcostal vessels pass behind the lateral lumbo-costal arch; and the aorta and thoracic duct pass between the crura, underneath the middle arcuate ligament (*hiatus aorticus* or *aortic opening*). The azygos vein is usually described as passing through the aortic opening, but it is placed postero-lateral to the thoracic duct and completely under cover of the right crus, a position which it usually gains by passing under cover of its lateral border. The special foramina are two in number. The *foramen venæ cavæ* in the right lobe of the central tendon transmits the inferior vena cava, and small branches of the right phrenic nerve. The *hiatus œsophageus* (*œsophageal opening*) is in the muscular substance of the diaphragm, posterior to the central tendon, and is surrounded by a sphincter-like arrangement of the crural fibres. Besides the œsophagus, this opening transmits the two vagi nerves.

The comparative morphology of the diaphragm and its derivation from the fourth cervical myotome are summarised on p. 479.

Nerve-Supply.—The intercostal muscles, levatores costarum, subcostal muscles, and transversus thoracis are all supplied by the anterior rami of the **thoracic nerves**. The diaphragm receives its chief, if not its entire, motor supply from the **phrenic nerves** (C. 3. 4. 5.). It is innervated also by the diaphragmatic plexus of the sympathetic, and is sometimes said to receive fibres from the lower thoracic nerves.

Actions.—The act of respiration consists of two opposite movements—inspiration and expiration.

The **movement of inspiration** results in an increase in the capacity of the thorax which is partly brought about by muscles acting on the ribs, sternum, and vertebral column, and partly by the diaphragm. The transverse diameter of the thorax is increased by elevation and eversion of the ribs, and these movements are produced, during quiet respiration, by the intercostals (both groups), the subcostals, and the levatores costarum. As a result of the elevation of the ribs the sternum is thrust forwards, particularly in its lower part, thus increasing the thoracic capacity in an antero-posterior direction.

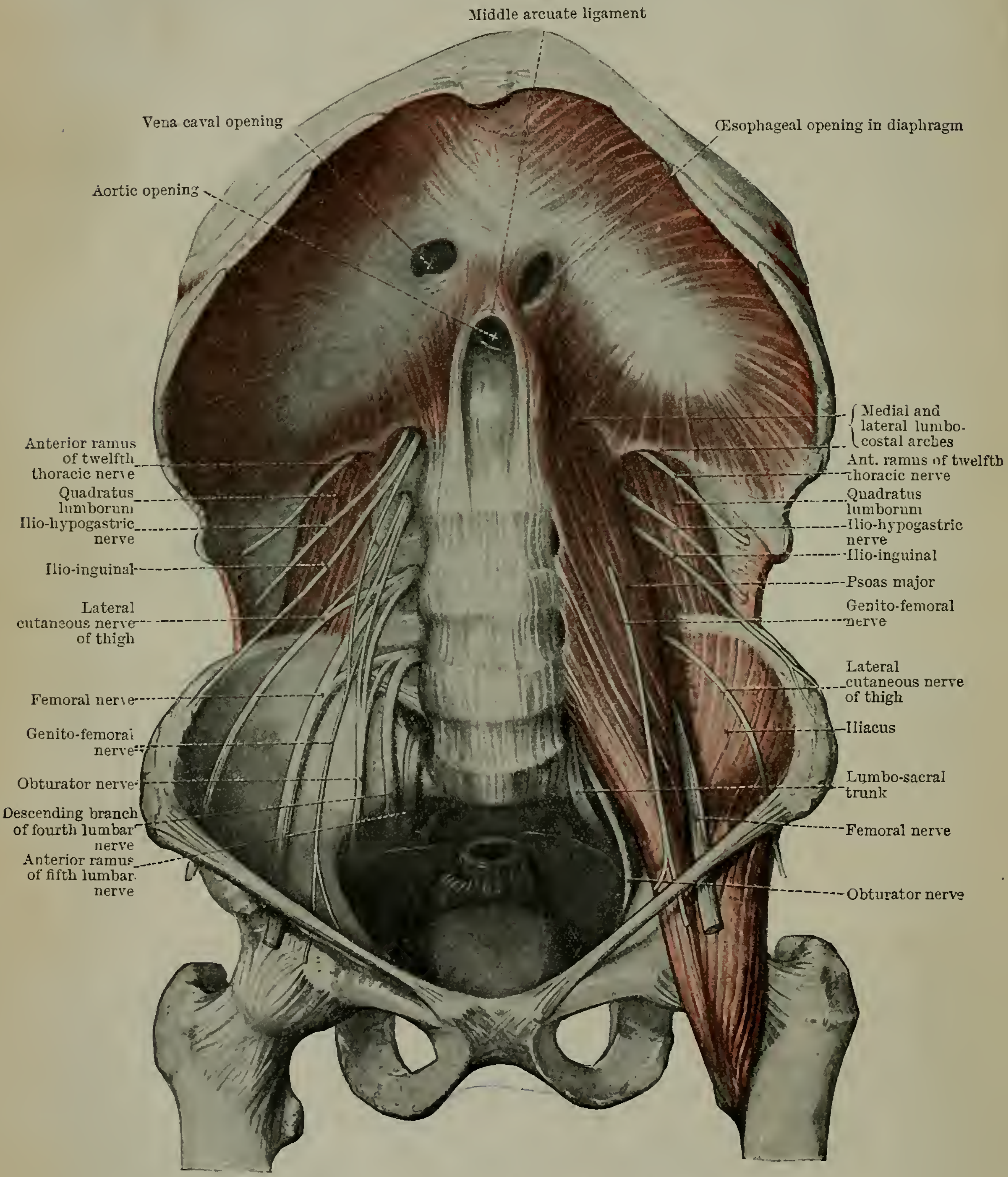

Fig. 395.—The Diaphragm and Posterior Abdominal Wall.

In forced inspiration, the transverse and antero-posterior diameters of the thorax are further increased by elevation of the first rib, elevation and forward movement of the upper part of the sternum, and diminution of the concavity of the curve of the thoracic part of the vertebral column, accompanied by further elevation and eversion of the ribs (2–8). Elevation of the first rib is produced by the scalenus anterior and medius muscles, and by the sterno-cleido-mastoid (acting through the sternum, the sterno-clavicular joint, and the costo-clavicular ligament). Elevation and forward movement of the upper part of the sternum necessarily accompany this movement. Extension of the vertebral column by the sacrospinalis renders possible further elevation of the ribs, and this is produced by the action of the serratus anterior and pectoralis minor. For this purpose it is necessary that the scapula should be fixed by the trapezius, the rhomboids, and the levator scapulæ.

The effect of the contraction of the diaphragm is threefold. (1) When relaxed, the fibres of the diaphragm curve upwards over the liver, stomach, and spleen, and the disappearance of this curve and consequent straightening of the fibres, when the muscle contracts, provide a great increase in the depth of the thorax. (2) The central tendon descends to a slight extent. As a result of (1) and (2) the abdominal viscera are thrust downwards and the relaxed abdominal parietes are bulged outwards. (3) The eighth, ninth, tenth, and eleventh ribs are slightly elevated by the diaphragm, but the lower ribs as a whole tend to be thrust outwards by the abdominal viscera, and the twelfth rib is fixed by the quadratus lumborum muscle.

In **the movement of expiration**, diminution of the transverse and antero-posterior diameters is effected by the elastic recoil of the costal cartilages and the weight of the thoracic skeleton. The depth of the thorax is diminished by the reproduction of the concavity of the cupolæ of the diaphragm. This result is brought about by the contraction of the abdominal muscles. In forced expiration these muscles are reinforced by the latissimus dorsi (p. 372), which exerts a powerful compressing effect, and the vertebral column is flexed, thus allowing the ribs to be still further approximated.

There has been considerable diversity of opinion regarding the action of the intercostal muscles. It is generally agreed that the external muscles elevate the ribs; it is probable that the whole of each internal muscle acts in the same way, although it has been stated by different observers that the whole internal muscle is a depressor; or that the interosseous part is a depressor, the interchondral portion of the muscle an elevator of the ribs.

FASCIÆ AND MUSCLES OF THE ABDOMINAL WALL.

The space between the base of the bony thorax and the pelvis is filled up by a series of muscular sheets, covered externally and internally by fasciæ.

FASCIÆ.

The fasciæ of the abdominal wall are—*externally*, the superficial and deep fasciæ; *internally*, the fascia transversalis, which clothes the deep surface of the anterior and lateral walls of the abdominal cavity, and is continuous with the diaphragmatic, lumbo-dorsal, psoas, iliac, and pelvic fasciæ, and is lined within by the **subserous coat** of extra-peritoneal tissue. In this way a fascial envelope is formed, which encloses the abdominal and pelvic cavities, the retro-peritoneal viscera, and the great vessels.

The **superficial fascia** of the abdomen is liable to contain a large quantity of fat. In the groin it is separated into *two layers*: a superficial fatty layer continuous over the inguinal ligament with the fascia of the anterior surface of the thigh (p. 404), and a deeper membranous layer attached to the medial half of the inguinal ligament, and more laterally to the fascia lata of the thigh distal to the inguinal ligament. The two layers are separated by the lymph glands and the superficial vessels of the groin. Higher up in the abdominal wall the two layers blend together. As they pass downwards over the spermatic funiculus, they are replaced by the fascia and dartos muscle of the scrotum. The attachment of the fascia to the groin prevents the passage into the thigh of fluid extravasated in the abdominal wall.

The **deep fascia** of the abdominal wall resembles similar fasciæ in other situations. It forms an investment for the obliquus externus muscle, and becomes thin and almost imperceptible in relation to the aponeurosis of that muscle.

Fascia Transversalis.—The **fascial lining** of the abdominal cavity consists of a continuous layer of membrane which receives different names in different parts of its extent. The **fascia transversalis** covers the deep surface of the transversus muscle, and is continuous medially with the fasciæ of the quadratus lumborum and the psoas muscles. It is continuous above with the diaphragmatic fascia, and below the iliac crest and the inguinal ligament with the fascia iliaca. Along with the last-named fascia it forms the **femoral sheath**, enclosing the femoral vessels and the femoral canal in their passage to the thigh behind the medial part of the inguinal ligament (p. 478). It is pierced by the spermatic funiculus or round ligament of the uterus at the abdominal inguinal ring, and its prolongation into the inguinal canal around the funiculus forms the **internal spermatic** or **infundibuliform fascia**. It is lined internally by the peritoneum, from which it is separated by a layer of **extraperitoneal tissue**.

The **subserous coat** or **extraperitoneal tissue** is usually loaded with fat; it envelops the kidneys, ureters, suprarenal glands, abdominal aorta, and inferior vena cava and their branches, and forms sheaths for the vessels and ducts (ureter, ductus deferens, etc.). It is continued upwards into the posterior mediastinum of the thorax through the aortic opening in the diaphragm, and below is in continuity with the extraperitoneal tissue in the pelvis. It not only completely invests the kidneys and suprarenal glands, but it also becomes interpolated between the layers of peritoneum upholding and enveloping the intestines. This tissue is absent in relation to the diaphragm, on the under surface of which there is no fat.

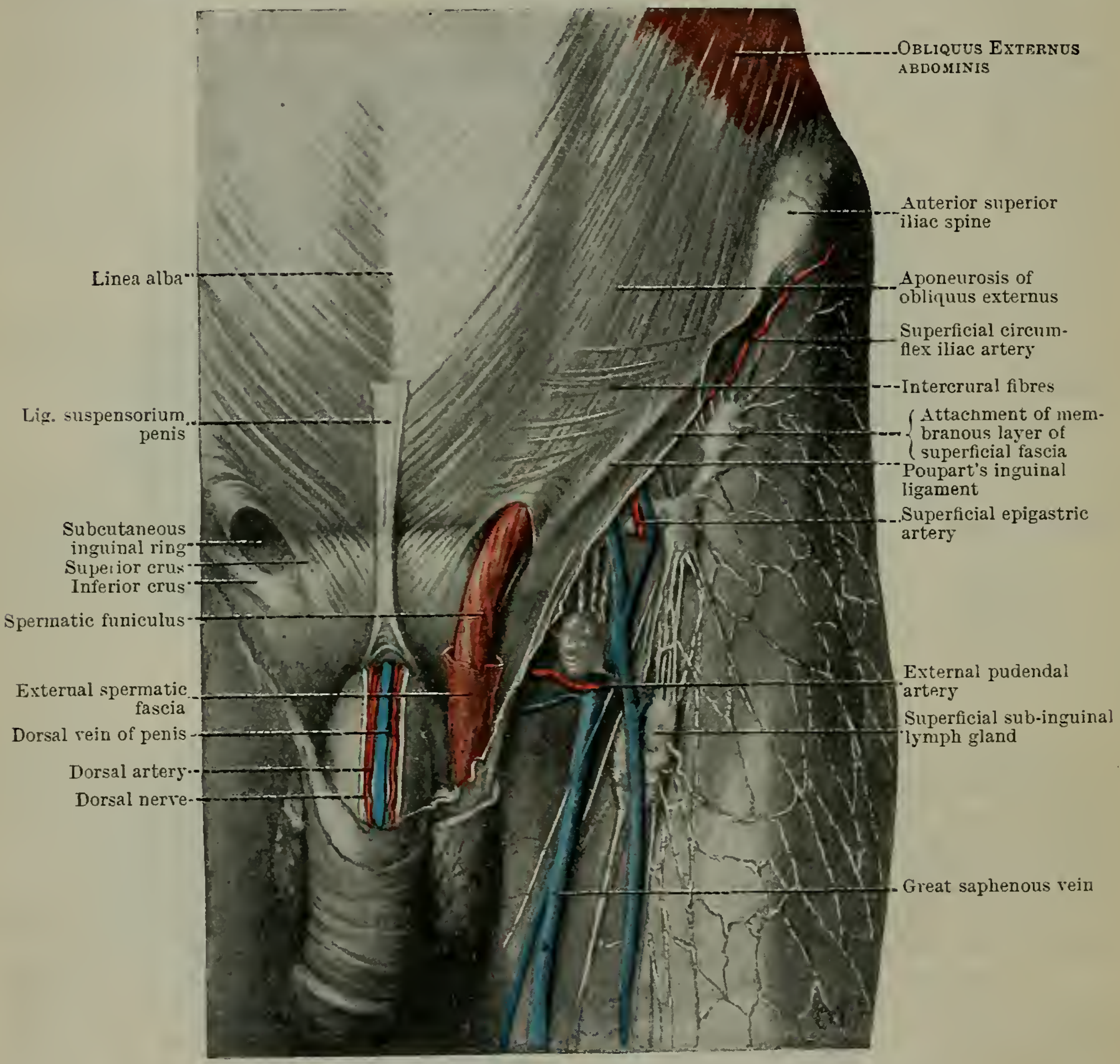
Obliquus Externus abdominis
Anterior superior iliac spine
Linea alba
Aponeurosis of obliquus externus
Superficial circumflex iliac artery
Intercrural fibres
Lig. suspensorium penis
Attachment of membranous layer of superficial fascia
Poupart's inguinal ligament
Superficial epigastric artery
Subcutaneous inguinal ring
Superior crus
Inferior crus
Spermatic funiculus
External pudendal artery
External spermatic fascia
Superficial sub-inguinal lymph gland
Dorsal vein of penis
Dorsal artery
Dorsal nerve
Great saphenous vein

Fig. 396.—Superficial Anatomy of the Groin.

THE MUSCLES OF THE ABDOMINAL WALL.

The muscles of the abdominal wall are in three series—lateral, anterior, and posterior.

The **lateral muscles** of the abdominal wall comprise the obliquus externus abdominis, obliquus internus abdominis, and transversus abdominis.

M. Obliquus Externus Abdominis.—The **obliquus externus abdominis** is a broad thin sheet of muscle, with an **origin** from the lateral surfaces of the lower eight ribs, by slips which interdigitate with the serratus anterior and latissimus dorsi muscles. The muscular fibres radiate downwards and forwards, the lowest fibres passing vertically downwards.

The muscle fibres of the lower and posterior part of the muscle are **inserted**, directly, into the external lip of the iliac crest in its anterior half or two-thirds (Fig. 343, p. 417). The rest of the muscle fibres are inserted into an extensive triangular aponeurosis which forms part of the anterior abdominal wall. This aponeurosis is broader below than above; it is united with part of the aponeurosis of the obliquus internus in the superior three-fourths of its extent, and with the whole aponeurosis of that muscle as well as with that of the transversus abdominis in its lower fourth, thus forming the anterior wall of the **sheath of the rectus muscle.** It thus gains attachments, below to the symphysis pubis, above to the xiphoid process, and by its intermediate fibres to the **linea alba.**

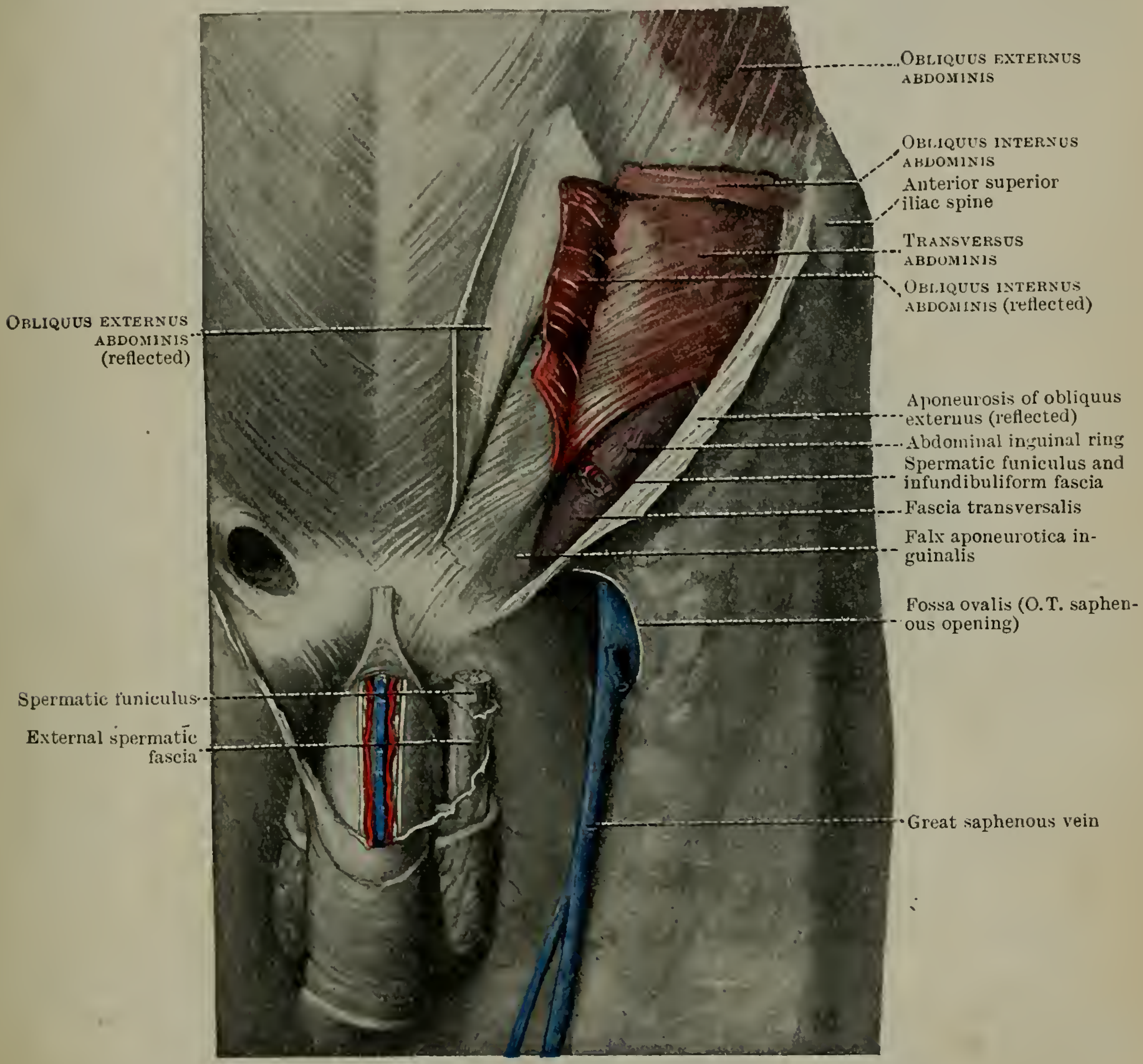
Obliquus externus abdominis
Obliquus internus abdominis
Anterior superior iliac spine
Transversus abdominis
Obliquus internus abdominis (reflected)
Obliquus externus abdominis (reflected)
Aponeurosis of obliquus externus (reflected)
Abdominal inguinal ring
Spermatic funiculus and infundibuliform fascia
Fascia transversalis
Falx aponeurotica inguinalis
Fossa ovalis (O.T. saphenous opening)
Spermatic funiculus
External spermatic fascia
Great saphenous vein

Fig. 397.—The Dissection of the Inguinal Canal.

The **linea alba** is a band of interlacing fibres, narrow below the umbilicus but increasing to about half an inch in width in its upper part. It occupies the median plane of the anterior abdominal wall in its whole extent, is pierced by the umbilicus (**annulus umbilicalis**), and forms the greater part of the ultimate insertion of all the lateral abdominal muscles.

The fleshy fibres of the muscle do not extend forwards as far as the linea semilunaris nor downwards below the level of the anterior superior iliac spine (Fig. 399, p 479).

The superior part of the aponeurosis covers the insertion of the rectus abdominis muscle on the chest wall, and gives origin to fibres of the pectoralis major. Inferiorly, in the groin, the lower part of the aponeurosis gives rise to the inguinal ligament, the ligamentum lacunare, the two crura of the subcutaneous inguinal ring, the external spermatic fascia and the intercrural fibres, and the ligamentum inguinale reflexum of Colles.

Lig. Inguinale [Poupart's].—The **inguinal ligament** is an aponeurotic band which extends from the anterior superior iliac spine to the tubercle of the pubis, arching over the iliacus, psoas, and pectineus muscles. It represents the inferior margin of the aponeurosis of the obliquus externus abdominis which is folded back upon itself, so as to present a grooved upper surface. Its lower convex surface gives attachment below to the iliac portion of the fascia lata of the thigh. Its upper surface affords partial origin to the obliquus internus and transversus muscles, and receives the attachment of the fascia transversalis and fascia iliaca in its lateral part; in its medial part it forms the gutter-like floor of the inguinal canal. At its medial end a triangular band of fibres is reflected horizontally backwards to the ilio-pectineal line, forming the **lig. lacunare [Gimbernat's]**, the lateral edge of which forms the medial boundary of the **femoral ring.** The femoral vessels, enclosed in the femoral sheath, enter the thigh posterior to the inguinal ligament, on the anterior surface of the psoas major muscle, and the term *superficial femoral arch* is given to the part of the ligament which covers the vessels.

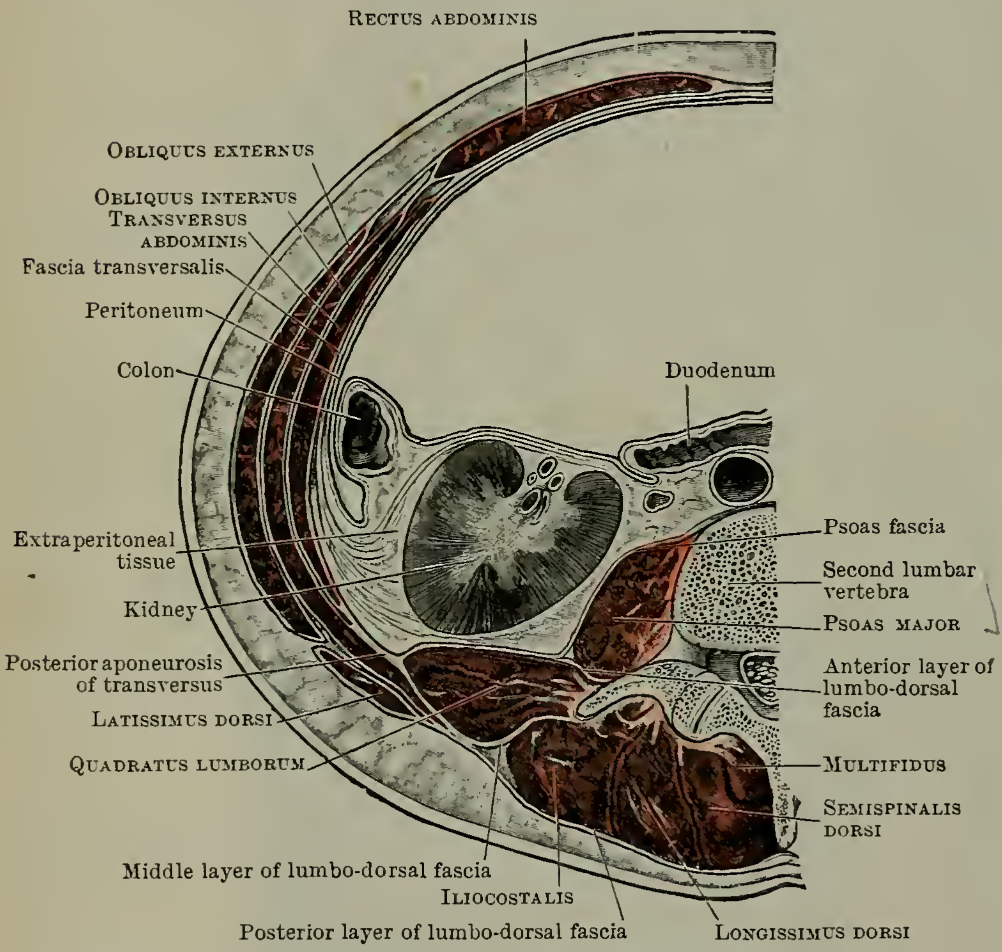

Fig. 398.—Transverse Section through the Abdomen, opposite the Second Lumbar Vertebra.

Annulus Inguinalis Subcutaneus.—The **subcutaneus inguinal ring** (O.T. **external abdominal ring**), the place of exit of an inguinal hernia, is a split in the aponeurosis of the obliquus externus, just above the tubercle of the pubis. It transmits the spermatic funiculus, or (in the female) the round ligament of the uterus, covered by the cremaster muscle or cremasteric fascia. The opening is of considerable extent, and its edges are drawn together by a thin fascia, strengthened superficially by a number of arched and horizontal fibres, called the **intercrural fibres**, which arise from the inguinal ligament and sweep medially across the cleft in the aponeurosis.

The margins of the ring constitute its crura. The **inferior crus** is narrow, and is formed from that part of the aponeurosis which joins the pubic tubercle, and is continuous with the medial end of the inguinal ligament. The **superior crus** is the part of the aponeurosis medial to the ring which is attached to the crest and symphysis of the pubis. It is flat and broad.

The intercrural fibres and the crura of the subcutaneous inguinal ring are continuous with a thin tubular sheath, the **intercolumnar or external spermatic fascia,** which forms an envelope for the spermatic funiculus or round ligament after they have passed beyond the abdominal wall.

Lig. Inguinale Reflexum Collesi.—The **reflexed inguinal ligament of Colles** (O.T. **triangular fascia**) is a triangular band of fibres placed behind the (medial) superior crus of the subcutaneous inguinal ring. It consists of fibres from the *opposite* external oblique aponeurosis, which, having traversed the linea alba, gain an insertion into the front of the pubis. It is placed in front of the falx inguinalis (O.T. **conjoined tendon**) and, when well developed, is covered by the spermatic cord as it emerges from the subcutaneous inguinal ring.

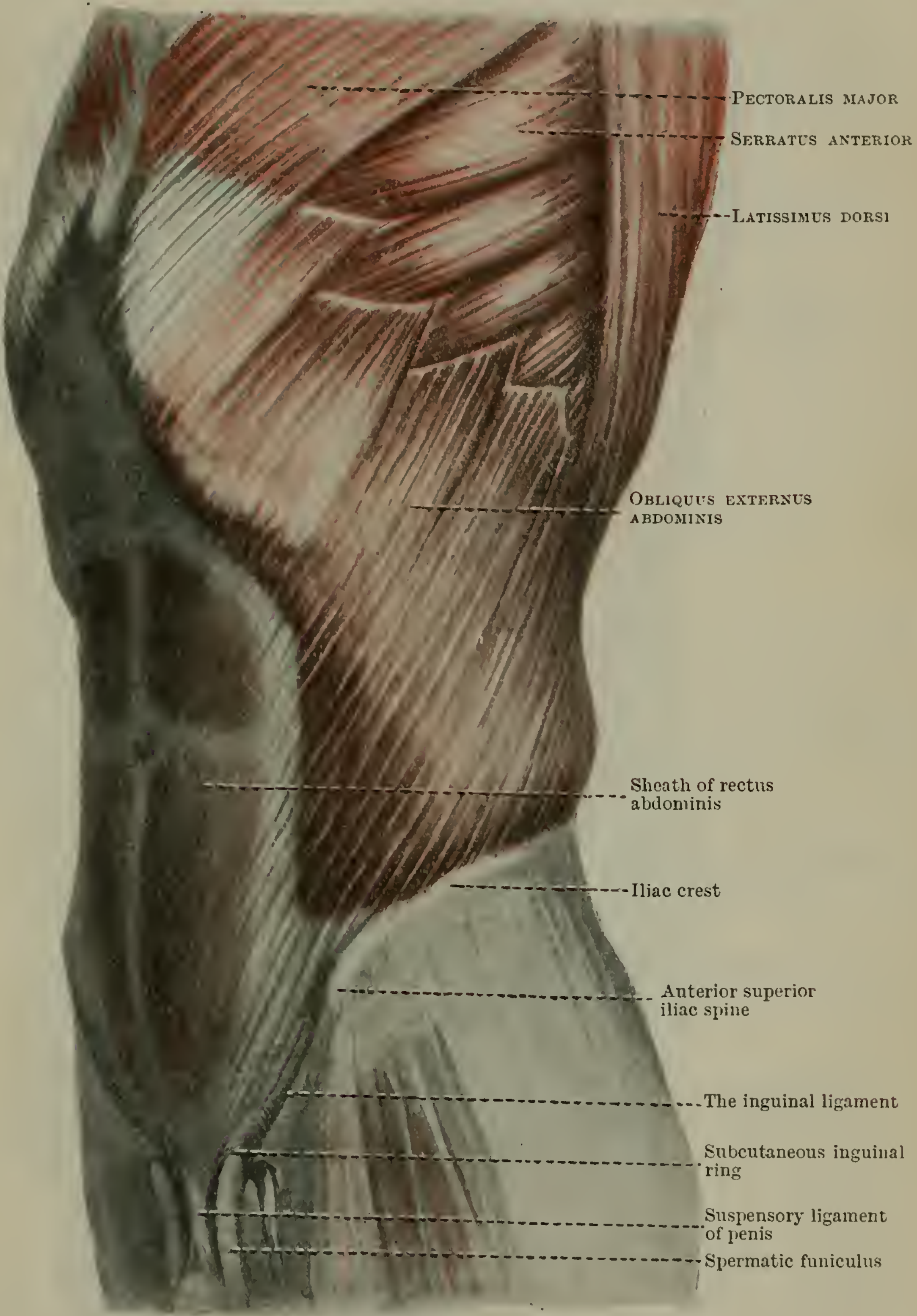
PECTORALIS MAJOR
SERRATUS ANTERIOR
LATISSIMUS DORSI
OBLIQUUS EXTERNUS ABDOMINIS
Sheath of rectus abdominis
Iliac crest
Anterior superior iliac spine
The inguinal ligament
Subcutaneous inguinal ring
Suspensory ligament of penis
Spermatic funiculus

FIG. 399.—THE LEFT OBLIQUUS EXTERNUS ABDOMINIS

The obliquus externus muscle is superficial in almost its whole extent. It is overlapped posteriorly by the latissimus dorsi muscle, but may be separated from it just above the iliac crest by an angular interval (**trigonum lumbale** or triangle of Petit).

M. Obliquus Internus Abdominis.—The **obliquus internus abdominis** is a broad thin sheet of muscle which lies between the obliquus externus and the transversus. It arises from (1) the lumbo-dorsal fascia, (2) the anterior two-thirds of the iliac crest, and (3) the lateral half of the inguinal ligament.

It runs for the most part, upwards and forwards, and its highest fibres are **inserted** directly into the last three ribs. The rest of the fibres extend almost to the linea semilunaris, where they give place to an aponeurosis, which at once splits to form, along with the aponeuroses of the obliquus externus and transversus muscles, the **sheath of the rectus abdominis**, and is **inserted** into the ninth, eighth, and seventh costal cartilages, and into the linea alba from the xiphoid process to the symphysis pubis. The fibres arising from the inguinal ligament join with those of the transversus muscle having a similar origin to form the **falx aponeurotica inguinalis** (O.T. **conjoined tendon**), which passes altogether anterior to the rectus muscle, to be attached to the pubic crest and tubercle, and to the ilio-pectineal line.

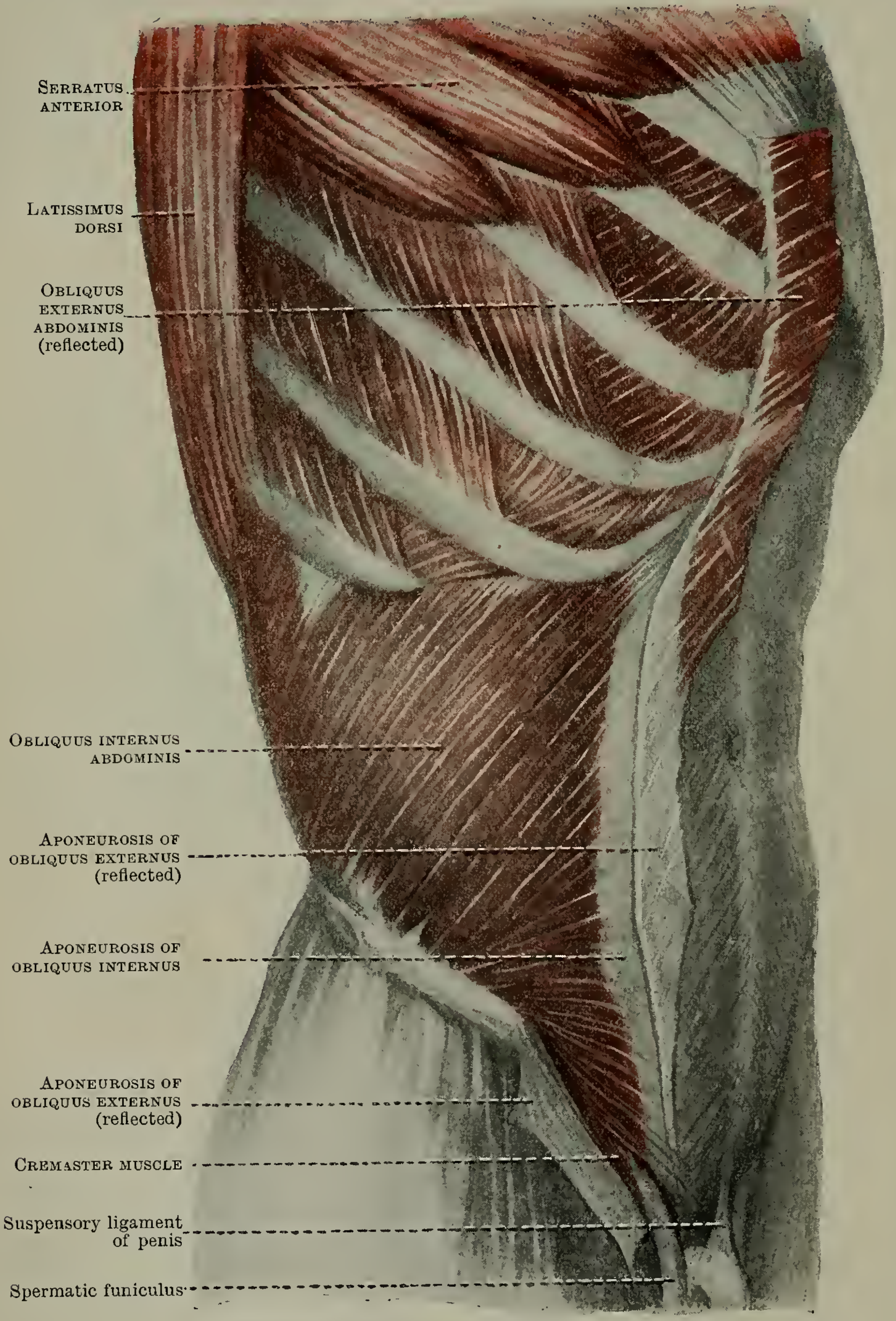
SERRATUS ANTERIOR
LATISSIMUS DORSI
OBLIQUUS EXTERNUS ABDOMINIS (reflected)
OBLIQUUS INTERNUS ABDOMINIS
APONEUROSIS OF OBLIQUUS EXTERNUS (reflected)
APONEUROSIS OF OBLIQUUS INTERNUS
APONEUROSIS OF OBLIQUUS EXTERNUS (reflected)
CREMASTER MUSCLE
Suspensory ligament of penis
Spermatic funiculus

FIG. 400.—THE RIGHT OBLIQUUS INTERNUS ABDOMINIS.

The obliquus internus is limited above by the inferior margin of the thorax. Its lower fibres, arching over the spermatic funiculus, assist in forming, laterally, the anterior wall of the inguinal canal; medially, by means of the falx inguinalis, they help to form the posterior wall of the canal.

Its lowest fibres are continued into the **cremaster muscle**, which is prolonged along the spermatic cord through the inguinal canal.

M. Cremaster.—The **cremaster muscle** forms an investment for the testis and spermatic funiculus deep to the external spermatic fascia. In the female it is more largely represented by fascia than muscular fibres, and constitutes the **cremasteric fascia.** It may be said to have an **origin** from the inferior edge of the obliquus internus and the adjacent part of the inguinal ligament. Its fibres form loops over the spermatic funiculus and testis, the highest fibres getting an **insertion** into the pubic tubercle.

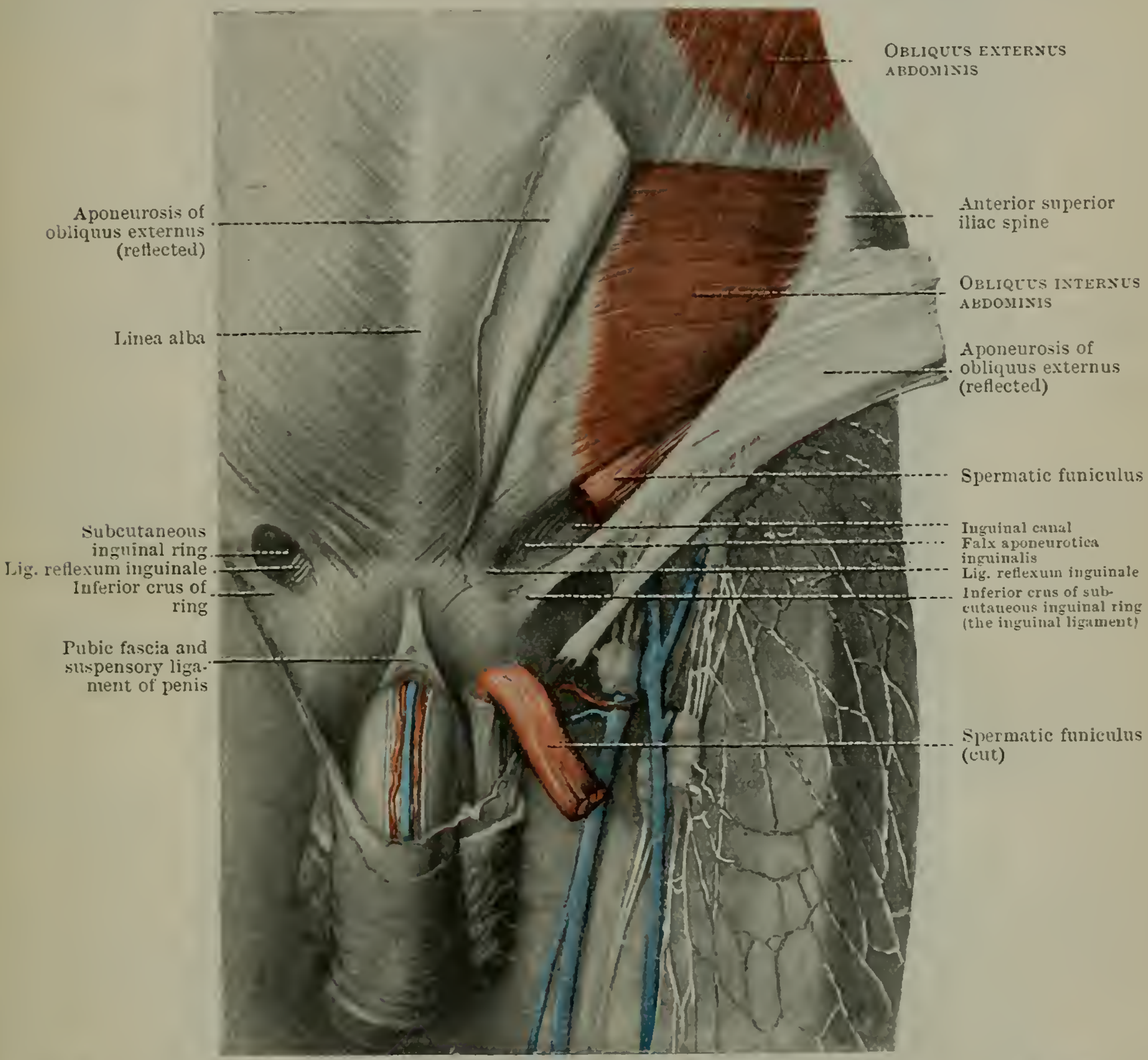
Obliquus externus abdominis
Aponeurosis of obliquus externus (reflected)
Anterior superior iliac spine
Linea alba
Obliquus internus abdominis
Aponeurosis of obliquus externus (reflected)
Spermatic funiculus
Subcutaneous inguinal ring
Lig. reflexum inguinale
Inferior crus of ring
Inguinal canal
Falx aponeurotica inguinalis
Lig. reflexum inguinale
Inferior crus of subcutaneous inguinal ring (the inguinal ligament)
Pubic fascia and suspensory ligament of penis
Spermatic funiculus (cut)

FIG. 401.—THE LEFT INGUINAL CANAL. STRUCTURES SEEN ON REFLEXION OF THE OBLIQUUS EXTERNUS.

M. Transversus Abdominis.—The **transversus abdominis muscle** arises (1) from the deep surfaces of the costal cartilages of the lower six ribs, interdigitating with the origins of the diaphragm; (2) from the lumbo-dorsal fascia; (3) from the anterior two-thirds of the internal lip of the iliac crest; and (4) from the lateral third of the inguinal ligament.

The muscular fibres run, for the most part, horizontally forwards, and end in an aponeurosis which has a twofold **insertion.** (1) After taking part in the formation of the sheath of the rectus, the aponeurosis is attached to the xiphoid process, the whole length of the linea alba, and the symphysis pubis. (2) The inferior fibres of the muscle arising from the inguinal ligament are joined by the inferior part of the obliquus internus to form the larger part of the **falx aponeurotica inguinalis** (O.T. **conjoined tendon**), which passes anterior to the inferior part of the rectus muscle, to be inserted into the front of the pubis, the pubic tubercle, and the ilio-pectineal line.

The aponeurosis of the transversus abdominis is widest opposite the interval between the last rib and the iliac crest, and it gradually becomes narrower above and below this region. Below the xiphoid process it is barely 3 cm. wide, and in this situation fleshy fibres of the muscle are separated from the rectus abdominis only by the posterior lamella of the aponeurosis of the obliquus internus (Fig. 403, p. 483).

The transversus muscle is separated by the lower intercostal nerves from the obliquus internus muscle, and is lined on its deep surface by the fascia transversalis. Its inferior border forms a concave edge, separated from the inguinal ligament by a lunular interval in which the fascia transversalis appears, and through which the spermatic funiculus emerges at the abdominal inguinal ring, under cover of the obliquus internus muscle and the aponeurosis of the obliquus externus.

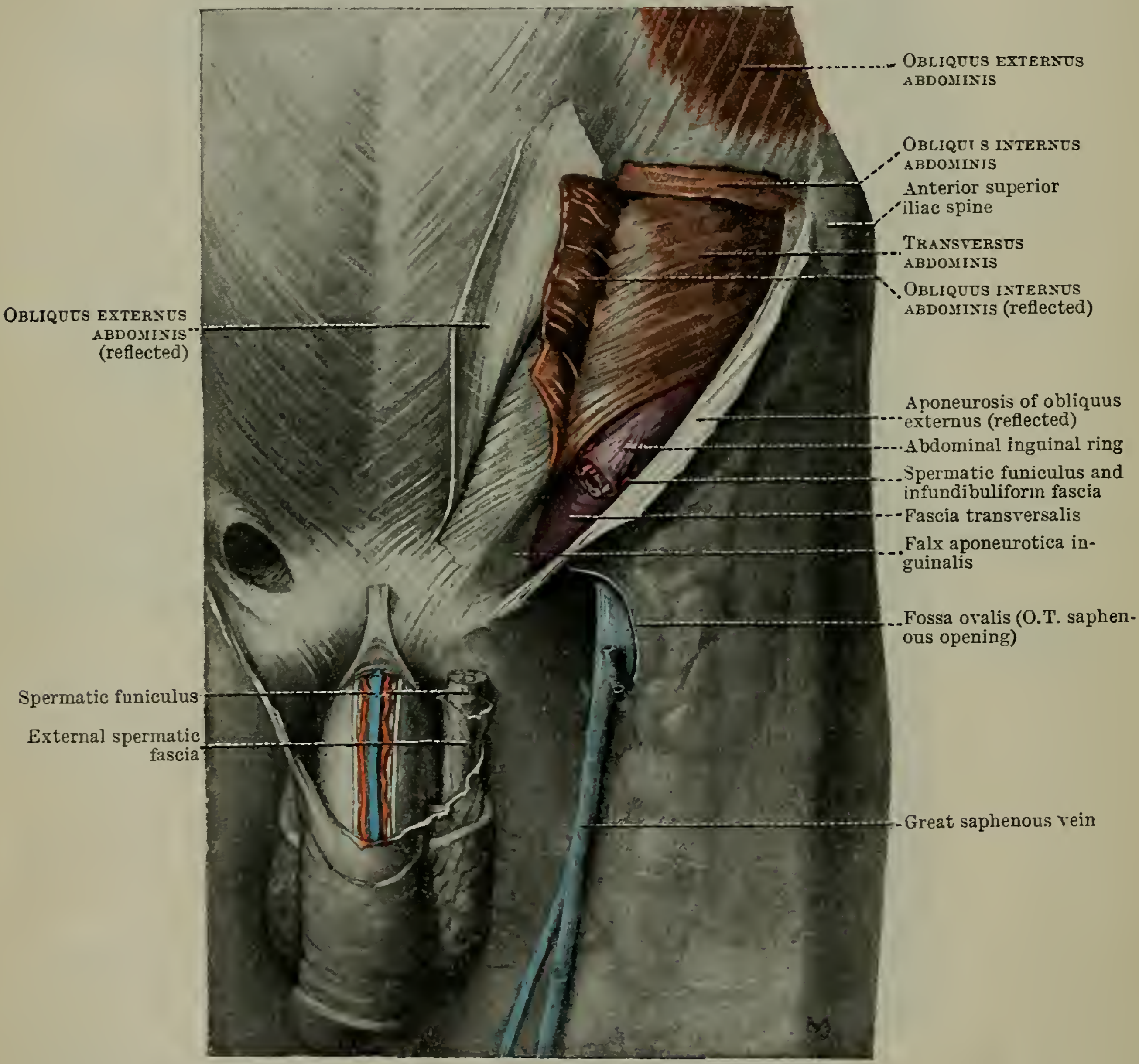
Obliquus externus abdominis
Obliquus internus abdominis
Anterior superior iliac spine
Transversus abdominis
Obliquus internus abdominis (reflected)
Obliquus externus abdominis (reflected)
Aponeurosis of obliquus externus (reflected)
Abdominal inguinal ring
Spermatic funiculus and infundibuliform fascia
Fascia transversalis
Falx aponeurotica inguinalis
Fossa ovalis (O.T. saphenous opening)
Spermatic funiculus
External spermatic fascia
Great saphenous vein

Fig. 402.—The Dissection of the Inguinal Canal.

The **anterior muscles** of the abdominal wall include the pyramidalis and rectus abdominis, enveloped by the sheath of the rectus, on each side of the linea alba.

M. Pyramidalis Abdominis.—The **pyramidalis abdominis** is a small triangular muscle **arising** from the front of the pubis, below the rectus muscle (Fig. 403, p. 483).

It is directed obliquely upwards, to be **inserted**, for a variable distance, into the linea alba. The muscle is often absent.

M. Rectus Abdominis.—The **rectus abdominis muscle** is broad and strap-like, and **arises** by a medial head from the ligaments in front of the symphysis pubis, many of the fibres coming from the opposite side, and by a lateral head from the crest of the pubis (Fig. 340, p. 414).

The muscle expands as it passes upwards, and is **inserted**, from medial to lateral side, into the anterior surface of the xiphoid process (Fig. 304, p. 374), and into the superficial surfaces of the seventh, sixth, and fifth costal cartilages. On its anterior surface, but not extending through the entire substance of the muscle, are three or more transverse tendinous intersections (**inscriptiones tendineæ**), firmly adherent to the sheath of the muscle; the lowest opposite the umbilicus, and the highest about the level of the xiphoid process. The medial border of the muscle lies alongside the linea alba; its lateral border is convex, and corresponds to the **linea semilunaris**. The muscle is pierced by the terminal branches of the lower thoracic nerves.

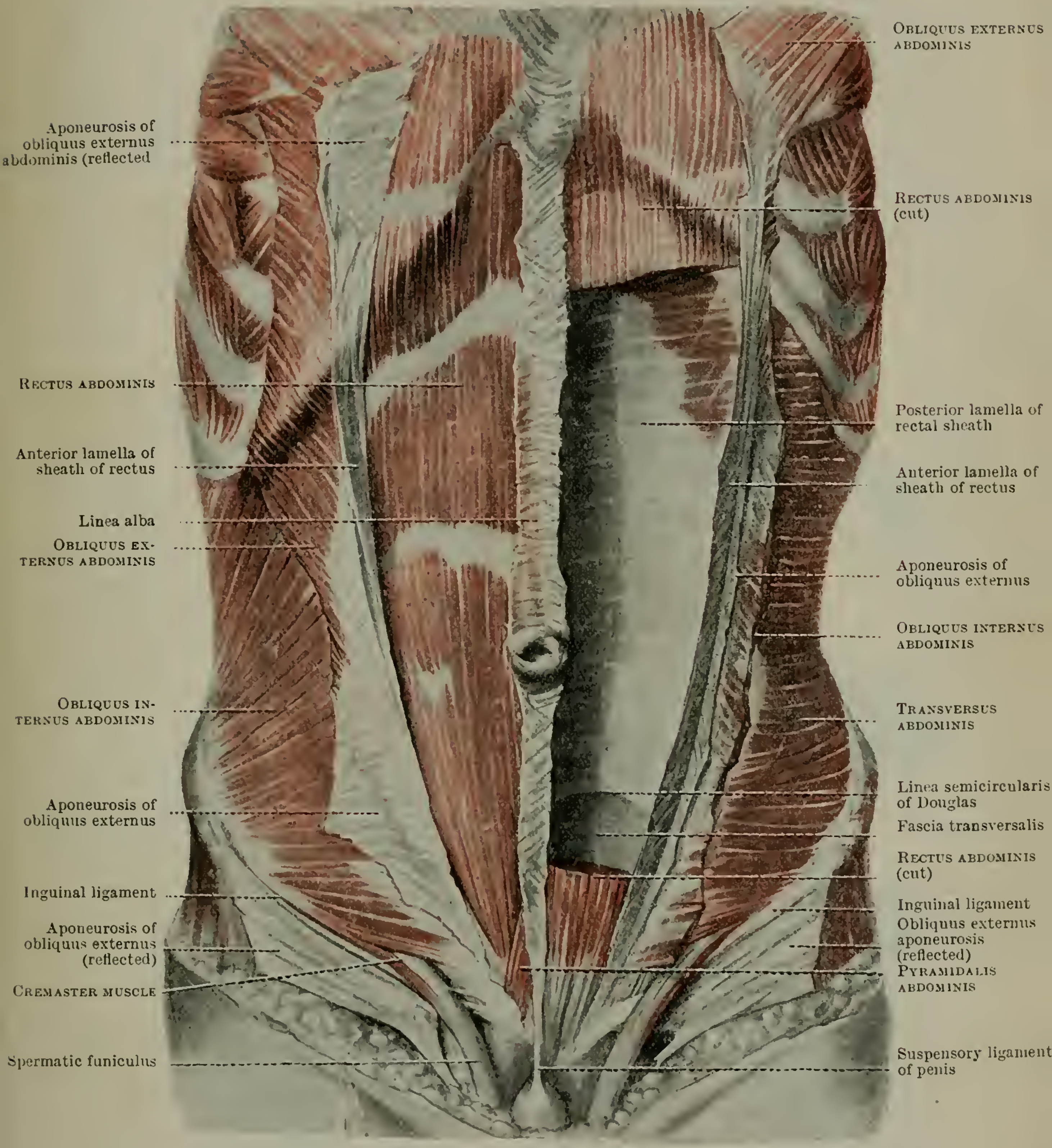
Obliquus externus abdominis
Aponeurosis of obliquus externus abdominis (reflected
Rectus abdominis (cut)
Rectus abdominis
Posterior lamella of rectal sheath
Anterior lamella of sheath of rectus
Anterior lamella of sheath of rectus
Linea alba
Obliquus externus abdominis
Aponeurosis of obliquus externus
Obliquus internus abdominis
Obliquus internus abdominis
Transversus abdominis
Linea semicircularis of Douglas
Aponeurosis of obliquus externus
Fascia transversalis
Rectus abdominis (cut)
Inguinal ligament
Inguinal ligament
Obliquus externus aponeurosis (reflected)
Aponeurosis of obliquus externus (reflected)
Pyramidalis abdominis
Cremaster muscle
Spermatic funiculus
Suspensory ligament of penis

FIG. 403.—DEEP DISSECTION OF THE ABDOMINAL WALL. THE RECTUS MUSCLE AND ITS SHEATH.

Vagina M. Recti Abdominis.—The **sheath of the rectus muscle** is derived from the aponeuroses of the lateral muscles of the abdominal wall, which, after enclosing the muscle, give rise, in the median plane, to the linea alba. At the linea semilunaris along the lateral border of the rectus muscle, the aponeurosis of the obliquus internus splits into anterior and posterior layers. The anterior layer, joined by the aponeurosis of the obliquus externus, passes in front of the rectus, and constitutes the anterior lamina of the sheath. The posterior layer, joined by the aponeurosis of the transversus muscle, passes behind the rectus, and constitutes the posterior lamina of its sheath. This arrangement obtains in the superior three-fourths of the abdominal wall. Below the level of the iliac crest the sheath of the muscle is deficient posteriorly, and a crescentic border, the **linea semicircularis (semilunar fold of Douglas)**, marks the inferior limit of the posterior lamina. In consequence, the rectus in the lower fourth of the abdominal wall rests directly upon the fascia transversalis. Close examination, however, usually reveals a thin layer behind the muscle in continuity with the fold of Douglas, and merging below with the fascia transversalis. In this region the rectus is covered anteriorly by the aponeurosis of the obliquus externus, obliquus internus and transversus (Fig. 404). The superior part of the rectus, lying on the chest wall, is only covered anteriorly by a single layer of aponeurosis derived from the obliquus externus, which in this situation is giving origin to the pectoralis major muscle.

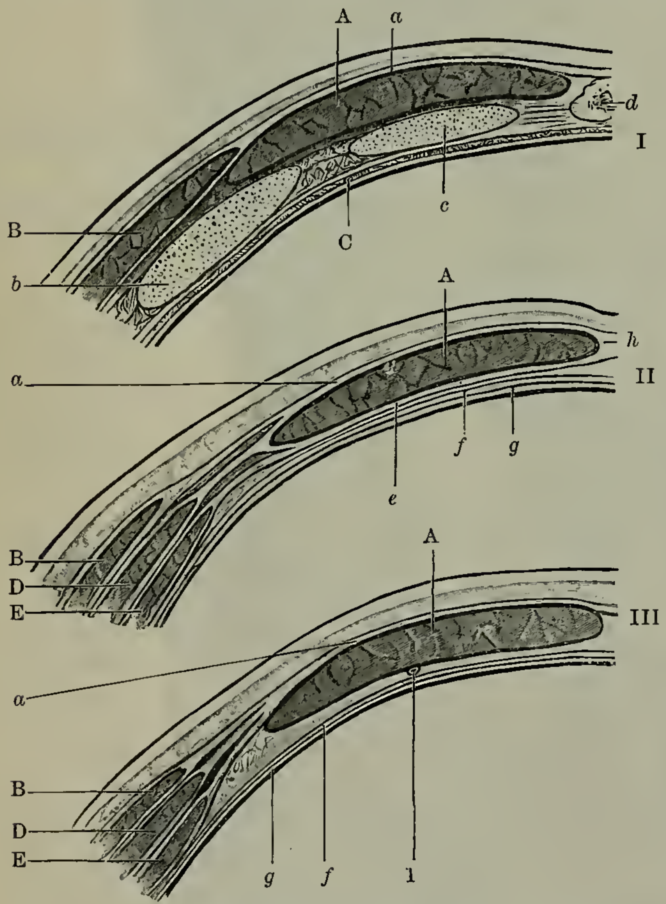

Fig. 404.—The Sheath of the Rectus Abdominis Muscle.

(I.) In the thoracic wall; (II.) In the superior three-quarters of the abdominal wall; (III.) In the inferior fourth of the abdominal wall.

A, Rectus muscle; B, Obliquus externus; C, Diaphragm; D, Obliquus internus; E, Transversus abdominis. *a*, Anterior layer of rectus sheath; *b*, Fifth costal cartilage; *c*, Sixth costal cartilage; *d*, Xiphoid process; *e*, Posterior layer of rectus sheath; *f*, Fascia transversalis; *g*, Peritoneum; *h*, Linea alba. 1, Inferior epigastric artery.

Canalis Inguinalis.—Inguinal canal.—The spermatic funiculus in the male, and the round ligament in the female, in their passage through the inferior part of the abdominal wall, pass through the inguinal canal, which is bounded by these abdominal muscles. The canal begins at the *abdominal inguinal ring*, which is an opening in the fascia transversalis, placed half an inch above the inguinal ligament, and midway between the anterior superior iliac spine and the symphysis pubis. It ends at the *subcutaneous inguinal ring*, placed above the tubercle and crest of the pubis. The *anterior wall* of the canal is formed by the aponeurosis of the obliquus externus, and in its lateral part by the muscular fibres of the obliquus internus; the *posterior wall* of the canal is formed by the fascia transversalis, and in its medial part by the falx aponeurotica inguinalis and by the ligamentum inguinale reflexum, when that structure is well developed. Thus the anterior wall is strongest opposite to the abdominal inguinal ring, and the posterior wall opposite to the subcutaneous ring. The *floor* of the canal is formed by the inguinal ligament, and in its medial part by the lacunar ligament. The spermatic funiculus, piercing the transversalis fascia, enters the inguinal canal at the abdominal inguinal ring, and is there invested by its *first envelope*, the **infundibuliform or internal spermatic fascia**, a sheath of fascia derived from the margins of the ring and continuous with the fascia transversalis. It then passes obliquely medially, downwards, and forwards, and escapes below the inferior border of the obliquus internus muscle, from which it carries off a *second investment*, partly fascial, partly muscular,—the **cremaster muscle** or **cremasteric fascia**. Continuing its course, in front of the falx inguinalis, it emerges through the subcutaneous inguinal ring, from the edges of which the **intercolumnar** or **external spermatic fascia** is derived, the *third* or *external investment* for the funiculus.

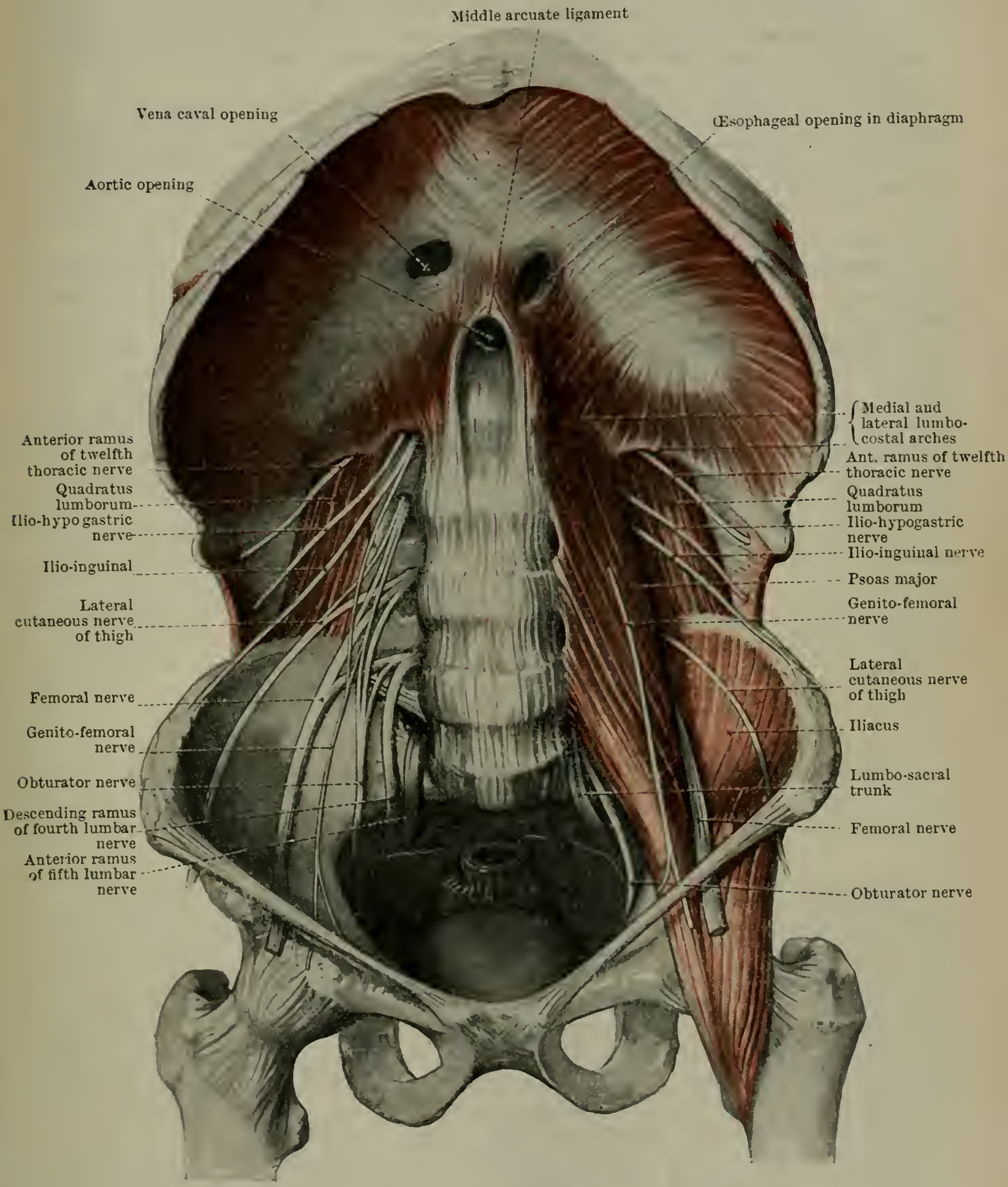

Fig. 405.—The Diaphragm and Posterior Abdominal Wall.

[redacted], bounded below by the line of the inguinal ligament [redacted] abdominis muscle, and laterally by the inferior epigastric artery, coursing upwards and medially behind the fascia transversalis on the medial side of the abdominal inguinal ring, is the site of one form of inguinal hernia The spermatic funiculus passes over the base of the triangle, covered over by the aponeurosis of the obliquus externus. Behind the funiculus, and forming the floor of the triangle, is the fascia transversalis partially covered, in the medial portion of the triangle, by the falx inguinalis of the obliquus internus and transversus muscles.

Inguinal Hernia.—For an account of the anatomical relations of the inguinal canal to the various forms of inguinal hernia, see the section on "Applied Anatomy."

Nerve-Supply.—The nerve-supply of the majority of the foregoing muscles is derived from the anterior rami of the **lower six thoracic nerves.** The pyramidalis muscle is innervated by the last **thoracic nerve.** The cremaster muscle receives its supply from the **genito-femoral nerve** (L. 1. 2.). In addition, the lower fibres of the obliquus internus and the transversus abdominus are innervated by the ilio-hypogastric nerve (L. 1.).

Actions.—(1) By virtue of their normal tone, these muscles support the abdominal viscera and help to retain them in their respective positions. Acting in association with the diaphragm they can compress the contents of the abdomen, and are powerful agents in vomiting, defæcation, micturition, and parturition. (2) They take part in forced expiration. (3) They are also flexors of the vertebral column and pelvis—the muscles of both sides acting together; the vertebral column and pelvis are laterally flexed, when one set of muscles acts alone.

The **posterior muscles of the abdominal wall and pelvis major** include the psoas (major and minor) and iliacus, described already (p. 411), and the quadratus lumborum.

M. Quadratus Lumborum.—The **quadratus lumborum** lies in the posterior wall of the abdomen, lateral to the psoas, and extends between the iliac crest and the last rib. It **arises** from the posterior part of the iliac crest, from the ilio-lumbar ligament, and from the transverse processes of the lower lumbar vertebræ.

It is **inserted**, above, into the medial part of the inferior border of the last rib and the transverse processes of the lumbar vertebræ. Its lateral border is directed obliquely upwards and medially.

It is enclosed between the anterior and middle layers of the lumbo-dorsal fascia (p. 438), between the psoas major muscle, in front, and the sacrospinalis behind.

Nerve-Supply.—The quadratus lumborum is supplied directly by branches from the anterior rami of the first three or four lumbar nerves.

Actions.—The muscle is a lateral flexor of the vertebral column, and assists in inspiration by fixing the twelfth rib and so facilitating the action of the diaphragm.

FASCIÆ AND MUSCLES OF THE PERINEUM AND PELVIS.

FASCIÆ OF THE PERINEUM.

The **superficial fascia** of the perineum possesses certain special features. It is continuous with the superficial fascia of the abdominal wall, thigh, and buttock, and is prolonged on to the penis and scrotum. In the penis, it is devoid of fat and consists only of areolar tissue. In the scrotum, it is intermingled with involuntary muscular fibres, and constitutes the **dartos muscle**, which assists in suspending the testes and corrugating the skin of the scrotum. This fascia also forms the **septum of the scrotum**, which, extending upwards, incompletely separates the two testes and their coverings. In the female the superficial fascia, in which there is a considerable quantity of fat, takes a large share in the formation of the mons Veneris and labia majora pudendi.

The fascia over the posterior part of the perineum fills up the ischio-rectal fossæ, in the form of two pads of adipose tissue, on either side of the rectum and anal canal. Over the tuberosities of the ischium the fat is intermingled with bands of fibrous tissue closely adherent to the subjacent deep fascia.

The fascia in the anterior part of the perineum closely resembles the same fascia in the groin. It is divisible into a superficial fatty and a deeper membranous layer. The former is continuous with the same layer in the thigh, and with the fat of the ischio-rectal fossa posteriorly. The deeper membranous layer (fascia of Colles) is attached on each side to the body of the pubis and the pubic arch, posteriorly to the base of the fascia inferior of the urogenital diaphragm and in the median plane to the bulb and corpus cavernosum urethræ by a median raphe continuous, farther forwards, with the septum of the scrotum mentioned above. Anteriorly the fascia invests the scrotum and gives a tubular covering to the penis. Finally it is continued over the spermatic funiculi to the anterior abdominal wall. The importance of this fascia lies in relation to the extravasation of urine from a rupture of the urethra in the perineum. By the fascial attachments the fluid is prevented from passing posteriorly into the ischio-rectal fossa, or laterally into the thigh. It is directed forwards into relation with the scrotum and penis, and along the spermatic funiculus to the anterior abdominal wall. The septum of the scrotum being incomplete, fluid extravasated on one side can pass across the median plane to the opposite half of the perineum and scrotum.

The **deep fascia** of the perineum exists only in the form of the delicate fasciæ of the muscles.

The **Central Point of the Perineum** is a fibro-muscular node of considerable importance in the anatomy of the perineum. It is placed in front of the upper part of the anal canal, behind the bulb of the urethra and below the postero-inferior portion of the prostate (Fig. 410). Both striated and plain muscle fibres enter into its constitution, and it is inseparably blended with the fasciæ of the urogenital diaphragm and the prostatic sheath. The superficial and deep transverse perineal muscles, the bulbocavernosus, the external sphincter ani, and the levatores prostatæ all contribute fibres to its constitution. In addition, it receives the insertions of the *recto-urethral muscles* (of Roux). The superior recto-urethralis is the downward and forward continuation of the longitudinal muscular fibres of the rectum which lie on its anterior wall in and near the median plane, and it passes into the upper and posterior part of the central point of the perineum. The inferior recto-urethralis, which is inserted into the lower and posterior part of the central point of the perineum, is formed by longitudinal fibres in the anterior wall of the anal canal, and curves upwards and forwards to reach its insertion.

THE MUSCLES OF THE PERINEUM.

The perineal muscles are naturally separated into a superficial and a deep set by the fascia inferior of the urogenital diaphragm. Superficial to it are the sphincter ani externus, transversus perinei superficialis, bulbocavernosus, and ischiocavernosus; deep to it are the sphincter muscle of the membranous urethra and the transversus perinei profundus.

M. Sphincter Ani Externus.—This muscle is fusiform in outline, flattened, and obliquely placed around the anus and anal canal. It can be separated into three layers,—subcutaneous, superficial, and deep. (1) The most superficial lamina consists of **subcutaneous fibres** decussating posterior and anterior to the anus, but without bony attachments. (2) The **sphincter ani superficialis** constitutes the main portion of the muscle. It is attached posteriorly to the coccyx, and, anterior to the anus, it reaches the central point of the perineum. (3) The **deep fibres** of the muscle form, for the most part, a complete sphincter for the anal canal. They are continuous above with the fibres of the pubo-rectalis portion of the levator ani; they encircle the anal canal, and blend anteriorly with the central point of the perineum and the transversus perinei superficialis muscle.

M. Corrugator Cutis Ani.—The **corrugator cutis ani** consists of bundles of unstriped muscular fibres which radiate from the margin of the anal opening superficial to the external sphincter.

Nerve-Supply.—The external sphincter is supplied by the inferior hæmorrhoidal branch of the pudendal nerve (S. 3. 4.), by the perineal branch of the fourth sacral nerve, and by the deep perineal branch of the pudendal nerve (S. 3. 4.).

Actions.—The muscle closes the anal aperture. It is a voluntary muscle.

M. Transversus Perinei Superficialis.—The **transversus perinei superficialis** is not always present. It consists of a more or less feeble bundle of fibres, which arises from the forepart of the medial aspect of the tuberosity of the ischium and the fascia over it, and from the base of the fascia inferior of the urogenital diaphragm.

It passes obliquely over the base of the fascia inferior to be **inserted** into the central point of the perineum.

Nerve-Supply.—Deep perineal branch of pudendal nerve (S. 3. 4.).
Action.—The two muscles acting together draw backwards and fix the central point of the perineum.

M. Bulbocavernosus.—The **bulbocavernosus** (O.T. **ejaculator urinæ**), *in the male,* surrounds the bulb, corpus cavernosum urethræ, and root of the penis.

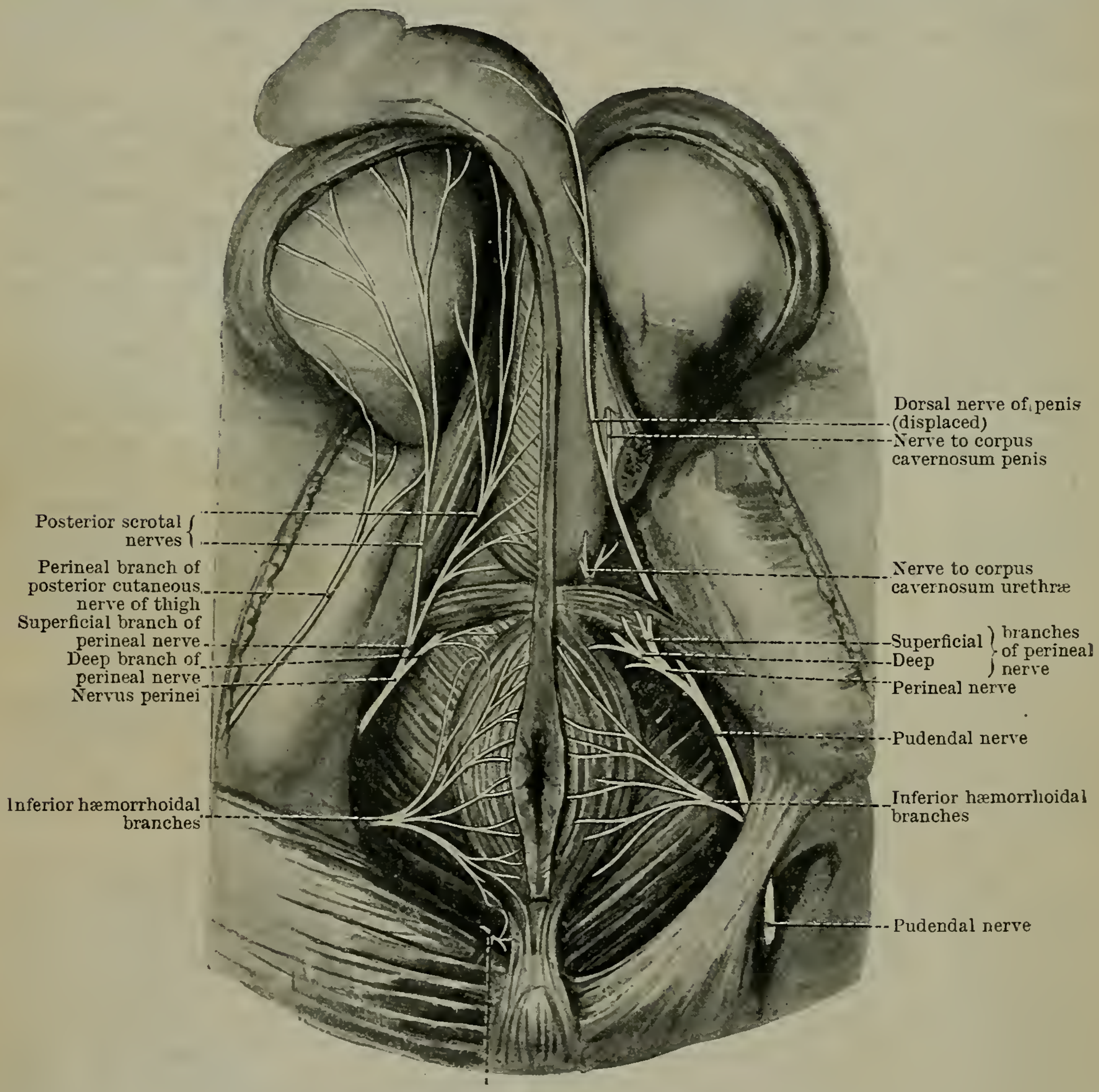
Dorsal nerve of penis (displaced)
Nerve to corpus cavernosum penis
Posterior scrotal nerves
Perineal branch of posterior cutaneous nerve of thigh
Superficial branch of perineal nerve
Deep branch of perineal nerve
Nervus perinei
Nerve to corpus cavernosum urethræ
Superficial
Deep
branches of perineal nerve
Perineal nerve
Pudendal nerve
Inferior hæmorrhoidal branches
Inferior hæmorrhoidal branches
Pudendal nerve

FIG. 406.—THE MUSCLES AND NERVES OF THE MALE PERINEUM.

It is sometimes separated into two parts—*posterior* (compressor bulbi), and *anterior* (compressor radicis penis). It **arises** from the central point of the perineum, and from a median raphe on the under surface of the bulb and corpus cavernosum urethræ.

The muscular fibres pass laterally and forwards and have a triple **insertion**: from behind forwards, (1) into the inferior surface of the fascia inferior of the urogenital diaphragm; (2) into the dorsal aspect of the corpus cavernosum urethræ; and (3), after encircling the corpora cavernosa penis, into the fascia covering the dorsum of the penis.

The **ischiobulbosus**, not always present, **arises** from the ischium, and passes obliquely medially and forwards over the bulbocavernosus, to be **inserted** into the raphe superficial to that muscle. It belongs to the same stratum as the transversus perinei superficialis and ischiocavernosus.

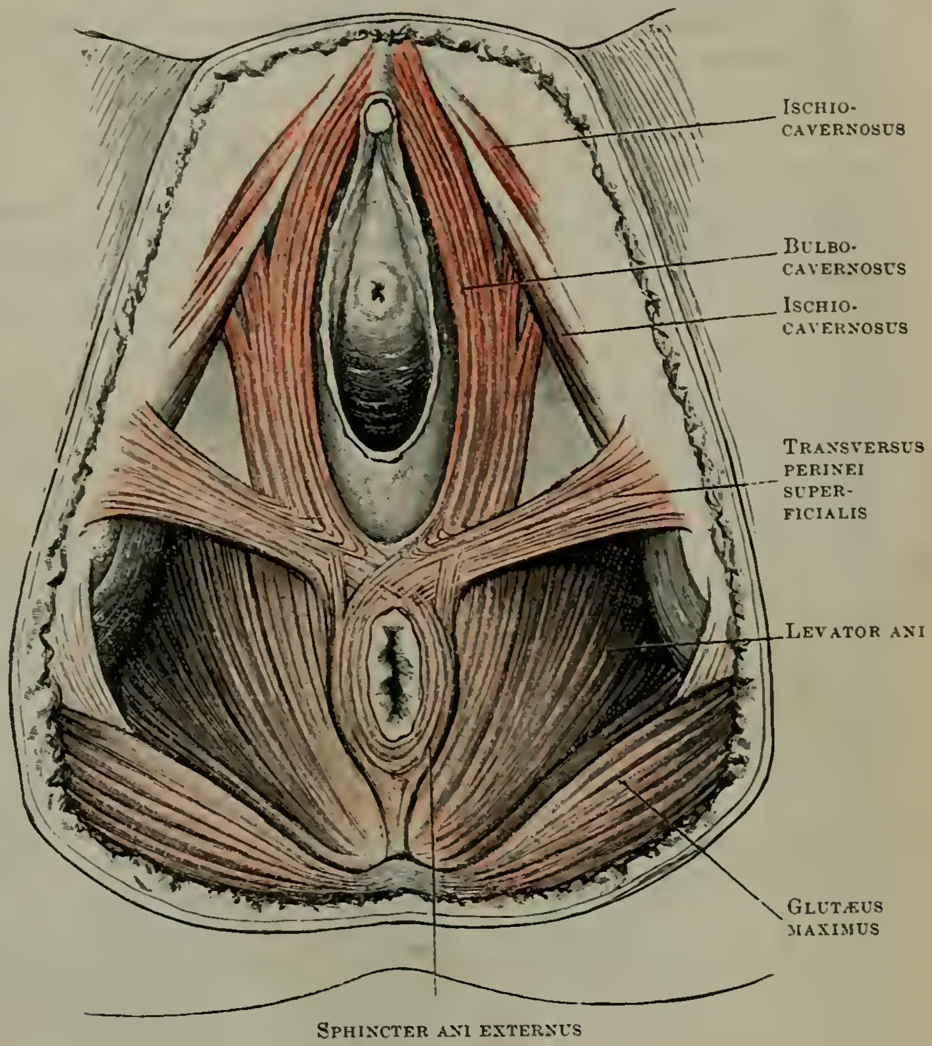

Fig. 407.—The Muscles of the Female Perineum. (After Peter Thompson.)

M. Bulbocavernosus.—The **bulbocavernosus**, *in the female* (O.T. sphincter vaginæ), is separated into lateral halves by the vaginal and urethral openings. It forms two thin lateral layers covering the bulb of the vestibule, and **arises** behind the vaginal orifice from the central point of the perineum.

Anteriorly it is **inserted** into the root of the clitoris, some of its fibres embracing the corpora cavernosa clitoridis so as to reach the dorsum of the clitoris.

Nerve-Supply.—Deep branch of the perineal nerve (pudendal, S. 3. 4.).

Actions.—In the male.—The bulbocavernosus contracts the urethra in the emission of urine and semen, and is an accessory muscle in erection of the penis.

In the Female.—The muscle contracts the vaginal orifice, and compresses the bulb of the vestibule of the vagina.

M. Ischiocavernosus. — The **ischiocavernosus**, *in the male,* covers the crus penis. It **arises** from the ischial tuberosity and the sacrotuberous ligament.

Passing forwards, it is **inserted** by a fascial attachment into the inferior surface of the crus penis, and into the lateral and dorsal aspects of the corpus cavernosum penis.

The ischiocavernosus, *in the female,* has a similar disposition, but is of much smaller size than in the male.

The **pubocavernosus** is an occasional slip **arising** from the pubic ramus, and **inserted** into the dorsum of the penis. It corresponds to the levator penis of lower animals.

Nerve-Supply.—Deep branch of the perineal nerve (pudendal, S. 3. 4.).

Action.—The muscle assists in erection of the penis (or clitoris).

Diaphragma Urogenitale.—The sphincter urethræ membranaceæ and the transversus perinei profundus constitute the deeper muscular stratum of the perineum and form the **urogenital diaphragm.** They lie between two layers of fascia called the *fascia inferior,* and *fascia superior* of the *urogenital diaphragm* (O.T. *superficial and deep layers of the triangular ligament*).

The fascia inferior is a strong layer which stretches across the pubic arch. Posteriorly, it extends between the foreparts of the ischial tuberosities, and, in the median plane, is intimately connected with the central point of the perineum. Anteriorly, it ends in a thickened band (*ligamentum transversum pelvis*) which is separated from the arcuate ligament by a small gap for the passage of the deep dorsal vein of the penis. This fascia is formed by the blending of the fascial sheath of the muscles of the urogenital diaphragm with the strong fibrous sheath which encloses the corpus cavernosum urethræ and the bulb, and it is to the latter constituent that it owes its strength.

The superior fascia of the urogenital diaphragm, as defined by its name, is a weak covering of the muscles of the diaphragm. It gains in strength but loses in definition by its intimate association with the sheath of the prostate gland and, more posteriorly, with the central point of the perineum. On each side, as it approaches the pubic arch, the fascia becomes blended with the dense connective tissue in which the dorsal nerve of the penis and the internal pudendal artery are embedded.

M. Sphincter Urethræ Membranaceæ.—The **sphincter** of the membranous urethra **arises** from the inferior part of the pubic ramus, and is directed medially, its fibres radiating so as to enclose the membranous urethra.

It is **inserted** into a median raphe, partly anterior to the urethra, but for the most part posterior to it. The fibres most intimately related to the urethra form a muscular sheath for the canal, and have no bony attachments.

M. Transversus Perinei Profundus.—The **transversus perinei profundus** consists of a bundle of fibres on each side which **arises** from the inferior ramus of the ischium just below the sphincter urethræ membranaceæ. It is **inserted** into a median raphe continuous, behind, with the central point of the perineum. The muscle, in fact, constitutes a separate bundle below and behind the sphincter.

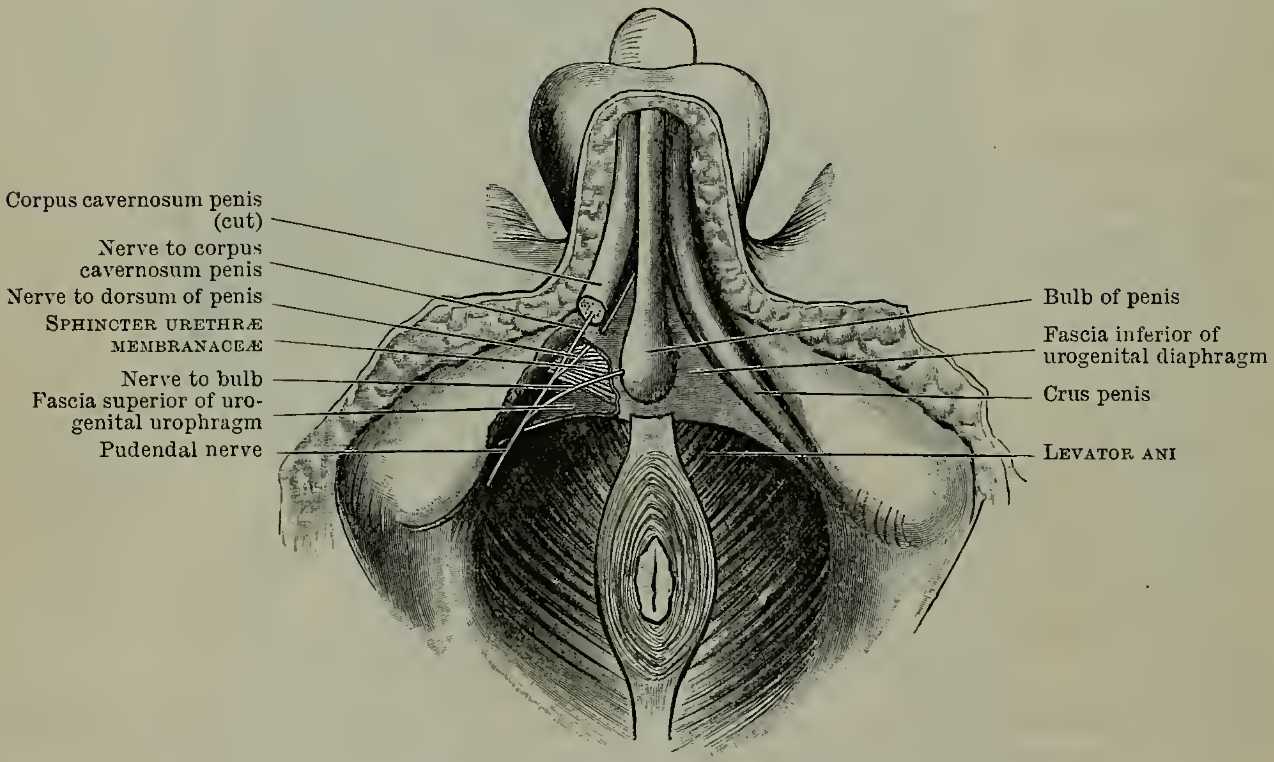
Corpus cavernosum penis (cut)
Nerve to corpus cavernosum penis
Nerve to dorsum of penis
SPHINCTER URETHRÆ MEMBRANACEÆ
Nerve to bulb
Fascia superior of urogenital urophragm
Pudendal nerve
Bulb of penis
Fascia inferior of urogenital diaphragm
Crus penis
LEVATOR ANI

FIG. 408.—THE FASCIÆ OF THE UROGENITAL DIAPHRAGM OF THE PERINEUM, AND THE TERMINATION OF THE PUDENDAL NERVE.

The **ischiopubicus** is a term applied to a feeble bundle of fibres which, when present, lies above and in front of the sphincter urethræ membranaceæ. It **arises** from the pubic ramus, and is **inserted** into a median raphe on the dorsum of the membranous urethra. This muscle is homologous with the **compressor venæ dorsalis penis** of lower animals.

The sphincter urethræ *in the female* is smaller than in the male. Its insertion is modified by the relations of the urethra to the vagina. The anterior fibres are continuous with those of the opposite side above the urethra; the intermediate fibres pass between the urethra and vagina, and the posterior fibres are attached, along with the **transversus perinei profundus** (transversus vaginæ), into the side of the vagina.

Nerve-Supply.—Deep branch of the perineal nerve (pudendal, S. 3. 4.).

Action.—It is a feeble compressor of the membranous urethra, and by no means a sphincter. In the female it has an accessory influence in constricting the vagina.

THE FASCIÆ OF THE PELVIS.

The extra-peritoneal tissue in the pelvic cavity is of great importance. The hypogastric vessels and their branches, the visceral nerves and plexuses, the ureters, and ductus deferentes, take their course in this tissue outside the peritoneum. It forms in relation to **the rectum** a thick sheath, for the most part devoid of fat, which encloses the lower part of the rectum completely, down to its termination in the anal canal. It forms a kind of packing for the parts of **the bladder** uncovered by peritoneum, and surrounds the prostate with a strong sheath. In the female it forms, in addition, the basis or matrix of the **broad ligament**, and also occurs as a layer devoid of fat, which loosely connects the anterior surface of the **cervix uteri** with the base of the bladder.

FASCIA PELVINA.

The muscles which line the walls (obturator internus and piriformis) and those which form the floor of the pelvis (levator ani and coccygeus) are covered on their pelvic surfaces by a layer of fascia, thicker over the obturator internus than it is elsewhere. This thickening is, in reality, the aponeurosis of origin of the ilio-coccygeus muscle (p. 495), and it is continued upwards to reach the ilio-pectineal line. The surface of this aponeurosis is crossed by a linear thickening (*arcus tendineus*) which extends from the ischial spine to the pelvic surface of the body

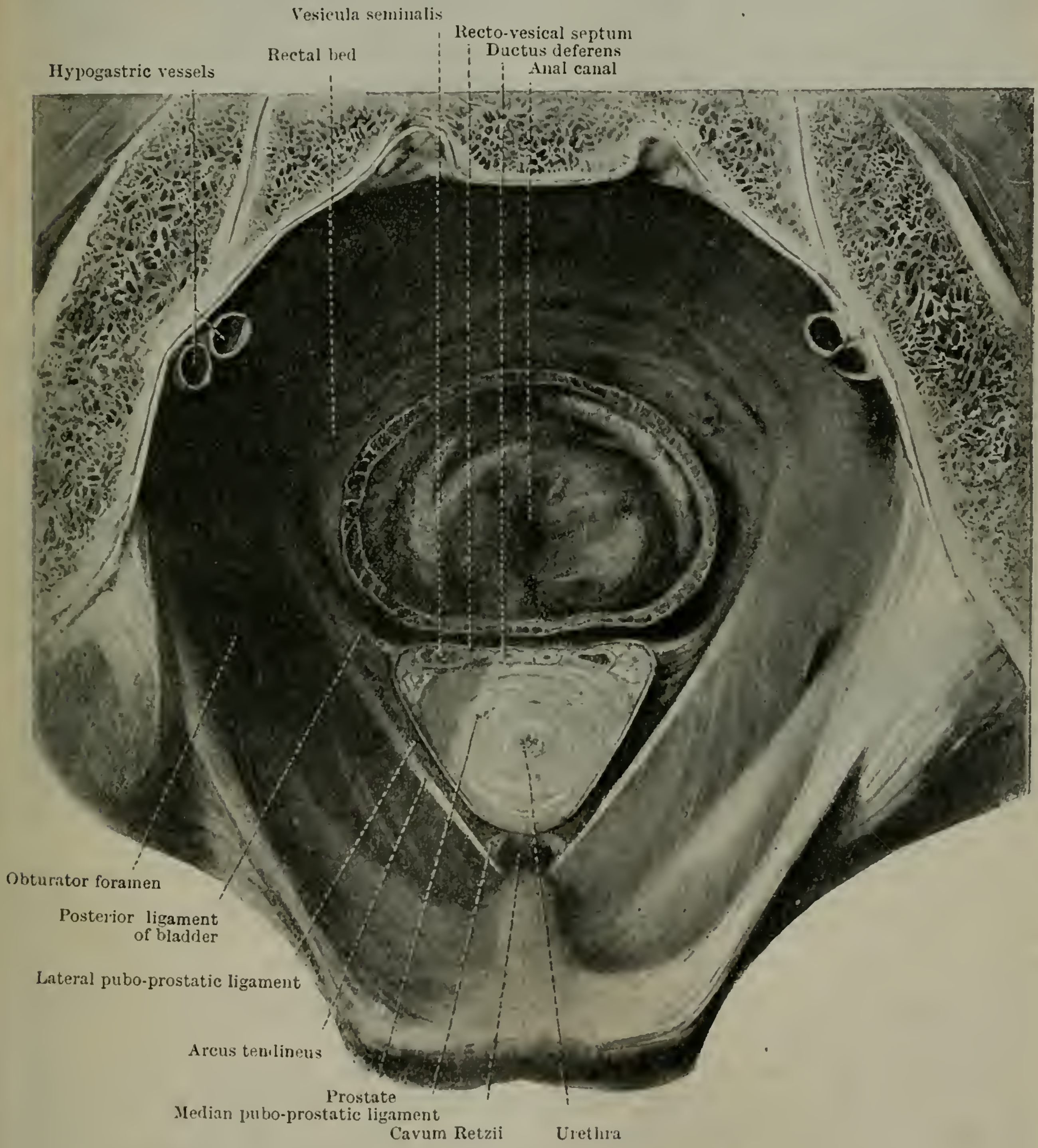

FIG. 409.—RELATIONS OF THE PELVIC FASCIA TO THE RECTUM AND PROSTATE.

of the os pubis, where it blends with the median pubo-prostatic ligament. In its posterior part it marks the origin of the fleshy fibres of the ilio-coccygeus, but its anterior part crosses the pelvic surface of the pubo-coccygeus at least 1·5 cm. below its origin from the bone. It has been suggested that the anterior portion of the arcus tendineus represents an additional tendon of origin for the ilio-coccygeus.

As in other parts of the body, connective tissue is condensed around the viscera and the vessels. It will be sufficient to indicate the situations in which this condensation is best marked or gives rise to structures which have a practical bearing for the surgeon.

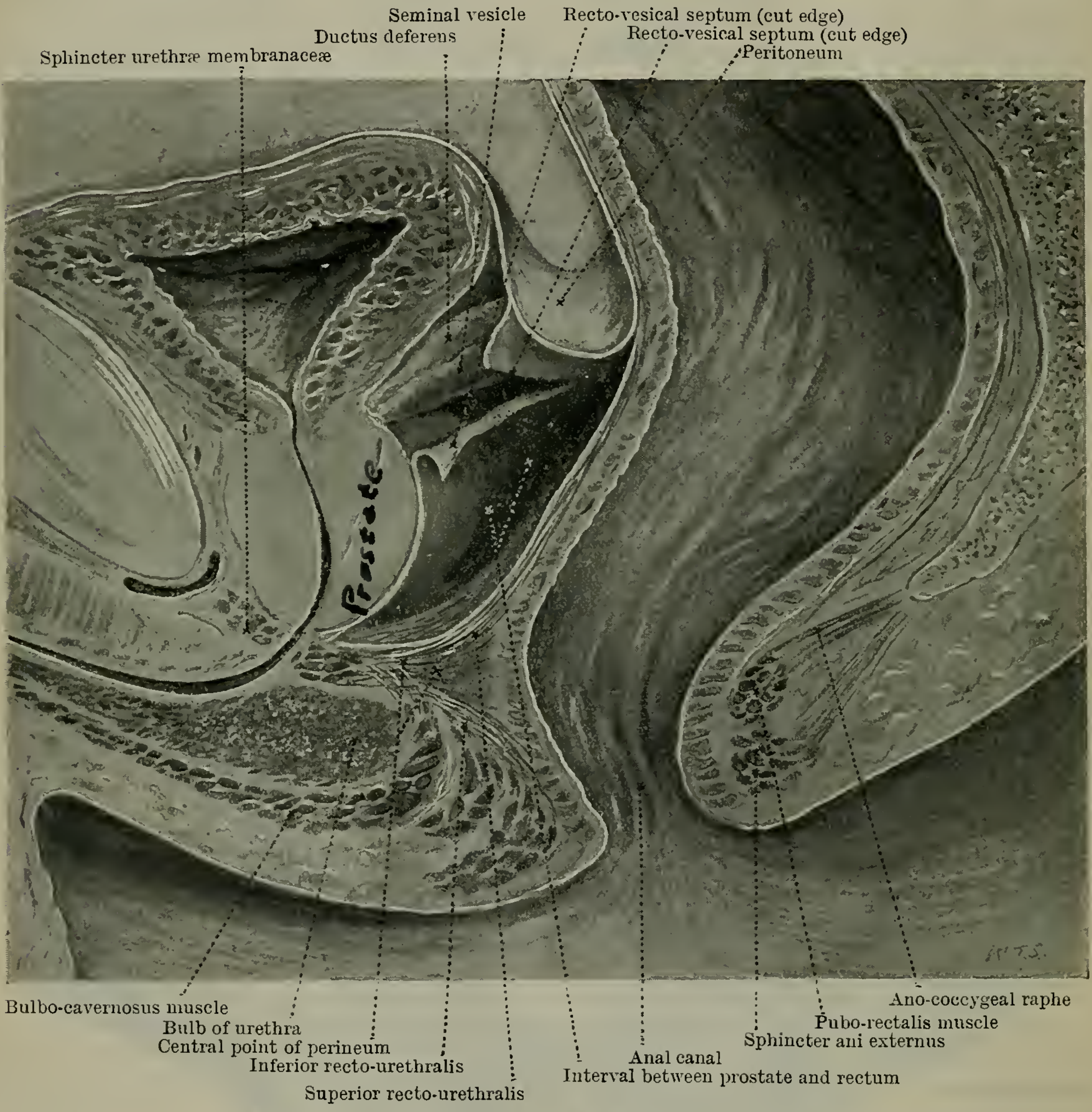
Seminal vesicle
Recto-vesical septum (cut edge)
Ductus deferens
Recto-vesical septum (cut edge)
Sphincter urethræ membranaceæ
Peritoneum
Prostate
Bulbo-cavernosus muscle
Bulb of urethra
Central point of perineum
Inferior recto-urethralis
Superior recto-urethralis
Interval between prostate and rectum
Anal canal
Sphincter ani externus
Pubo-rectalis muscle
Ano-coccygeal raphe

FIG. 410.—MEDIAN SAGITTAL SECTION OF MALE PELVIS TO SHOW THE RELATIONS OF THE PELVIC FASCIA.

A strong fascial sheath is provided for the prostate, derived to a very large extent from the fibrous tissue which is condensed around the pudendal (O.T. prostatic) and the prostatico-vesical plexuses of veins. Inferiorly, it abuts on and is inseparably blended with the superior fascia of the urogenital diaphragm and the central point of the perineum, in the median plane (Fig. 410), and with the fascial sheaths of the levatores prostatæ, on each side. Superiorly, the prostatic sheath is continuous with the connective tissue which is condensed upon the infero-lateral aspect of the bladder in association with the vesical veins. Anteriorly, the sheath is attached to the pelvic surface of the pubic bones near the symphysis by the median pubo-prostatic ligaments. These bands and the fascia which connects them to one another and to the sheaths of the levatores prostatæ contain a number of smooth muscle fibres.

It is necessary to point out that the posterior part of the prostatic sheath differs from the rest of the sheath in its mode of formation, and is a definite layer which can easily be demonstrated by dissection. In a four months' fœtus the recto-vesical peritoneal fossa is very much deeper than it is in the adult, and this alteration in level is brought about by the occlusion of the lower part of the fossa. The two fused layers retain their connexion with the floor of the recto-vesical fossa, above, and they constitute the posterior wall of the prostatic sheath (Fig. 410). This structure is the recto-vesical fascia (of Cunningham), the prostato-peritoneal aponeurosis (of Denonvilliers), and the recto-vesical septum (of Elliot-Smith). Roughly triangular in outline, it reaches the central point of the perineum, below, and the posterior ligaments of the bladder on each side. As it extends upwards to the floor of the recto-vesical fossa, it lies behind the prostate, the seminal vesicles and the deferent ducts, and the base of the bladder, and is separated from all these structures by a cellular interval. Posteriorly, a similar cellular interval separates it from the anterior aspect of the rectal ampulla (Fig. 410).

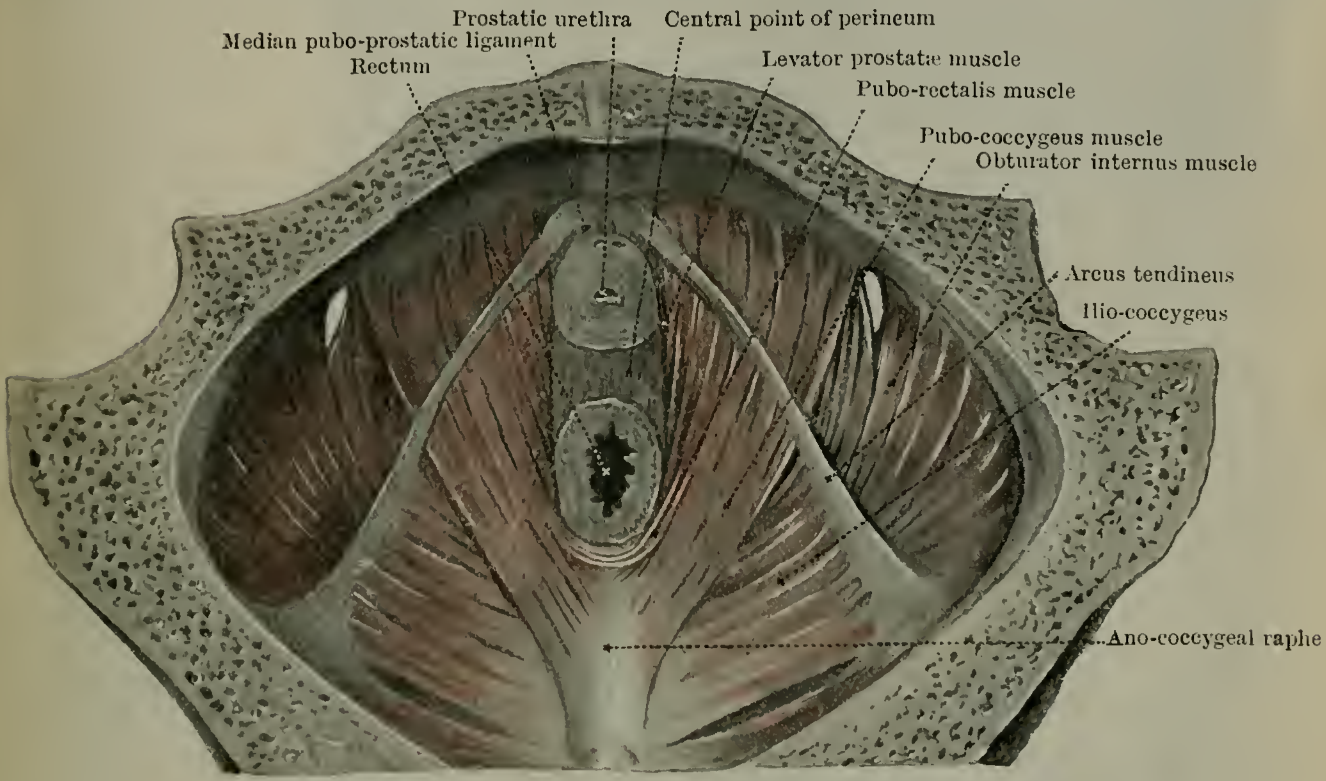

Fig. 411.—The Levator Ani Muscle viewed from above.

The **posterior ligaments of the bladder** consist of a condensation of the sub-peritoneal connective tissue around the ureter, vesical arteries and corresponding veins as they extend between the postero-lateral borders of the urinary bladder and the hypogastric vessels. Anteriorly, this ligament becomes continuous with the condensations which surround the prostatico-vesical and pudendal plexuses of veins, *i.e.* with the fascial coverings of the urinary bladder and the prostate. As they sweep backwards from the bladder, these ligaments lie to the lateral side of the rectum.

A similar condensation of connective tissue surrounds the internal pudendal vessels, the dorsal nerve of the penis, and the perineal branch of the pudendal nerve, as they lie in the lateral wall of the ischio-rectal fossa, and is prolonged forwards around them into the urogenital triangle.

MUSCLES OF THE PELVIS.

Diaphragma Pelvis.—The **pelvic diaphragm** is formed by the levator ani and coccygeus muscles, which serve to uphold the pelvic floor, and are related to the rectum and the prostate or vagina.

M. Levator Ani.—The **levator ani** muscles form a flattened sheet which stretches across the pelvic cavity and separates it from the perineum. Anteriorly, the two muscles are separated by a narrow interval, which is occupied, in the male, by the apex of the prostate and the anal canal, and, in the female, by the urethra, the vagina, and the anal canal. Posteriorly, they meet one another in the ano-coccygeal raphe, which extends between the upper end of the anal canal and the tip of the coccyx.

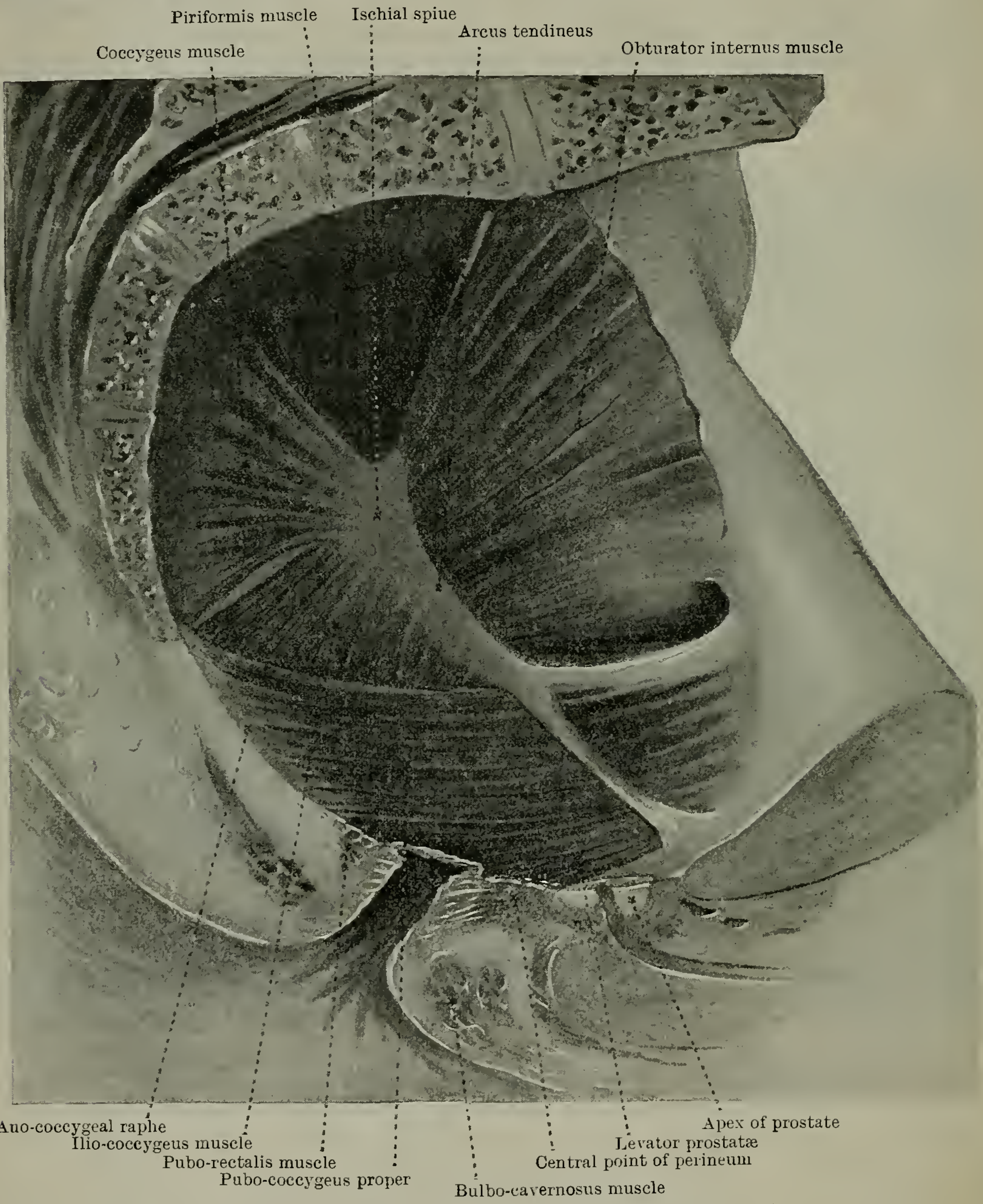

FIG. 412.—THE LEFT LEVATOR ANI MUSCLE.

The muscle **arises** from the pelvic surface of the ischial spine, behind, and from the pelvic surface of the pubic bone, in front, but it does not extend medially so far as the symphysis. Between these two bony attachments it takes a linear origin from the thick fascia which covers the obturator internus muscle (*vide infra*).

Its fibres run backwards and medially and very slightly downwards, with varying degrees of obliquity, and are **inserted** (1) into the central point of the perineum and the wall of the anal canal, (2) into the ano-coccygeal raphe, and

(3) into the front and sides of the coccyx. In addition, some of the fibres form a sling around the upper end of the anal canal.

The levator ani is divisible into two distinct portions, namely, the **ilio-coccygeus** and the **pubo-coccygeus**, and the latter can be subdivided into three parts, imperfectly separated from one another, viz.—the *pubo-coccygeus proper*, the *pubo-rectalis*, and the *levator prostatæ*.

The **ilio-coccygeus** forms the posterior part of the levator ani and its origin extends as far forwards as the obturator canal. The strong fascia from which it arises represents the upward continuation of the muscle to reach the ilio-pectineal line, and has, secondarily, become blended with the fascial covering of the obturator internus. This attachment to the ilio-pectineal line is the primitive origin of the ilio-coccygeus and is the normal condition in many mammals. The fibres run medially to be inserted into the side of the coccyx and the ano-coccygeal raphe, but, at their insertion, they are covered, on their pelvic aspect, by the backward running fibres of the pubo-coccygeus (Fig. 411).

The **pubo-coccygeus** is composed of those fibres of the levator ani which arise in front of the obturator canal. The most anterior (medial) fibres constitute the *levator prostatæ*. They pass backwards in contact with the lateral aspect of the prostate and are inserted into the central point of the perineum and into the wall of the anal canal, where they mingle with the deeper fibres of the sphincter ani externus.

The fibres which arise from the pubic bone lateral to the origin of the levator prostatæ form the *pubo-rectalis*. This muscle sweeps backwards over the lateral aspect of the prostate (or vagina) and the upper part of the anal canal, around which it becomes directly continuous with the corresponding muscle of the opposite side. The pubo-rectales, therefore, form a U-shaped sling for the ano-rectal junction (Fig. 411), and they can constrict the anal canal in the male, and the vagina and anal canal in the female.

The *pubo-coccygeus proper* forms the remainder of this part of the levator ani muscle. Its fibres run backwards and medially, above the fibres of the ilio-coccygeus, and are inserted (1) into the ano-coccygeal raphe, where they meet the fibres of the opposite side, and (2) into the sides and front of the coccyx.

The **coccygeus**, which lies on the same plane as the ilio-coccygeus, is a fan-shaped muscle, **arising** from the pelvic surface of the ischial spine and the sacro-spinous ligament, and being **inserted** into the lateral border of the lower two pieces of the sacrum and the upper two pieces of the coccyx. Its anterior border may be closely applied to the posterior border of the ilio-coccygeus, or a distinct interval, occupied by fat and areolar tissue, may intervene between them (Fig. 412).

Nerve-Supply.—Branches from the anterior rami of the third and fourth sacral nerves supply the levator ani and the coccygeus on their pelvic surfaces. In addition the levator ani is supplied on its perineal surface by the perineal branch of the pudendal nerve.

Actions.—Both these muscles play a very important part in retaining the pelvic viscera in position. In addition, the pubo-rectales reinforce the sphincters of the vagina and anal canal, and the levatores prostatæ draw the central point of the perineum upwards and forwards. This latter action assists in the later stages of expulsion, during defæcation and parturition.

Comparative Morphology.—In pronograde mammals, the ilio- and pubo-coccygei are inserted into the caudal vertebræ and act, respectively, as abductors and flexors of the tail. Although the pubo-coccygei may have a compressing effect on the vagina and rectum, such action is purely secondary. In these animals there is not the same need for a muscular pelvic diaphragm, and, consequently, the two muscles are separated from one another both dorsal and ventral to the rectum.

The adoption of the erect attitude necessitates the provision of a strong, but elastic, pelvic floor, to maintain the pelvic viscera in position and to permit the downward passage of the fœtus. This function is assumed by the pubo- and the ilio-coccygei, which are no longer needed to act on a tail.

THE DEVELOPMENT AND MORPHOLOGY OF THE SKELETAL MUSCLES.

The mesoderm on either side of the embryonic medullary tube separates into three main parts—the **myotome, nephrotome,** and **sclerotome** or **lateral plates** (somatopleure and splanchnopleure).

The skeletal muscles are derived for the most part from the myotomes of the mesodermic somites. The limb muscles, however, appear to be formed from the mesenchymal core of the limb-bud, and the visceral muscles of the head and neck are derived from the mesenchyme of the branchial arches. Each **myotome** consists at first of a quadrilateral bilaminar mass, resting against the medullary tube and notochord on either side. The cleft between its two layers represents a diverticulum of the cœlomic cavity. In the early stages of embryonic life the growth of the myotome is rapid. On its medial side masses of cells arise, which grow medially and surround the medullary tube and notochord to form the foundation of the vertebral column. On its lateral side cells appear to be given off which participate in the formation of the cutis vera. At the same time the dorsal and ventral borders of the myotome continue to extend, and present extremities (growing points) with an epithelial structure for a considerable period. *On the dorsal side* it overlies the medullary tube, and gives rise to the muscles of the back; while by its *ventral extension*, which traverses the somato-pleuric mesoderm in the body wall, it produces the lateral and ventral muscles of the trunk. By a medial extension it probably gives rise also to the hypaxial muscles of the neck. The cells of the medial layer of the myotome are responsible for the formation of the muscle fibres. The innervation of a myotome or of a pre-muscle mass is determined at a very early stage of development, and the nerve-supply of a muscle is consequently the best guide to its morphology.

Portions of two or more neighbouring myotomes may fuse to form a skeletal muscle, and this is the common mode of origin, as it is only in a few groups that the individual muscles can be referred to single myotomes.

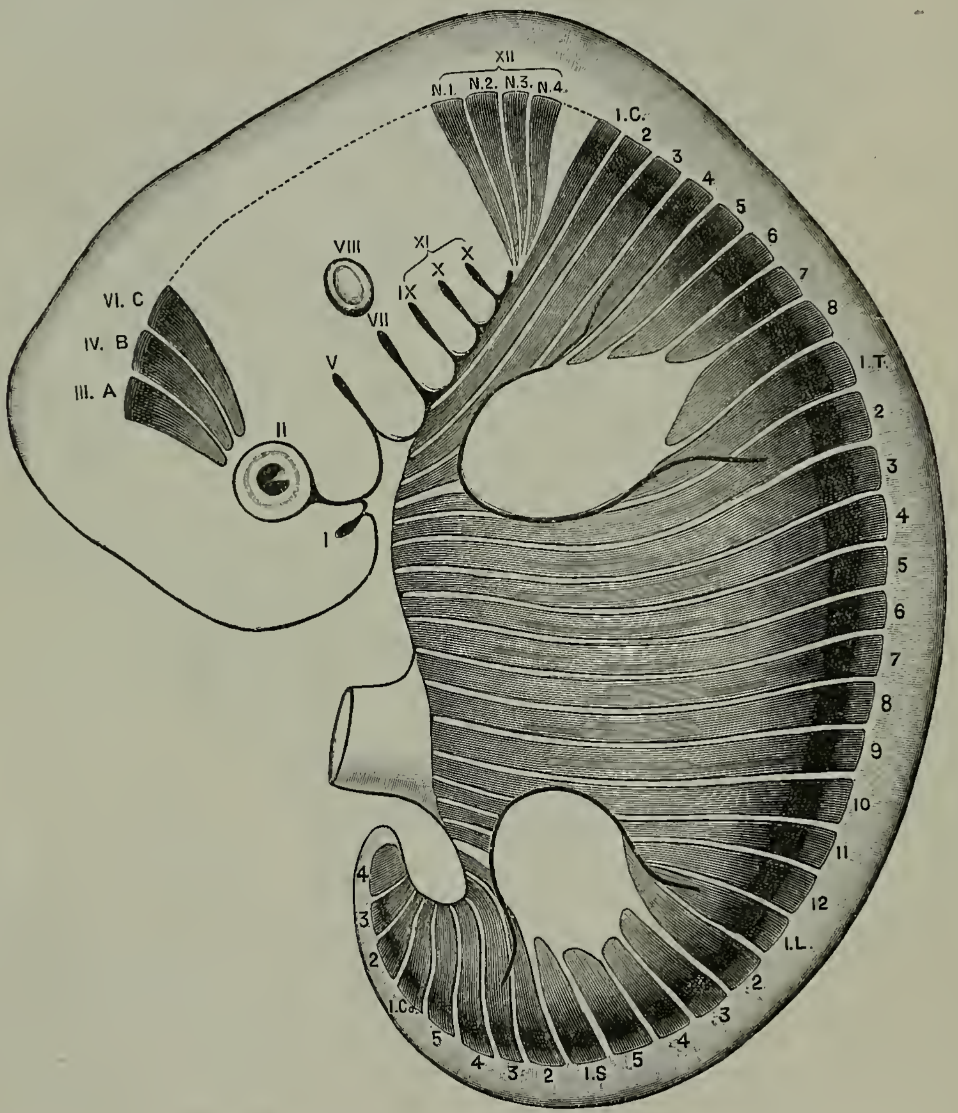

Fig. 413.—Scheme to illustrate the Disposition of the Myotomes in the Embryo in relation to the Head, Trunk, and Limbs.

A, B, C, First three cephalic myotomes; N, 1, 2, 3, occipital myotomes; C., T., L., S., Co., The myotomes of the cervical, thoracic, lumbar, sacral, and caudal regions; I., II., III., IV., V., VI., VII., VIII., IX., X., XI., XII., refer to the cerebral nerves and the structures with which they may be embryologically associated.

In the course of growth and development a muscle may become widely separated from the skeletal elements which are derived from the same somites as its myotomic constituents. The diaphragm (C. 3. 4. and 5.) is an excellent example of "muscle migration." In the same way muscles derived from the mesenchymal core of the limb-buds may spread to the trunk and there obtain attachments to skeletal elements at a considerable distance. Such "migration" occurs to a very marked extent in the case of the latissimus dorsi muscle.

Musculature of the Trunk.—The dorsal portion of each myotome becomes separated off and becomes continuous with the corresponding portions of neighbouring myotomes, so that a longitudinal pre-muscle column is formed, to which the posterior rami of the spinal nerves are distributed. This column gives rise to the muscles of the back of the neck and the back of the trunk, and they become differentiated from one another by the formation of longitudinal septa. The deeper parts of the dorsal portions of the myotomes remain separate in certain regions and constitute the rotatores and interspinales.

The **ventral portion** of each myotome carries off the anterior ramus of the corresponding nerve and spreads ventrally into the somatopleure, dorsi-lateral to the derivatives of the intermediate cell tract. (*a*) The dorsal portion of this strip separates off from the rest and fuses with the corresponding portions of neighbouring segments. The column so formed persists in man only in the cervical region, where it gives rise to the longus colli, longus capitis, and the crura of the diaphragm. (*b*) The ventral extremities of this extension into the somatopleure behave in a similar way, giving rise, in man, to the rectus abdominis, the pyramidalis, the sterno-costal portions of the diaphragm, and, probably, the infra-hyoid group of muscles. (*c*) The intermediate portions of these strip-like extensions into the somatopleure become fused and then are delaminated into as many as five layers in some vertebrates. In man, only three such layers are formed, viz. the obliquus externus, the obliquus internus, and the transversus abdominis. Dorsally, the quadratus lumborum, with its enclosing layers of the lumbo-dorsal fascia, is derived from the same source. In the thoracic region, however, the fusion of the individual myotomic derivatives is only carried out in the case of the transversus thoracis. The more superficial derivatives constitute the external and internal intercostal muscles, which retain their segmental characters. In the cervical region it appears probable that the corresponding myotomic derivatives in part disappear and in part form the scalene muscles and the remaining portion of the diaphragm.

The ventral portions of the lumbar (with the exception of the first) and the upper sacral myotomes disappear in man, but they persist in the third and fourth sacral somites and give rise to the levator ani and the coccygeus.

The occipital myotomes form the muscles of the tongue.

It may here be pointed out that the diaphragm, which may justly be termed the most essential of all the skeletal muscles in man, is derived to a very large extent, if not entirely, from the ventral portion of the fourth cervical myotome. The crura are on the same morphological plane as the longus colli; the sterno-costal portions are on the same morphological plane as the rectus abdominis; and the rest of the muscle is on the same morphological plane as the transversus abdominis. The phylogenetic history of the diaphragm shows that it represents the detached cervical portion of the transversus sheet. In Amphibia and Reptilia there is no separation of the pleural and peritoneal cavities, and the whole transversus sheet functions as a compressor of the cœlom and so as a muscle of expiration. In Mammalia, on the other hand, the diaphragm intervenes between the pleural and the peritoneal cavities, and its action as a cœlomic compressor is restricted to the latter. At the same time, its new position makes it a powerful inspiratory muscle, and in man it is of very much greater importance than all the other muscles which, primarily or secondarily, help to increase the capacity of the thorax. In pronograde mammals, on the other hand, inspiration depends much more on elevation of the ribs by the external respiratory muscles, and the principal action of the diaphragm in these animals would seem to be its primitive action as a compressor of the cœlom.

The **branchial musculature** is formed in the mesenchyme of the branchial arches and is quite distinct from the musculature derived from the occipital and cervical myotomes, not only in its source but also in its innervation, which is obtained from certain of the cranial nerves. Although laid down in the substance of the arches, the branchial muscles may undergo extensive "migration." This change of position is best exemplified by the muscles of the second arch (*vide infra*).

The accompanying table indicates the muscles derived from the individual branchial arches with their nerves of supply :—

Arch.	Nerve.	Muscles.
First (mandibular)	Mandibular division of trigeminal nerve	Muscles of mastication Tensor tympani Tensor veli palatini
Second (hyoid)	Facial	Muscles of facial expression (including mm. of scalp and platysma) Stylo-hyoid Posterior belly of digastric Stapedius
Third	Glosso-pharyngeal	Stylo-pharyngeus Constrictors of pharynx (in part) ? Muscles of soft palate (in part)
Fourth Fifth ? Sixth	Vagus (superior laryngeal and recurrent branches)	Muscles of larynx Constrictors of pharynx (in part) Muscles of soft palate (in part)

Muscles of the Orbit.—It has not been possible to identify cephalic myotomes in the human embryo. The muscles of the orbit can be distinguished in the embryo as a single pre-muscle mass, closely related to the optic vesicle and receiving the terminations of the third, fourth, and sixth cranial nerves. Myotomes have been demonstrated in the head region of elasmobranch fishes: the precise number is uncertain, but there are probably at least nine, of which the last four are occipital. The first three cephalic myotomes form the muscles of the orbit, the first giving rise to the group supplied by the oculo-motor nerve, the second to the superior oblique, and the third to the lateral rectus muscle. The fourth and subsequent myotomes disappear, but the occipital myotomes persist to form the muscles of the tongue.

Musculature of the Limbs.—The developing limb-bud consists of an ectodermal envelope enclosing a mass of mesenchyme, from which both the skeletal elements and the musculature of the limb are derived. Ventral and dorsal sheets of muscle are laid down, and they are at first continuous with one another along the pre- and post-axial borders of the bud. The anterior rami of the spinal nerves which eventually enter into the formation of the limb plexus are at first arranged segmentally in the developing limb, and each gives ventral and dorsal branches to exactly corresponding portions of the muscle sheets. It will therefore be found that the muscles which develop along the pre-axial border, whether ventral or dorsal, are innervated by the highest nerve of the plexus, while those which develop along the post-axial border are innervated by the lowest nerve of the plexus. This early subdivision of the limb musculature into ventral and dorsal sheets, and the innervation of portions of both sheets by every nerve of the limb plexus, are indicated in the upper limb of the adult by the division of the trunks of the brachial plexus into anterior and posterior divisions prior to the formation of the cords.

The proximal portions of these muscle sheets extend towards the trunk and eventually constitute the muscles which connect the limb or its girdle to the trunk (with the exception of the trapezius). These muscles are much more numerous in the upper than they are in the lower limb, where their only representatives are the psoas magnus and the psoas parvus.

THE NERVOUS SYSTEM.

I.—THE CENTRAL NERVOUS SYSTEM.

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ELEMENTS OF THE CENTRAL NERVOUS SYSTEM.

Every type of nervous system with which we are acquainted, from the simplest and most primitive, such as that of Hydra, to the most complex and highly elaborated mechanism found in man, is composed essentially of three categories of elements. These are (1) **sensory cells**, so situated and so specialised in structure as to be capable of being affected by changes in the animal's environment, and of transmitting the effects of such stimulation, directly or indirectly, to (2) **efferent nerve-cells**, which influence the muscles or other active tissues, so that the stimulation may find expression in some appropriate action; and (3) **intercalated nerve-cells**, which regulate such responsive behaviour by bringing it under the influence of other sensory impressions and of the state and activities of the body as a whole.

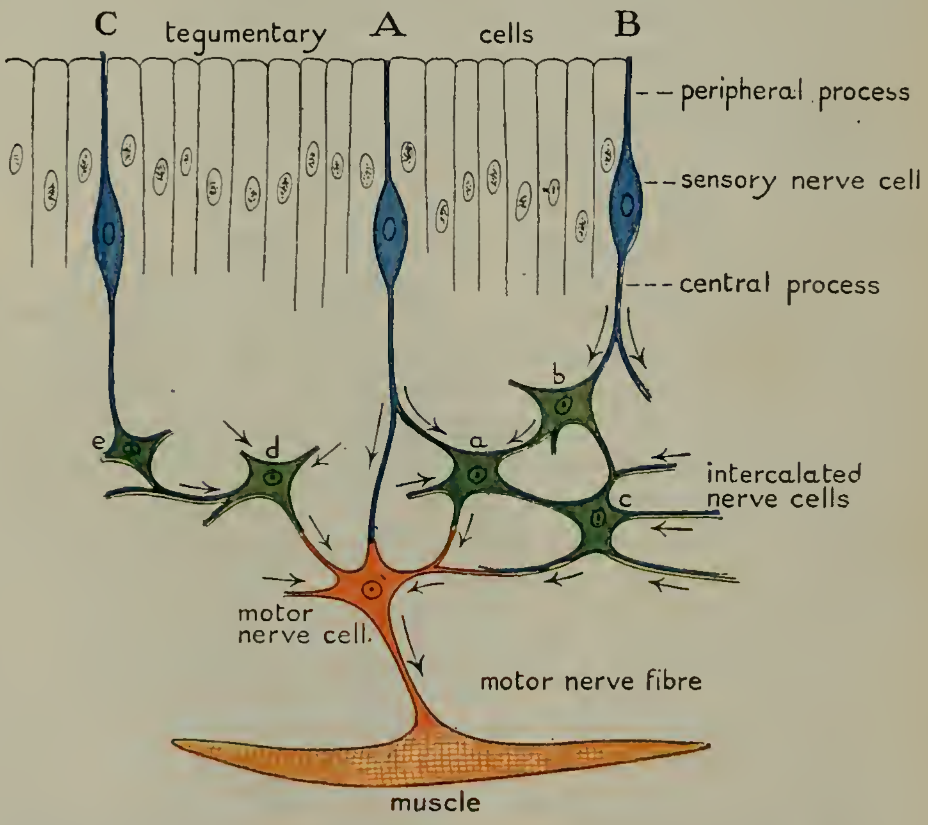


Fig. 414.—A Diagram representing the Essential Features in the Arrangement of the most primitive Type of Nervous System.

The study of a simple scheme representing the relationship that obtains between these three classes of elements in the extremely primitive animal, Hydra (Fig. 414), will make these fundamental facts plain. Changes in the animal's environment affect the extremities of the **peripheral processes** of the sensory cells (*A*, *B*, and *C*), which in Hydra are situated amongst the ordinary tegumentary cells: the effect is transmitted by the **central processes** of such cells (*A*, for example), either directly to the efferent cell, represented in the diagram by a **motor nerve-cell**, or more usually to an intercalated nerve-cell (*a*, *b*, or *e*). Into this (*a*) impulses stream from other intercalated cells (*b* and *c*), bringing the impulse from the sensory cell *A* under the influence of those coming from *B* and from more distant parts of the body through the intermediation of the intercalated cell *c*. The cells *a*, *c*, and *d* are connected with the motor nerve-cell. Thus, there is provided a mechanism whereby the conditions affecting other regions of the body, *B* and *C*, may influence the nature of the response which the stimulation of *A* evokes—either increasing or diminishing its effect or perhaps altering its character.

In this way the intercalated nerve-cells form a great co-ordinating mechanism, linking together all parts of the body in such a way that the activity of any part of the organism may be influenced by the rest, and thus be enabled to act in the interest of the whole.

Hence the nervous system becomes the chief means whereby the various parts of the body are brought into functional relationship one with the other, and co-ordinated into one harmonious whole.

Throughout the whole course of its subsequent evolution the nervous system is formed of these three kinds of elements; and the essential feature in its elaboration and increasing complexity is the multiplication of the intercalated cells, and their concentration, together with the motor nerve-cells, to form a definite organ, which we call the **central nervous system.**

During this process of development of the more complex forms of nervous system, most of the sensory cells migrate from their primitive positions in the skin (Fig. 414); and, as the free extremity of the peripheral process retains its primitive relationship to the skin, such migration of the cell bodies necessitates a great elongation of their peripheral processes. Although these sensory cells thus move inwards into the deeper tissues of the body, the great majority of them do not become incorporated in the central nervous system, but become collected into groups, which form the **ganglia** of the sensory nerves.

In addition to its primary functions of (*a*) providing the means whereby the organism can be brought under the influence of its surroundings, and (*b*) co-ordinating the activities of the whole body, the nervous system also comes to perform other functions of wider significance.

In the course of its evolution the co-ordinating mechanism formed by the intercalated cells becomes so disposed in each animal that an appropriate stimulus applied to the sensory nerves can evoke a definite response, often of great complexity and apparent purposiveness. In other words, the nervous system becomes the repository of those inherited dispositions of its constituent parts which determine the instincts: and in the course of time it eventually provides also the apparatus by which individual experience and the effects of education can be brought to bear upon and modify such instinctive behaviour. In other words, from the nervous system is formed the instrument of intelligence; and the relatively great bulk and extreme complexity of that instrument—the brain—in man are in a sense the physical expression of human intellectual pre-eminence.

In conformity with its primary function of affording a means of communication with the outside world, a great part or, according to most writers, the whole of the nervous system in the human embryo, as in other animals, is developed from the ectoderm, as has already been explained in the chapter dealing with General Embryology (p. 35 *et seq.*). In the most primitive Metazoa the sensory cells remain in the ectoderm (Fig. 414), but other cells become converted into motor nerve-cells and intercalated nerve-cells, which are found in the underlying tissues (Fig. 415). In the human embryo there is an analogous process of development, but with the important difference that the various nervous elements do not wander into the mesoderm individually. A definite patch of ectoderm is set apart to produce the greater part of the nervous tissues for the whole body; and all except the margins of this area sinks into the body, *en masse.*

In one area all the motor nerve-cells develop (Fig. 415, *d*), in another (*c*) only intercalated nerve-cells, in yet another (*b*) the sensory cells originate; and the rest forms the epidermis of the skin (*a*). With our knowledge of the fact that the sensory cells were originally distributed throughout the skin (Fig. 414), the idea naturally suggests itself that in man also the units of the sensory ganglia might be formed *in situ* in the ectoderm, and that the collection of sensory cells in the ganglia might possibly be brought about by the migration of such sensory cells inwards, while their peripheral processes elongate to permit such migration of the cell bodies without disturbing their original endings in the skin. But there is no evidence to show, or even to suggest, that such a process takes place in the human embryo. The facts at our disposal seem to indicate that the sensory cells are derived from sharply circumscribed patches of ectoderm, and that the peripheral processes of these cells are distributed to the outlying area of ectoderm beyond them, from which the epidermis is eventually formed (Fig. 415).

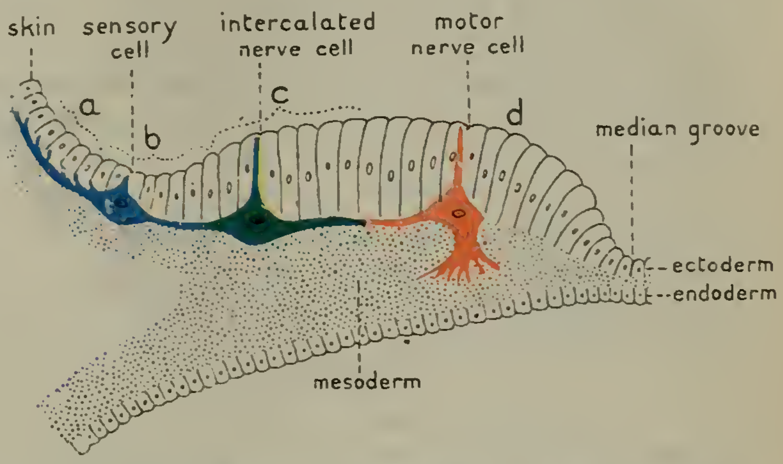


Fig. 415.—Diagram representing (in black) the Left Half of a Transverse Section of a 2 mm. Human Embryo. Superimposed upon it there is shown (in colours) the hypothetical primitive arrangement of the nervous elements derived from each part of the ectoderm.

At the beginning of the second week the nervous system of the human embryo is represented by two thickened plates of ectoderm lying parallel the one to the other, alongside the median axis of the embryo (Fig. 416), which is occupied by a shallow furrow.

Upon a diagram (Fig. 415), representing a transverse section through one-half of such an embryo (the uncoloured part), colours corresponding to those employed in Fig. 414 have been placed to indicate the nature of the elements that are known to develop in relation with each area of the ectoderm at a later period in the history of the embryo: *b* represents an area which later will form the **crista neuralis**, from which the sensory cells will be developed. The peripheral processes of these cells will pass into the skin (*a*) and their central processes into the area *cd*, which will become part of the neural tube. In the area *c* intercalated cells will develop to

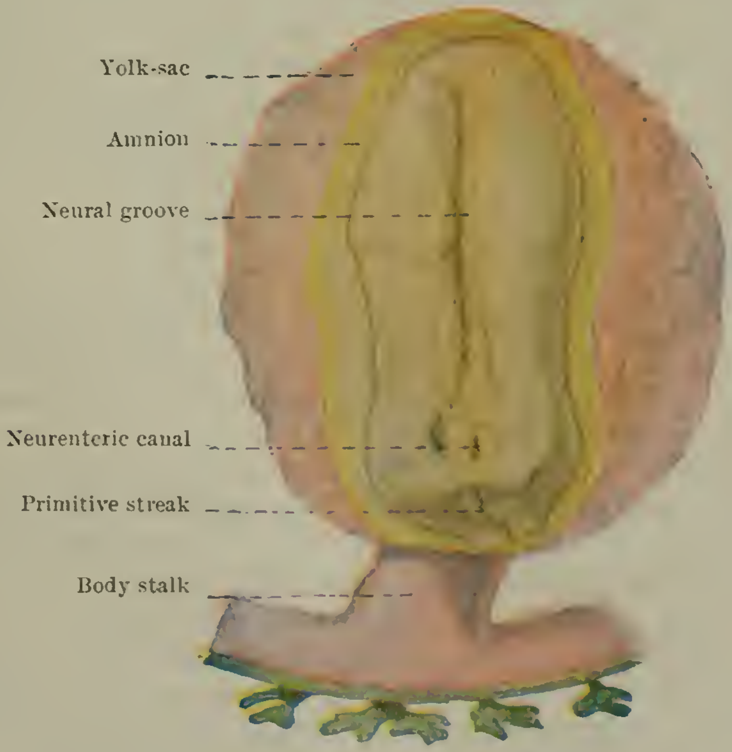


Fig. 416.—The Dorsal Aspect of a Very Early Human Embryo. (After von Spee.)

receive the incoming sensory nerves; and in connexion with the area *d* the motor nerve-cells (as well as other intercalated cells) will be formed.

While we are studying Fig. 415 it is important to emphasise the fact that in accordance with the commonly accepted ideas it is taught that the area *b* becomes completely severed from *a* and *c*, and shortly afterwards fibres are budded off from the cells in the area *b* to form the sensory nerves linking *a* to *c*, thus re-establishing a connexion which existed a few days earlier. This suggests the possibility that the connexions between these three series of elements may not have been completely sundered during the intermediate phase of development. Early in the second week in the human embryo the axial groove separating the two bands of thickened ectoderm (Fig. 416) that form the medullary plate becomes deepened by the tilting-up of the lateral margins of the two bands. This process becomes accentuated during the next day or two until a deep cleft is formed, the walls of which consist of the thickened ectoderm and the floor of the thinner ectoderm **(floor-plate)** joining them together. Before the end of the week the dorsal edges of these thickened plates become joined in the region which will develop into the neck; and during the third week the sealing of the lips of the neural groove extends upwards (headwards) and downwards (tailwards), so that the neural tube becomes completely closed by the end of that week. The extreme anterior (head-) end and the dorsal aspect of the caudal extremity of the tube are the last parts to close, the latter being, as a rule, a little later than the former. When the tube is in the stage of being patent only at its two ends, the openings are known as the **neuroporus anterior** and **neuroporus posterior**, respectively.

In the process of closing, the extreme dorsal edge of the medullary plate becomes excluded, in the greater part of its extent, from participation in the constitution either of the neural tube or of the skin, and forms a column of cells lying between the two. This is the **neural crest** (Fig. 417, A, B, and C; *x* and *y* represent the places where the apparent sundering occurs).

It is commonly supposed that the neural crests do not extend the whole length of the neural tube. Nevertheless, peculiar ectodermal areas, which ultimately give origin to sensory nerves, are found at the junction of the medullary plate with the skin in those regions where the neural crest is supposed to be lacking. At the extreme anterior end of the neural tube the margins of the anterior neuropore become thickened to form crest-like patches; but when the tube closes these areas do not separate from the skin (at *x*, Fig. 417, D), as the rest of the neural crest does. They remain part of the skin and become the olfactory areas, in which sensory cells, precisely like those found in Hydra (Fig. 414), develop.

A little farther on the caudal side of the olfactory region a very large crest-like mass of ectoderm fails to separate from the medullary plate as it closes, and becomes a constituent part of the neural tube (Fig. 417, E). When the optic diverticulum grows out it carries out to the periphery these sensory cells mixed with intercalated cells of the medullary tube to form the composite sensitive membrane of the eye known as the retina.

In several other regions sensory nerves originate from cells of ectodermal, and possibly even entodermal, areas which do not form parts of the neural crest, as that term is usually understood. The nerves of hearing and taste are developed in a way that seems at first sight utterly abnormal, until it is remembered that they afford examples of very primitive methods of nerve-formation.

The essential part of the organ of hearing is an ectodermal sac (otic vesicle) that develops as a diverticulum on the side of the head, from a thickened patch of ectoderm, which in the lower vertebrates forms part of a more extensive area, known as the **dorso-lateral placode.** Some of the cells of this area seem to become transformed into nerve-cells, which migrate into the space between the otic vesicle and the neural tube (Fig. 418) and form the acoustic ganglion.

At the upper margins of the branchial clefts a series of ectodermal and entodermal thickenings develop, which are known as the **epibranchial placodes.** Comparison with the process of development in fish embryos, which has been elucidated by Landacre (*Journal of Comparative Neurology and Psychology*, 1910--1912), suggests that the nerve-cells arise from these placodes, which give origin to the nerves of taste. Such fibres are constituent elements of the facial, glosso-pharyngeal, and in some animals also the vagus cerebral nerves (Fig. 418), in connexion with the ganglia of which epibranchial placodes are formed (Froriep and Streeter). The observations of Professor J. P. Hill upon embryos of Echidna seem to suggest that in mammals the gustatory neuroblasts are derived from the entoderm.

When first formed, the neural tube is compressed from side to side and presents an elliptical outline in transverse section (Fig. 419). The two side walls are very thick, whilst the narrow dorsal and ventral portions of the wall are thin, and are termed the **roof-plate** and **floor-plate** respectively (Fig. 419). The cavity of the tube in transverse section appears as a narrow slit. The wall of the neural tube consists at first of low columnar epithelium arranged in a fairly regular series, but with a certain number of large spherical so-called **germinal cells** scattered between the columns. But this regular disposition as a single layer of cells does not last long. For even by the second week the rapid proliferation of the cells has led to a marked increase in the thickness of the side wall and a scattering of the more numerous nuclei, apparently irregularly, throughout its substance (Fig. 419). The latter consists of a network of protoplasm in which definite outlines of cells cannot be detected. As growth proceeds the innermost part of this nucleated protoplasmic syncytium becomes condensed to form a delicate membrane termed the **internal limiting membrane**, which lines the lumen of the tube, whilst its outermost part presents a similar relation to an **external limiting membrane**, which invests the outer surface of the tube. Toward the end of the first month the side walls of the tube show signs of a differentiation into three layers. Next to the central canal there is an epithelial-like arrangement of the innermost cells of the syncytium, forming the **ependyma**. Then there is an intermediate layer crowded with nuclei, hence known as the nuclear or **mantle layer**. On the surface is a layer singularly free from nuclei, which is called the non-nuclear or **marginal layer**. The germinal cells are placed in the ependymal layer between its radially arranged cells as they pass in towards the internal limiting membrane; and the protoplasm of the germinal cells forms part of the syncytium.

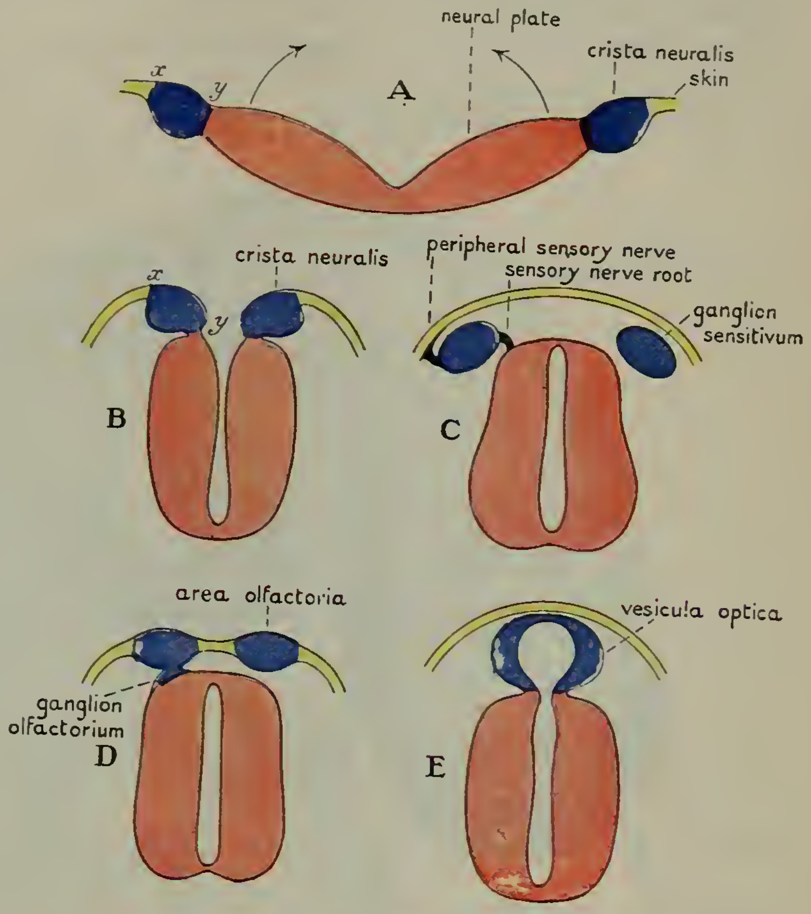


FIG. 417.—DIAGRAMS OF TRANSVERSE SECTIONS REPRESENTING THREE STAGES (A, B, AND C) IN THE DEVELOPMENT OF A SENSORY GANGLION FROM THE NEURAL CREST; AND TWO DIAGRAMS (D AND E) SUGGESTING A POSSIBLE HOMOLOGY OF THE OLFACTORY (D) AND VISUAL (E) EPITHELIUM WITH THE NEURAL CREST. The optic vesicle is a mixture of sensory and intercalated nerve-cells: hence it is not correct to represent it as a purely sensory element. The hypothetical arrangement labelled "vesicula optica" is the optic placode, the sensory elements of which mingle with the neuroblasts of the neural tube and a mixture of the two elements grows out to form the true optic vesicle.

At one time it was imagined that the germinal cells were embryonic nerve-cells, the parent-cells of the real **neuroblasts**, and that the whole of the rest of the syncytium represented the supporting tissues, which in the adult form the **neuroglia.** But it is now known that from the proliferation of the germinal cells, in which mitotic figures can usually be seen, some cells are formed which become ependymal epithelium, and others which migrate peripherally into the mantle layer. There, while forming part of the mantle syncytium, they undergo further proliferation and some of the resulting cells develop into **spongioblasts**, which constitute the supporting framework, the embryonic neuroglia; others become rudimentary nerve-cells or **neuroblasts**, and others again are known as **indifferent cells**. The latter are destined to undergo further subdivision and become the parents of more spongioblasts and neuroblasts.

From this it is clear that the greater part—all except the germinal cells—of the syncytium, which is known as the **myelospongium**, is not merely supporting neuroglial tissue, as was once supposed, but is the rudiment of both neuroglia and true nervous tissues.

The details of the process by which the neuroblasts become dissociated from the neuroglial network are quite unknown. It is commonly supposed that a spherical cell in the mantle layer that is to be transformed into a neuroblast frees itself from the syncytium, and remains for a time independent and wholly unattached amidst the meshes of the neuroglial network: it is supposed further that its true nature as a neuroblast becomes revealed when it takes on a pear-shape, and a protoplasmic process, the stalk of the pear, pushes its way into some other part of the nervous system, or out of it into the mesoderm to reach some muscular or glandular tissue, and becomes the axis cylinder process or axon of the nerve-cell.

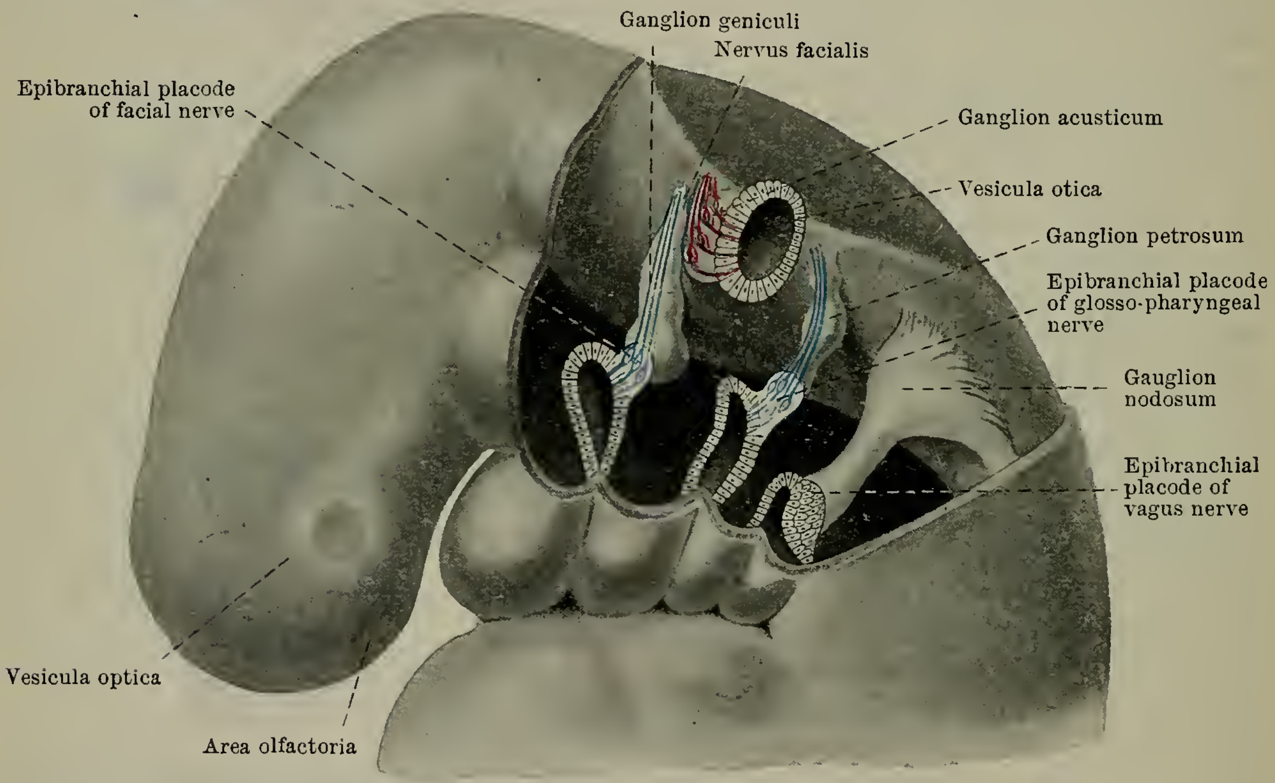


Fig. 418.—Reconstruction of the Ganglia of the Facial, Acoustic, Glosso-pharyngeal, and Vagus Nerves of a Human Embryo 5 Millimetres long (about three weeks old).

The epithelium of three branchial clefts and the otic vesicle is represented diagrammatically; and the supposed mode of origin of the gustatory nerve-cells (and their fibres) from the epibranchial placodes is indicated in blue, and of the acoustic nerve-cells from the otic vesicle in purple.

Such an interpretation of the appearances exhibited in the walls of the neural tube at the end of the first month is adduced in support of a view concerning the constitution of the nervous system known as the **neurone theory**. "Neurone" is the term applied to a nerve-cell and all its processes; and the neurone doctrine assumes that there is no continuity whatever between the substance of one neurone and that of another, such as occurs in Hydra (Fig. 414), and that the functional connexions between them are brought about merely by the contact of the processes of one element with the processes, or the cell-body itself, of another element. In accordance with this conception the facts of embryology are supposed (by His) to demonstrate that when the axon grows out from a previously spherical and unattached cell it is able to push into the surrounding tissues, and, as it were guided by some instinct, eventually finds its way to that particular area of skin, muscle, gland, or other part of the body where nature intends it to go.

This is the current teaching in regard to the neurone theory; and it is supposed to have been conclusively demonstrated by the facts revealed not only by embryology and the study of the minute structure of the nervous system, but also by the phenomena of degeneration and regeneration. Harrison has shown that the outgrowth of processes can be witnessed in the living nerve-cells of the frog. There are certain facts, however, which have always led some anatomists to refuse to believe in the validity of the neurone doctrine as a true expression of the real constitution of the nervous system. It has been clearly demonstrated by Graham Kerr that at a very early stage of development the neural syncytium of the spinal medulla (of the mud-fish Lepidosiren) is in free and uninterrupted continuity with the protoplasm of the muscle-plate, which lies in contact with the neural tube; and no stage is known in which these connexions do not exist. When, in the course of the subsequent growth of the embryo, the muscle-plate becomes removed further and further away from the central nervous system the protoplasmic strand, which links them the one to the other, gradually becomes stretched and elongated. As the neuroblast matures its chemical constitution becomes modified; it becomes specialised in structure to fit it for the peculiar functions it has to perform. These changes manifest themselves first in the body of the neurone itself and thence spread along its processes. With the knowledge that protoplasmic bridges exist long before the time His supposed the axon of his neuroblast to push its way outward, it seems not unreasonable to suppose that it is the chemical modification of these existing bridges which has been revealed in stained specimens, as it spreads from the cell-body outwards into its processes.

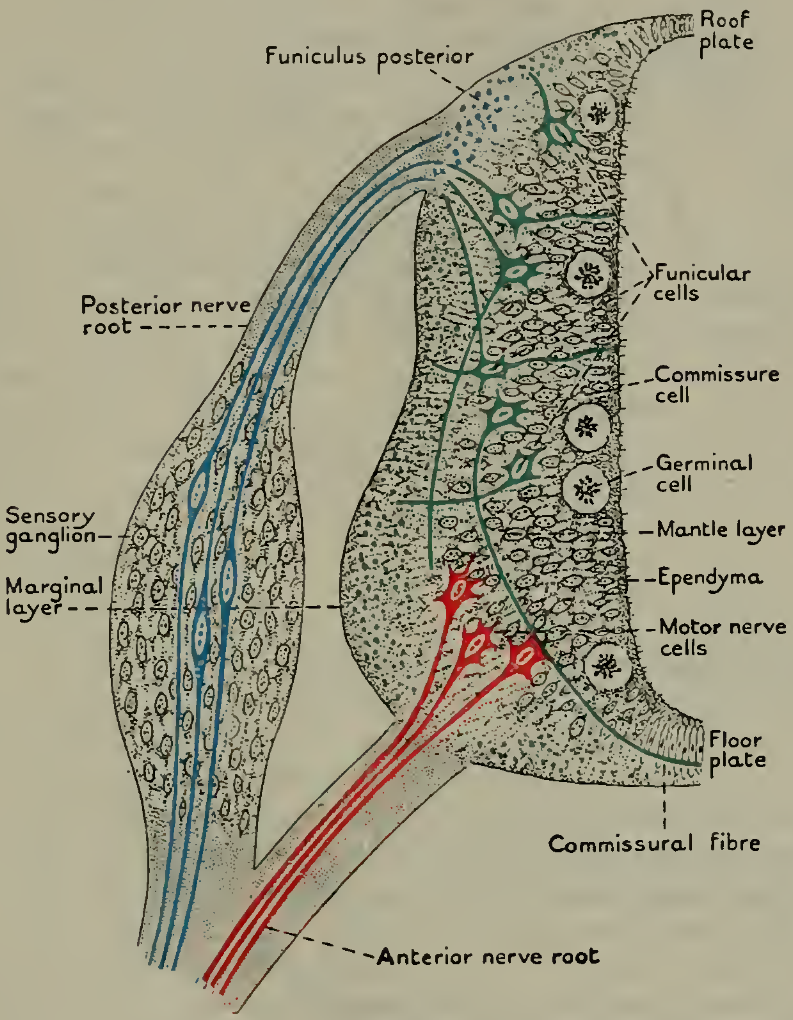


FIG. 419.—DIAGRAM OF TRANSVERSE SECTION OF EARLY NEURAL TUBE.

It is now a well-recognised fact that soon after the neural tube becomes closed the outlines of its constituent cells become blurred and then disappear, and a continuous protoplasmic network or syncytium is formed. No one has ever been able to detect the process of detachment of embryonic nerve-cells (neuroblasts) from this syncytium; and it is at least a possibility that the free anastomosis of the protoplasmic processes of many of the cells is not destroyed in the way demanded by the neurone doctrine. The known facts might be interpreted, at least as reasonably, by supposing that when nerve currents begin to traverse the syncytium (Fig. 419) structural modifications occur around the nuclei of the cells affected, and gradually spread along their processes, so as to give the appearance (in sections stained by special methods) of processes growing out from each neurone.

Impulses brought from the skin by the sensory nerves, the nutrition of which is controlled by the cells in the sensory ganglion (Fig. 419), are carried into the wall of the neural tube, where they are received by processes of intercalated cells, which in turn transmit their effects directly or indirectly to (*a*) motor nerve-cells (or other kind of efferent nerve-cells), which stimulate a muscle, a viscus, or other active tissue to perform some work, or (*b*) to intercalated cells, the axons of which proceed to some other part of the nervous system, perhaps above or below the place where the sensory nerve enters (Fig. 419, *funicular cells*). As the walls of the neural tube increase in size the various neurones gradually become drawn apart, and the protoplasmic links uniting them become stretched and extended to form processes of varying length.

It is right to explain that most writers give an explanation of the process of development which is at variance with that just sketched. The neuroblast is supposed to originate as a free-lying spherical cell, which is stimulated by some unknown force, sometimes assumed to be of the nature of a chemical attraction (chemotaxis), to protrude a process, which gradually elongates and pushes its way through the tissues, perhaps to some particular patch of skin, muscle, gland, or some other nerve-cell. The difficulty involved in such a conception is not only that it is opposed to all that is known of the early stages in the evolution of the nervous system, but also that it is difficult to conceive that every one of the millions of nerve-cells, muscle-cells, visceral and cutaneous elements can each have some specific attractive power which leads every individual nerve fibril to its appropriate and predestined place in the body.

The Efferent Nerves.—The efferent cells of the neural tube are distinguished by the fact that their axons leave the central nervous system and traverse the mesoderm for a longer or shorter distance to end in relation to some muscle or nerve-cell outside the nervous axis. In the course of the growth of the body the various structures supplied by efferent fibres become removed progressively further and further from the central nervous system; and in this process a distinction can be detected in the behaviour of the efferent fibres (*a*) proceeding to the striped or voluntary muscles, and those (*d*) conveying impulses destined for viscera and unstriped muscle, respectively. The efferent cells (*a*) which innervate voluntary muscles take up their positions in the central nervous system, their axis-cylinder processes (motor nerves) becoming elongated in proportion to the migration of the muscle from its original situation. But the cells (*c*) innervating non-striped muscles and viscera are disposed in a different manner. They lie outside the central nervous system either as constituent elements of one of the so-called **sympathetic** or **autonomic ganglia**, or as peripheral ganglia near to or within the walls of the viscera. Impulses from the central nervous system are transmitted to these sympathetic ganglia by means of fibres (white rami communicantes) arising from cells (*d*) within the central organ; and it is customary to distinguish these latter elements as **splanchnic efferent cells.** It is, however, a matter of fundamental importance to recognise clearly that the real splanchnic efferent cells, the homologues of the **somatic efferent cells**, are found in the sympathetic ganglia, and that the elements to which this term is usually applied are in reality intercalated cells.

Nerve Components.—From the statements in the preceding paragraphs it must be evident that there are several varieties of afferent and efferent nerves respectively entering and leaving the central nervous system. The cells of origin of the efferent nerves collect in the ventral part of the side wall of the neural tube; and for this reason this part of the wall becomes swollen at an early stage of development (Figs. 420 and 421). It is called the **basal lamina.** Most of the cells that emit afferent fibres are situated in the sensory ganglia outside the central nervous system, so that their growth can have no direct influence upon the form of the neural tube; but their central processes become inserted into the dorsal part of the side wall of the tube, which is called the **alar lamina**; and groups of intercalated cells collect around the entering fibres to form **receptive** or **terminal nuclei.** The growth of these terminal nuclei leads to an expansion of the alar lamina which is analogous to, but much less extensive than, that seen in the basal lamina. This unequal swelling of the dorsal and ventral parts of each side wall of the neural tube leads to the development of a longitudinal groove, **sulcus limitans,** as a demarcation between the alar and basal laminæ.

The nuclei of origin of the efferent fibres, which are found in the basal laminæ, may be divided into two (and, in some regions of the nervous axis, three) main groups. There is first the group of large multipolar nerve-cells which emit fibres to innervate the ordinary striped voluntary muscles. This is commonly called the **somatic efferent nucleus.** Then there is a group of small multipolar cells, the axons of which pass out into sympathetic ganglia, and indirectly control the involuntary unstriped muscles and other active parts of viscera. These cells form the **splanchnic efferent nucleus.**

In the upper cervical and lower cranial region a portion of the somatic efferent nucleus is set apart to innervate the striped muscles developed in the branchial arches. This is the **lateral somatic** or **intermediate efferent nucleus.** Many recent writers are of the opinion that this nucleus is **splanchnic**; but its component nerve-cells are typically somatic and its fibres directly innervate striped voluntary muscles, which are developed from the same material (myotomes) from which the other striped muscles are formed (Agar and Graham Kerr). Hence it is altogether unjustifiable to refuse it the appropriate designation "somatic."

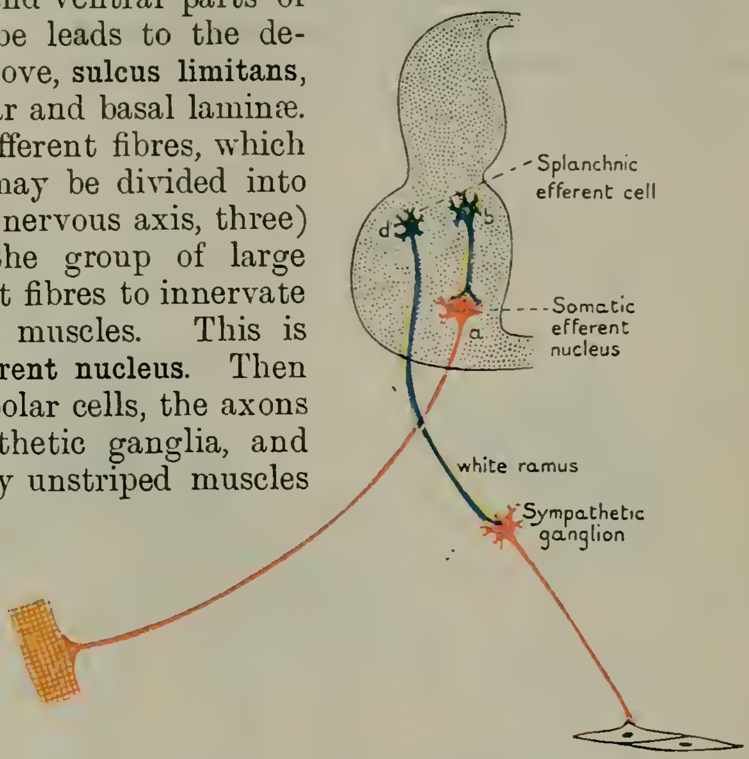


Fig. 420.—Diagram of a Transverse Section through the Left Half of the Neural Tube representing the Arrangement of the Efferent Nerves, to suggest the Possible Homology of a Sympathetic Ganglion Cell and a Central Motor Cell and of a White Ramus with the Axons of Intercalated Cells.

The alar lamina also can be subdivided into a series of functional areas (Fig. 421).

At the dorsal edge is the **somatic afferent terminal nucleus,** which receives impulses coming from the skin. In one region a part of this nucleus is specialised for the reception of impulses coming from the internal ear (**acoustico-lateral terminal nucleus**). Then there is a group of cells collected around the incoming visceral sensory nerves—the **splanchnic afferent terminal nucleus.** A part of this is specialised to receive taste impressions—the **gustatory nucleus**—but this has not yet been clearly demarcated from the rest of the nucleus.

This analysis of the various functional elements that may enter into the constitution of the various cerebral and spinal nerves is made use of in elaborating the **theory of nerve components,** which will help us to understand many features of the structure of the nervous system that otherwise would be unintelligible.

Nerve-cells.—We have already noticed that there is a broad distinction between the nerve-cells which are found in the ganglia of sensory nerves and those found in the rest of the nervous system. They differ not only in their mode of origin and in their subsequent development, but also in the connexions of their nerve-fibre processes.

Nerve-cells of the Brain and Spinal Medulla.—The cells in the cerebro-spinal axis are variable both in size and form. Some are relatively large, as, for example, certain of the pyramidal cells of the cerebral cortex and the motor cells in the spinal medulla, which almost come within the range of unaided vision; others are exceedingly minute, and require a high power of the microscope to bring them into view. The cell consists of a protoplasmic nucleated body, from which the **axon** proceeds, and the **protoplasmic processes of Deiters**, or the **dendrites** (Fig. 422).

The **axon** presents a uniform diameter and a smooth and even outline. It gives off in its course fine collateral branches, but does not suffer thereby any marked diminution in its girth. The most important point to note in connexion with the axon, however, is the fact that it becomes continuous with the axis-cylinder of a nerve-fibre. The axon then is simply a nerve-fibre, and in certain circumstances it assumes one or two investing sheaths, of which more will be said later. The axon may run its entire course within the substance of the brain or spinal medulla, either for a short or a long distance (intercalated cells), or it may emerge from the brain or spinal medulla in one of the cerebral or spinal nerves as the essential part of an efferent nerve-fibre, and run a variable distance before it finally reaches the peripheral structure in relation to which it ends (efferent nerve-cells). The axon and the collaterals which spring from it appear to terminate either in small button-like swellings or knobs, or more frequently in terminal arborisations, the extremities of which seem to be furnished with exceedingly small terminal varicosities. In those cases where the axon or its collaterals end within the brain or spinal medulla, some of the terminal arborisations interlace with the dendrites of nerve-cells, whilst others are twined around the bodies of other cells. In the latter case the interlacement may be so close and complete that it almost presents the appearance of an enclosing basket-work. In cases where the axon emerges from the cerebro-spinal axis its terminal arborisa-

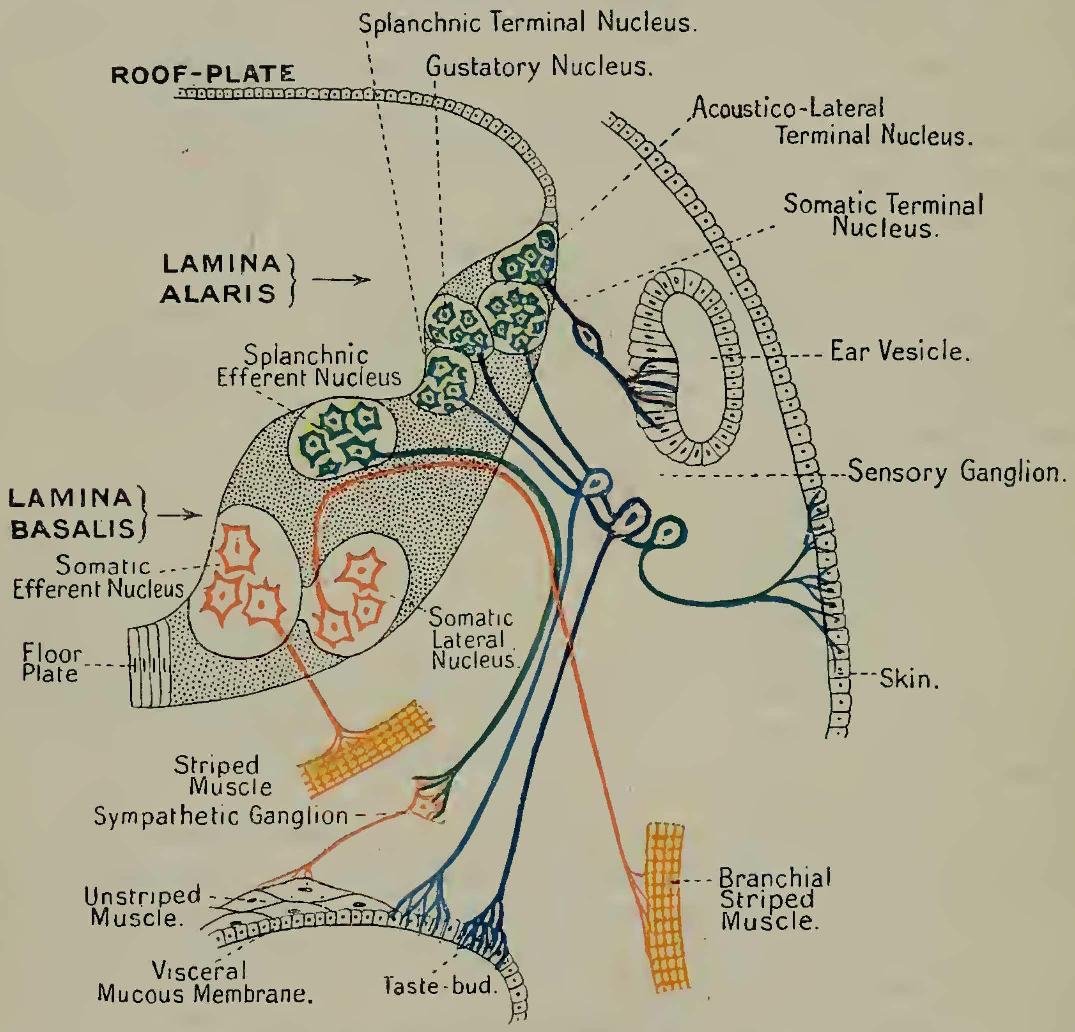


FIG. 421.—DIAGRAM OF A TRANSVERSE SECTION THROUGH THE RIGHT HALF OF THE FŒTAL RHOMBENCEPHALON AND EPITHELIAL AREAS ASSOCIATED WITH IT TO ILLUSTRATE THE DIFFERENT CATEGORIES OF NERVE COMPONENTS AND THEIR CENTRAL NUCLEI.

tion ends in relation to a muscle-fibre or some other tissue in the manner described below.

Nerve-fibres.—Nerve-fibres, arranged in bundles of greater or less bulk, form the nerves which pervade every part of the body. They also constitute the greater part of the brain and spinal medulla. Nerve-fibres are the conducting elements of the nervous system; they serve to bring the nerve-cells into relation both with each other and with the various tissues of the body.

There are different varieties of nerve-fibres, but in all the leading and essential constituent is a delicate thread-like axon. The most obvious difference between individual fibres depends upon the nature of the covering of the axon. When it is coated on the outside by a more or less thick sheath of a fatty substance, termed **myelin**, it is said to be a myelinated or medullated fibre. When the coating of myelin is absent, the fibre is termed a non-myelinated or a non-medullated fibre. A second sheath—thin, delicate, and membranous, and placed externally—may also be present in both cases. It is termed the **primitive sheath** or the **neurolemma.** From a structural point of view, therefore, four different forms of nerve-fibre may be recognised :—

Non-medullated—
  1. Naked axis-cylinders.
  2. Axis-cylinders with primitive sheaths.
Medullated—
  3. Primitive sheath absent.
  4. Primitive sheath present.

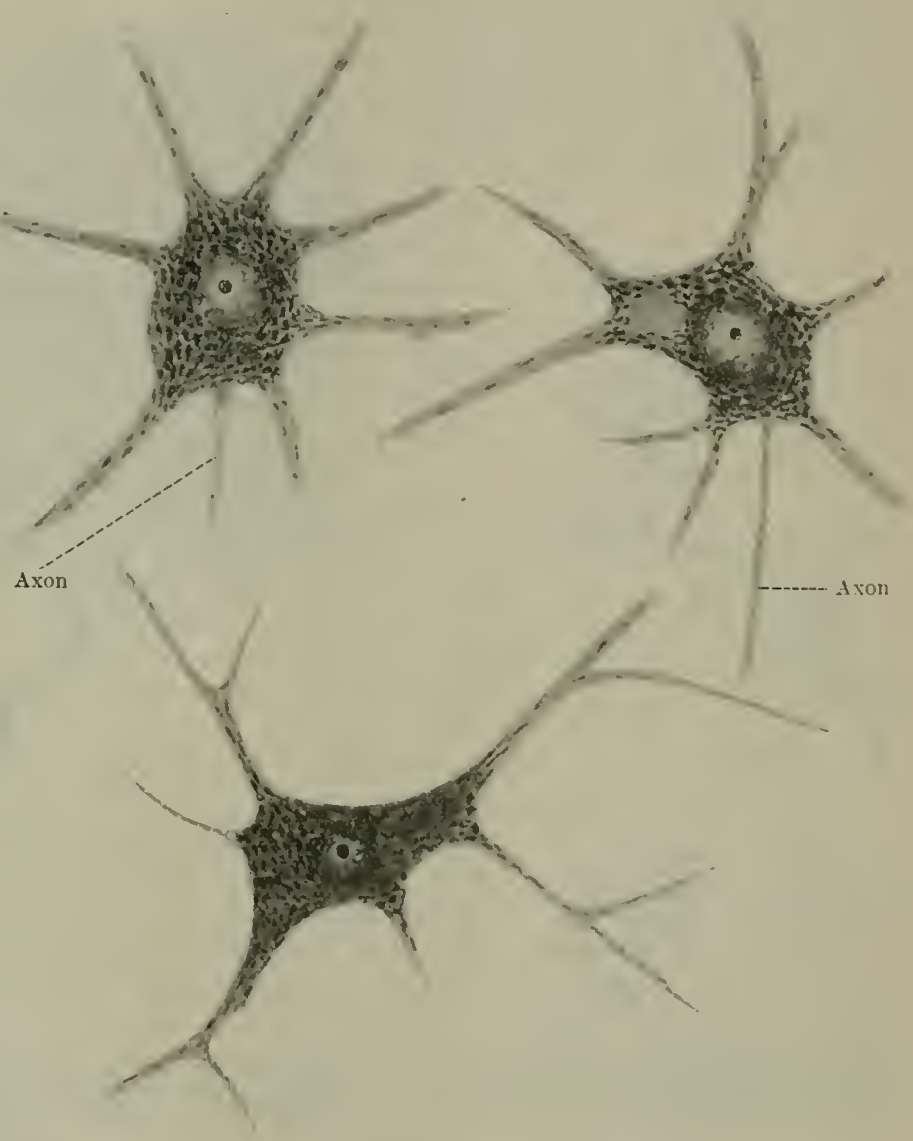


Fig. 422.—Three Nerve-cells from the Anterior Column of Gray Matter of the Human Spinal Medulla.

Every nerve-fibre near its origin and as it approaches its termination is unprovided with sheaths of any kind, and is simply represented by a non-medullated, naked axis-cylinder. The fibres of the olfactory nerves afford us an example of non-medullated fibres furnished with a primitive sheath.

Medullated fibres are present in greater quantity in the cerebro-spinal system than non-medullated fibres. Thus, all the nerves attached to the brain and spinal medulla, with the exception of the olfactory and optic, are formed of medullated fibres provided with a primitive sheath; whilst the entire mass of the white substance of the brain and spinal medulla, and also the optic nerves, are formed of medullated fibres devoid of a primitive sheath.

It is important to note that the distinction between the medullated and non-medullated fibres is not one which exists throughout all stages of development. As will be presently pointed out, every fibre is the prolongation of a cell, and in the first instance it is not provided with a medullary sheath. Indeed, it is not until about the fifth month of fœtal life that those fibres which are to form the white substance of the cerebro-spinal axis begin to acquire their coating of myelin. Further, this coating appears in the fibres of different fasciculi or tracts at different periods, and a knowledge of this fact has enabled anatomists to follow out the connexions of the tracts of fibres which compose the white matter of the brain and spinal medulla.

Every nerve-fibre is directly continuous by one extremity with a nerve-cell, whilst its opposite extremity breaks up into a number of ramifications, all of which end in relation to another nerve-cell, or in relation to certain tissues of the body, as, for example, muscle-fibres or the epithelial cells of the epidermis. The length of nerve-fibres, therefore, varies very greatly. Some fibres are short and merely bring two neighbouring nerve-cells into relation with each other; others travel long distances. Thus, a fibre arising from one of the motor cells of the lower end of the spinal medulla may, after leaving the spinal medulla, extend to the most outlying muscle in the sole of the foot, before it reaches its destination. But even when a fibre does not leave the central axis, a great length may be attained, and cells situated in the uppermost part of the brain give origin to fibres which pass down to the lower end of the spinal medulla.

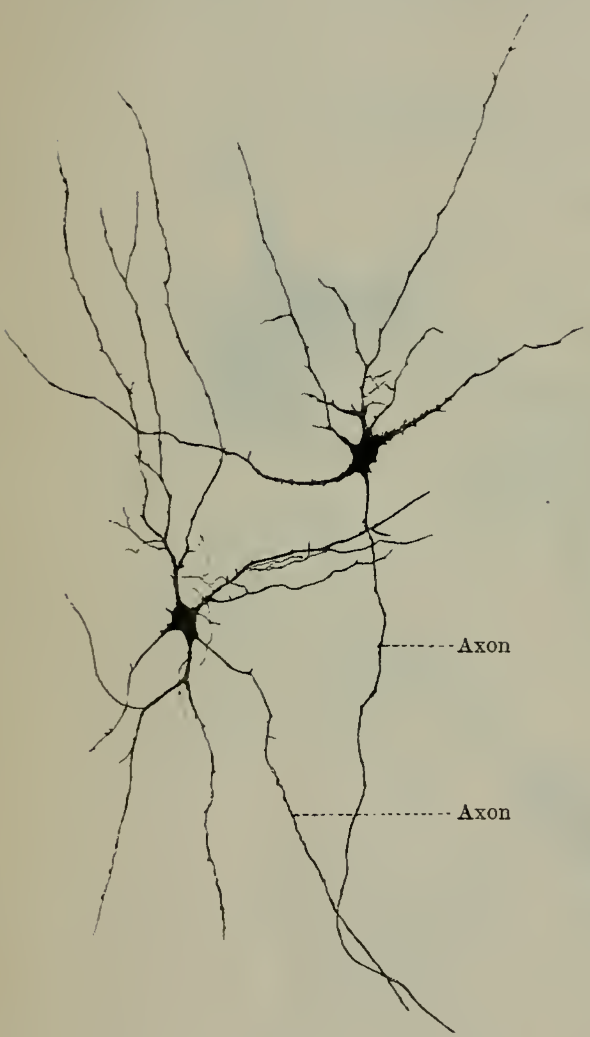


Fig. 423.—Two Multipolar Nerve-cells. (From a specimen prepared by the Golgi method.)

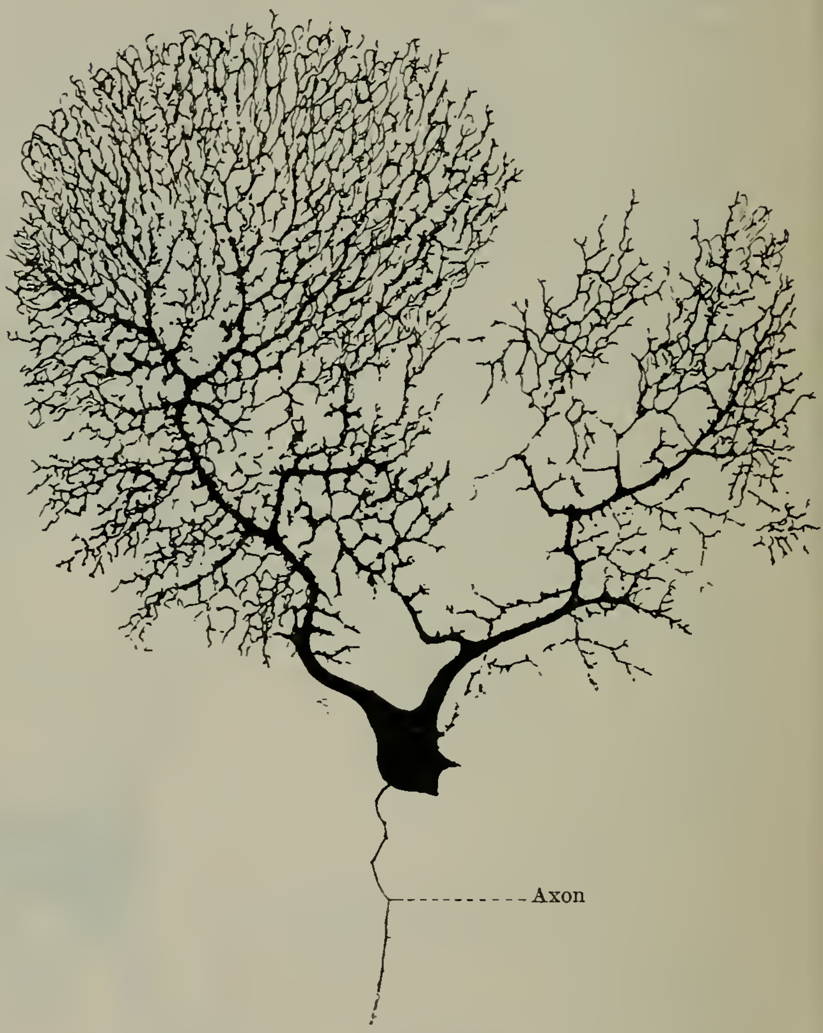


Fig. 424.—Nerve-cell from Cerebellum (Cell of Purkinje) showing the Branching of the Dendritic Processes. (From a photograph by Professor Symington.)

It has already been explained that fibres which form the nerves may be classified into two sets, afferent and efferent. **Afferent nerve-fibres** conduct impressions from the peripheral organs into the central nervous system; and as a change of consciousness, or, in other words, a sensation, is a frequent result, these fibres are often called *sensory*. **Efferent nerve-fibres** carry impulses out from the brain and spinal medulla to peripheral organs. The majority of these fibres go to muscles and are termed *motor*; others, however, go to glands and are called *secretory*;

whilst some are *inhibitory* and serve to carry impulses which restrain or check movement or secretion.

The **dendrites**, or protoplasmic processes of the nerve-cell, are thicker than the axon, and present a rough-edged irregular contour. They divide into numerous branches, and these gradually, as they pass from the cell-body, become more and more attenuated until finally they appear to end in free extremities. The branching of the dendritic processes sometimes attains a marvellous degree of complexity (Fig. 424), but it is commonly supposed that there is no anastomosis between the dendrites of neighbouring cells, or between the dendrites of the same cell.

It is commonly believed that the neuroblast passes through stages analogous to those shown in the diagram (Fig. 426); that just as a seed gives off a root which strikes downward, and leaves which grow upward, so the neuroblast sprouts out an axon (*a*) and subsequently develops a bunch of dendritic processes (*b*). In the case of the axon reasons have already been given for not accepting this view as the whole explanation; and in the case of the dendrites, although the appearance of microscopic sections seems to favour the view expressed in the diagrams, the fact that the neuroblasts are united into a continuous network or syncytium at an early stage of development (see p. 505) raises the possibility that the dendrites may be formed by the gradually drawing out of the existing bridges as the linked cell-bodies become moved apart.

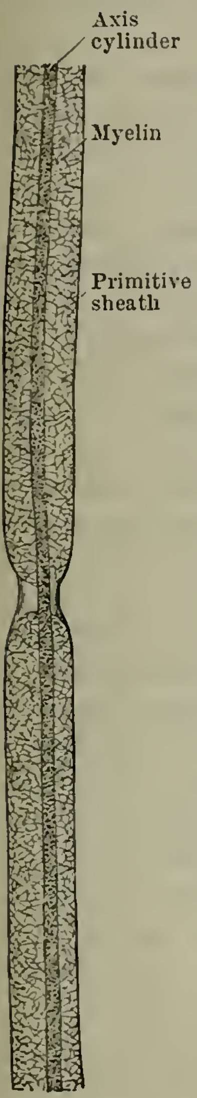


Fig. 425. Nerve-fibre from a Frog. (After v. Kölliker.)

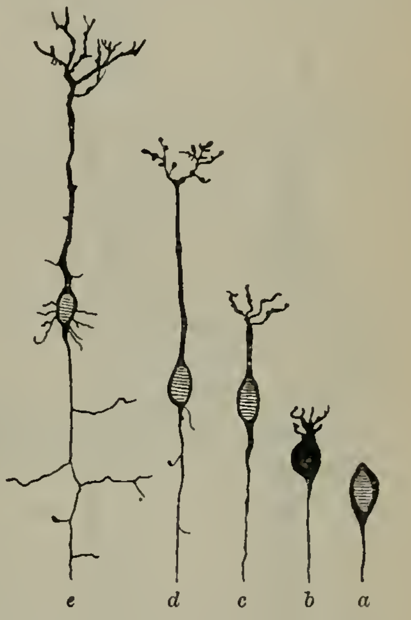


Fig. 426.—Ramón y Cajal's Interpretation of the Developmental Stages exhibited by a pyramidal Cell of the Brain.

a, Neuroblast with rudimentary axon, but no dendrites; *b* and *c*, The dendrites beginning to sprout out; *d* and *e*, Further development of the dendrites and appearance of collateral branches on the axon.

The Ganglia of the Sensory Nerves.—The cells found in the ganglia of the cerebral nerves and on the posterior or dorsal roots of the spinal nerves have a different origin, and present many points of contrast with neurones in the gray matter of the brain and spinal medulla. As already indicated, the ganglia in question are derived from the neural crest. The cells forming these ganglionic masses are somewhat oval in form, and each extremity or pole becomes drawn out into a process, so that the neurones become bipolar. These processes are distinguished as central and peripheral, according to the direction which they take. The central processes penetrate the wall of the neural tube. In the region of the spinal medulla they form almost the whole of the fibres which enter into the composition of the posterior roots of the spinal nerves. In the substance of the cerebro-spinal axis they give off numerous collaterals, and after a course of varying extent they end, after the manner of an axon, in terminal arborisations, which enter into relationships with certain nerve-cells in the cerebro-spinal axis. The peripheral processes proceed along the path of the particular nerve with which they are associated, and they finally reach the skin or other sensory surface. Thus, to take one example: the majority of the fibres which go to the skin break up into fine terminal filaments, which end freely between the epithelial cells of the epidermis. The two processes of a ganglion cell, therefore, form the afferent fibres of the cerebro-spinal nerves, and constitute the path along which the influence of peripheral impressions is conducted towards the brain and spinal medulla. The body of the cell is, as it were, interposed in the path of such impulses.

But the original bipolar character of these cells, with very few exceptions (ganglia in connexion with the acoustic nerve and the bipolar nerve-cells in the olfactory mucous membrane), gradually undergoes a change which ultimately leads to their transformation into unipolar cells. This is brought about by the tendency which the cell-body has to grow to one side, viz., the side towards the surface of the ganglion (v. Lenhossek). This unilateral growth leads to a gradual approximation of the attached ends of the processes, and finally to a condition in which they appear to arise from the extremity of a short common stalk in a T-shaped manner (Fig. 427). It is interesting to note that in fishes the original bipolar condition of these cells is retained throughout life, without change.

Both the central and peripheral processes of these ganglionic cells become the axis-cylinders of nerve-fibres, which, acquiring a medullary sheath, belong therefore to the medullated variety. From this it might very naturally be thought that the ganglionic neurone, with its two axons and no typical dendrites, is a nervous unit very different from a neurone in the gray matter of the cerebro-spinal axis. It is believed by some, however (van Gehuchten and Cajal), that the peripheral process, in spite of its enclosure within a medullary sheath, and though presenting all the characters of a true axon, is in reality a dendrite. If this is the case, the morphological difference between a dendrite and an axon disappears, and van Gehuchten's functional distinction alone remains characteristic, viz., that the axon is *cellulifugal* and conducts impulses away from the cell, whilst the dendrites are *cellulipetal* and conduct impulses towards the cell.

It is, however, more in accordance with the facts to regard the sensory neurones as genetically quite distinct from the rest of the nervous system (see p. 500).

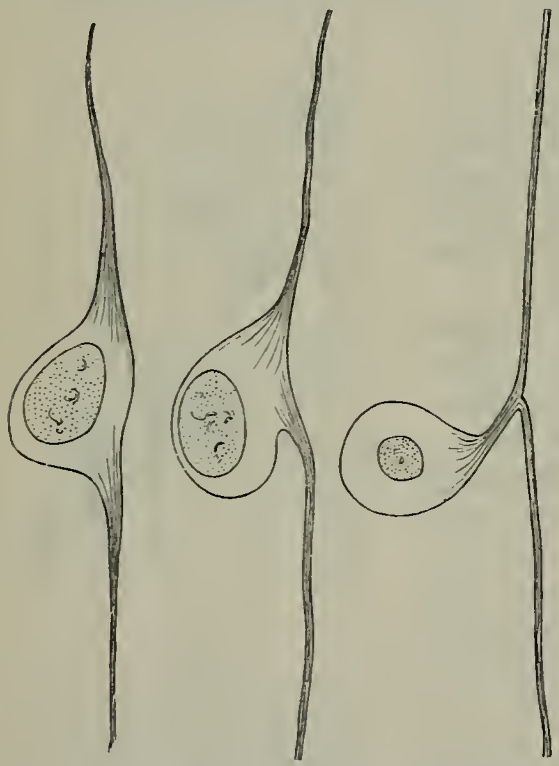


Fig. 427.—Three Stages in the Development of a Cell in a Spinal Ganglion.

Neuroglia.—The neuroglia is the supporting tissue of the cerebro-spinal axis. It may be considered to include two different forms of tissue, viz., the lining ependymal cells and the neuroglia proper. We place these under the one heading, seeing that they have a common developmental origin.

The **ependymal cells** are the columnar epithelial cells which line the central canal of the spinal medulla and the ventricles of the brain. In the embryonic condition a process from the deep extremity of each cell traverses the entire thickness of the neural wall and reaches the surface. It is not known whether this process exists in the adult.

The **neuroglia proper** is present in both the white and the gray matter of the cerebro-spinal axis. It constitutes an all-pervading basis substance, in which the various nerve elements are embedded in such a way that they are all bound together into a consistent mass, and are yet all severally isolated from each other. Neuroglia consists of cells and fine filaments. The fibrils are present in enormous numbers, and by their interlacements they constitute what appears to be a fine feltwork. At the points where the fibrils intercross may be seen the flattened *glial cells.* Whilst the neuroglia is for the most part intimately intermixed with the nerve elements, there are, in both brain and spinal medulla, certain localities where it is spread out in more or less pure layers. Thus, upon the surface of the brain and of the spinal medulla there is such a layer; likewise beneath the epithelial lining of the central canal and of the cavities of the brain there is a thin stratum of neuroglia.

The ependymal cells are derived from the original neuro-epithelial cells of the early neural tube, and in all probability the neuroglia proper has a similar origin. They both, therefore, are products of the ectoderm.

Summary.—1. The cerebro-spinal nervous system is composed of two parts, viz., (*a*) a **central part**, consisting of the brain and spinal medulla, with the efferent nerve-fibres which pass out from them; (*b*) the **ganglionic part**, with the afferent nerve-fibres.

2. Each of these parts has a different origin, and is composed of neurones which possess characteristic features.

3. The ganglionic neurones are derived from the primitive cells of the neural crest, and have each one process, which divides into two. Of these the central division enters the cerebro-spinal axis, whilst the peripheral division becomes connected with a peripheral part. The central fibres from the ganglionic cells in the region of the spinal medulla form the dorsal or posterior roots of the spinal nerves. The cells of origin of these posterior roots are outside the spinal medulla, and carry impulses into its substance.

4. The cerebro-spinal neurones are derived from the neuroblasts in the wall of the early neural tube. Certain of these furnish efferent nerve-fibres, which issue from the spinal medulla in separate bundles termed the anterior or ventral roots of the spinal nerves. In the case of the cerebral nerves, however, with the exception of the trigeminal and facial nerves, the efferent fibres are not thus separated from the afferent fibres at their attachment to the brain.

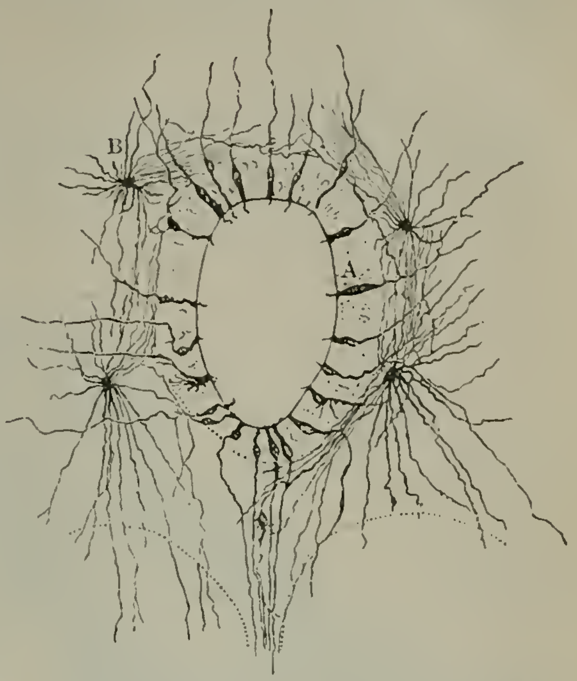


FIG. 428.—SECTION THROUGH THE CENTRAL CANAL OF THE SPINAL MEDULLA OF A HUMAN EMBRYO, SHOWING EPENDYMAL AND NEUROGLIAL CELLS. (After v. Lenhossek.)
A, Ependymal cell. B, Neuroglial cell.
[Note that the dorsal (posterior) aspect is *below*.]

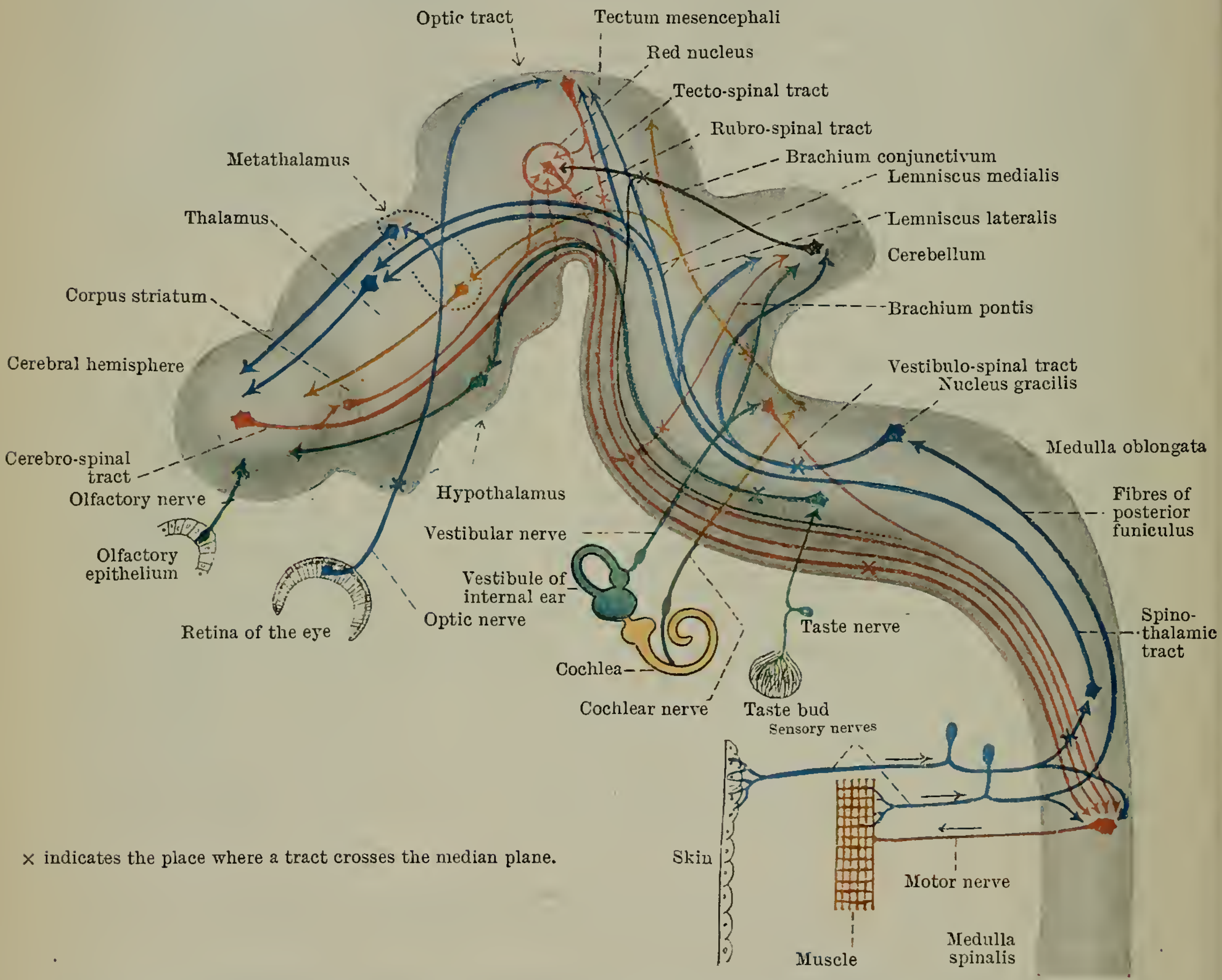
5. The brain and spinal medulla, when studied by the naked eye, are seen to be composed of white matter and gray matter. The white matter forms very nearly two-thirds of the entire cerebro-spinal axis. It is composed of medullated nerve-fibres embedded in neuroglial tissue. The gray matter is composed of nerve-cells with their dendrites and axons. Some of the axons are in the form of naked axis cylinders, whilst others have a coating of myelin. Intimately intermixed with these parts is the neuroglia, which isolates them more or less completely from each other.

THE NATURE OF THE BRAIN.

In the foregoing account it has been explained that the nervous system is composed of a series of afferent nerves bringing information from every part of the body into the central nervous system, from which efferent nerves pass out to the muscular and other active parts of the body, providing the means for translating such information into appropriate action. But it has been seen that the essential part of the central nervous system is the intercalated cells, which provide the means whereby the information brought in by any sensory nerve may be placed at the service of the whole body, and the response which it excites may be controlled and regulated by the condition of the rest of the body. The system of intercalated cells links together into one co-ordinated mechanism the whole nervous system, and, through it, every part of the body itself.

In some very primitive and remote ancestor of man (and in fact of the vast majority of animals) the front end of the nervous system became enhanced in importance to form a brain, which assumed a dominant influence over the rest. This was brought about in the first place by the fact that in an elongated prone animal moving forwards, the front end would naturally come first into relationship with any change in environment; and this earlier acquisition of information concerning the outside world would necessarily give the head end of the nervous system exceptional opportunities for influencing the rest of the nervous system.

This predominance is further accentuated by the development in the head region of the organs of special sense, which provide mechanisms specially adapted to be influenced by light, sound, and such delicate chemical forms of stimulation as excite in ourselves sensations of smell and taste. As the information conveyed by these special senses, such as the scent of food or the visual impression of some enemy, must be able immediately to influence the movements of the whole body, it follows that a specially abundant system of intercalated elements link the central ends of these nerves of the special senses with the rest of the central nervous system. Moreover the predominant influence of the head end of the central nervous system implies that it must be provided with a specially large series of nerve-fibres, not only for the purpose of bringing this influence to bear upon the rest of the nervous system, but also of being itself brought into intimate relationship with the nervous system as a whole, seeing that sensory impulses are constantly pouring into every part of it.



× indicates the place where a tract crosses the median plane.

Fig. 429.—Diagram representing the connexions of some important Sensory and Motor Tracts in the Brain to which references are made in pages 515 to 519. Motor paths in red; sensory in other colours.

Thus the head end of the central nervous system becomes the brain, which is characterised by a series of large irregular swellings, due to (*a*) the development around the insertion of each special sensory nerve of a mass, or group of masses, of intercalated cells which will enable the effects of the visual, acoustic, olfactory, gustatory or other sensations to influence the whole nervous system, and (*b*) the evolution of complicated systems of intercalated cells, which receive, and in a sense blend, impressions coming from all parts of the nervous system, and emit fibres which pass, directly or indirectly, to the various groups of motor nerve-cells and control their activities and, through them, the behaviour of the animal.

In the development of the human embryo this distinction between the head end and the rest of the central nervous system is indicated even before the medullary plate is completely folded up to form the neural tube. The widened part represents the rudiment of the **encephalon** or brain; and the rest of the tube will become converted into the **medulla spinalis.**

If the attempt is made to analyse the meaning of the early broadening of the brain rudiment it will be found to be due in great measure to the fact that there is added to the margins of the medullary plate (see Fig. 417, E, p. 503) the material from which the sensitive part of the eye and the optic nerve will be developed; but soon after the neural tube is closed irregular swellings will make their appearance around the attachments of the nerves of smell, vision, hearing, and taste (Fig. 429), and also the great vagus nerve that is widely distributed to the viscera of the neck, thorax, and abdomen.

But there are other factors besides these irregularities of growth of its walls which add complexity to the form of the encephalon in the embryo. In the course of their growth both parts (encephalon and medulla spinalis) of the neural tube undergo great extensions in length, breadth, and thickness; but in the case of the spinal medulla it is the increase in length that is most distinctive, whereas in the encephalon, the irregular expansion in breadth and thickness is more obtrusive. Nevertheless, the brain elongates more rapidly than that part of its mesodermal capsule which ultimately becomes the brain-case or cranium; and hence it becomes bent to permit of its being packed in the limited length of the cranial cavity. But if it is admitted that these mechanical considerations are in a measure responsible for the three bends which develop in the embryonic encephalon, their situation and the forms they assume are determined by the irregularities of growth inherent in the brain itself.

Even at a time, during the second week, when the anterior (oral) end of the neural tube is still open (**neuroporus anterior**), a right-angled bend has already developed in the rudiment of the brain (**cerebral vesicle**). Slightly less than half of the length of the vesicle had projected beyond the upper (anterior) end of the notochord and became flexed ventrally round it (Fig. 430).

This bend is known as the **cephalic flexure.** The region of the brain vesicle in which it develops will later on become the **mesencephalon** or **mid-brain**; and even at the early stage of development now under consideration (Fig. 430) there is a slight narrowing of the tube (**isthmus**) that marks the boundary between the mid-brain and the **rhombencephalon** or **hind-brain.** Just beyond the end of the notochord there is an even fainter trace of a constriction indicating the line of demarcation between the mid-brain and the **prosencephalon** or **fore-brain.**

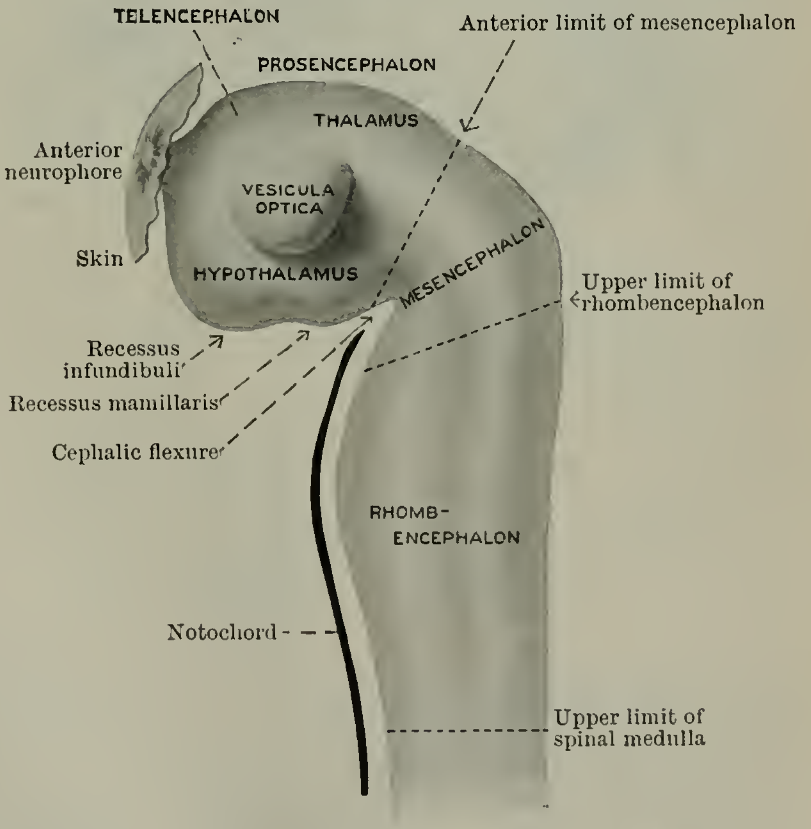


FIG. 430.—LEFT LATERAL ASPECT OF AN EARLY HUMAN EMBRYO. (After His's model, reversed.)

Shortly after the appearance of the cephalic flexure a similar bending occurs in the region where the encephalon becomes continuous with the medulla spinalis (Fig. 431, A). This is the **cervical flexure.**

But at this stage, or even earlier (Fig. 430), there has been developing a third bend which produces effects differing from those just mentioned. At the end of the second week a slight bulging can be detected on the ventral side of the hind-brain (Fig. 431): during the next four weeks this steadily becomes accentuated and forms the **pontine flexure.** The convexity of the bend is directed ventrally, differing in this respect from both of the other flexures. This difference in direction has a profound influence upon the form which the hind-brain assumes. If a plastic tube is bent a strain is thrown upon the wall in the concavity of the flexure. If this wall is strong and resisting, like the floor-plate of the neural tube (in the cases of the cephalic and cervical flexures) the bending does not affect the outline of the tube (in section) very materially. But when the strain is thrown upon the thin roof-plate during the development of the pontine flexure it is not strong enough to resist; it becomes stretched and allows the side walls of the neural tube to splay laterally in precisely the same manner as occurs when a rubber tube is bent towards a side which has been split (or weakened) longitudinally (Fig. 432). This mechanical factor determines the form assumed by the hind-brain at the end of the first month; and gives its cavity, the fourth ventricle, a lozenge or rhomboid form, when seen from its dorsal aspect through the thin translucent roof. For this reason the hind-brain is known as the **rhombencephalon.**

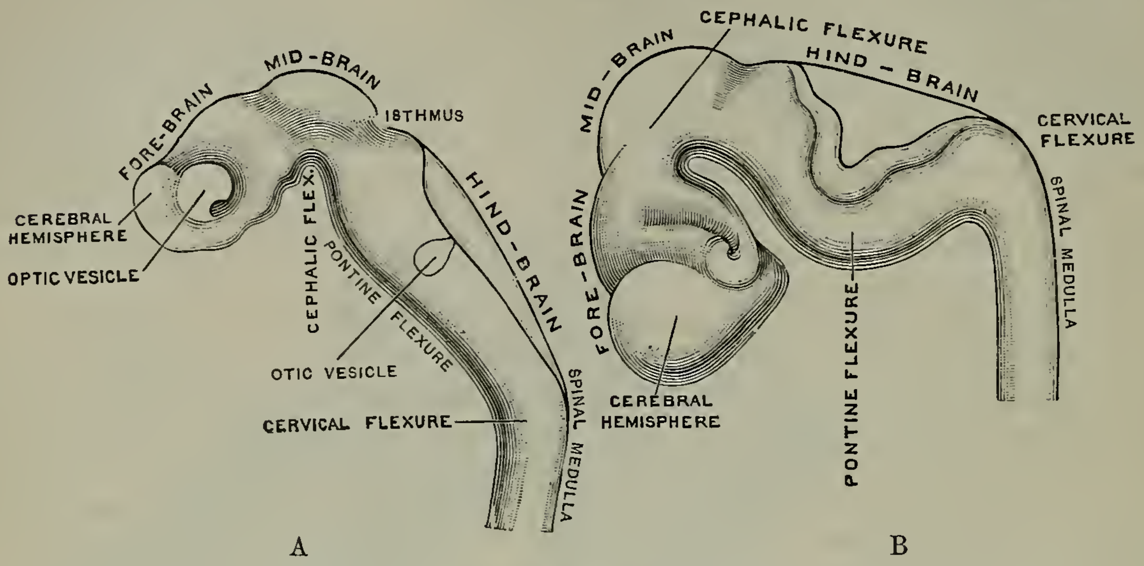


Fig. 431.—Two Stages in the Development of the Human Brain. (After His.)
A, Brain of an embryo of the third week. B, Brain of an embryo of five weeks.

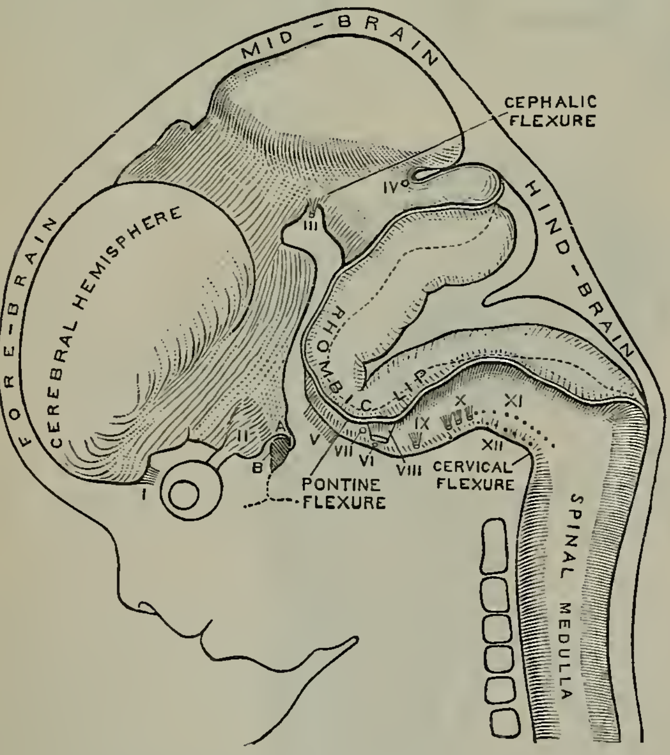


Fig. 432.—Profile View of the Brain of a Human Embryo of Ten Weeks. (His.)
The various cerebral nerves are indicated by numerals.
A, Cerebral diverticulum of hypophysis cerebri.
B, Buccal diverticulum of hypophysis cerebri.

The rhombencephalon forms at first more than half of the encephalon, and as it expands it appears to become marked off from the rest by a constriction (the **isthmus rhombencephali**).

The development of the pontine flexure subdivides the rhombencephalon into two parts, one joined to the spinal medulla, the **myelencephalon,** and the other, joined to the rest of the brain, the **metencephalon.**

In the myelencephalon develop the nuclei of the nerves that regulate the activities of the heart, lungs, and a considerable part of the alimentary canal, and also the receptive nuclei of the nerves of taste. It is known as the **medulla oblongata**.

The insertion of the nervus acusticus in the neighbourhood of the outsplayed lateral angle of the rhombencephalon leads to the profound transformation of the metencephalon. The nervus acusticus conveys into the hind-brain impulses which are stimulated by movements of fluid in the closed sac developed from the otic vesicle (Fig. 418, p. 504). The truly acoustic function of this apparatus is called into activity when the movements of this fluid are caused by waves of sound transmitted to it from the outside world. But it is obvious that motion may also be set up in this fluid by changes in position of the body itself; in other words, movements in the fluid of the otic vesicle may stimulate nerves to convey to the brain information concerning the position and movements of the body itself. A great mass of nerve-cells develops around the insertion of the nervus acusticus (that part of it, however, which is called vestibular and is not concerned with the function of hearing) to make use of this information for the regulation of the movements of the body in balancing or equilibration. To enable this terminal vestibular nucleus the better to perform this function of equilibration, depending as it does upon the co-operation and adjustment of the movements of vast numbers of widely separated muscles, nerve tracts coming from muscles and skin areas of all parts of the body make their way into this vestibular nucleus; and it expands and forms a great excrescence which is known as the **cerebellum**. And as this cerebellum has to adjust the activities of all the muscles of the body it necessarily becomes the great organ of muscular co-ordination, and as such it is made use of by those parts of the brain which have to initiate and control complex actions such as skilled movements. It will be shown in the subsequent account how the cerebellum becomes linked to the mesencephalon to co-ordinate the movements of the body which are excited by this part of the encephalon; and later how it becomes associated with the prosencephalon, when the latter becomes responsible for the acquisition and control of the most highly skilled actions. For the latter purpose a great pathway of nerve-fibres is laid down to connect the fore-brain with the cerebellum: the terminal stage of this connexion is situated upon the ventral (anterior) aspect of the metencephalon in the form

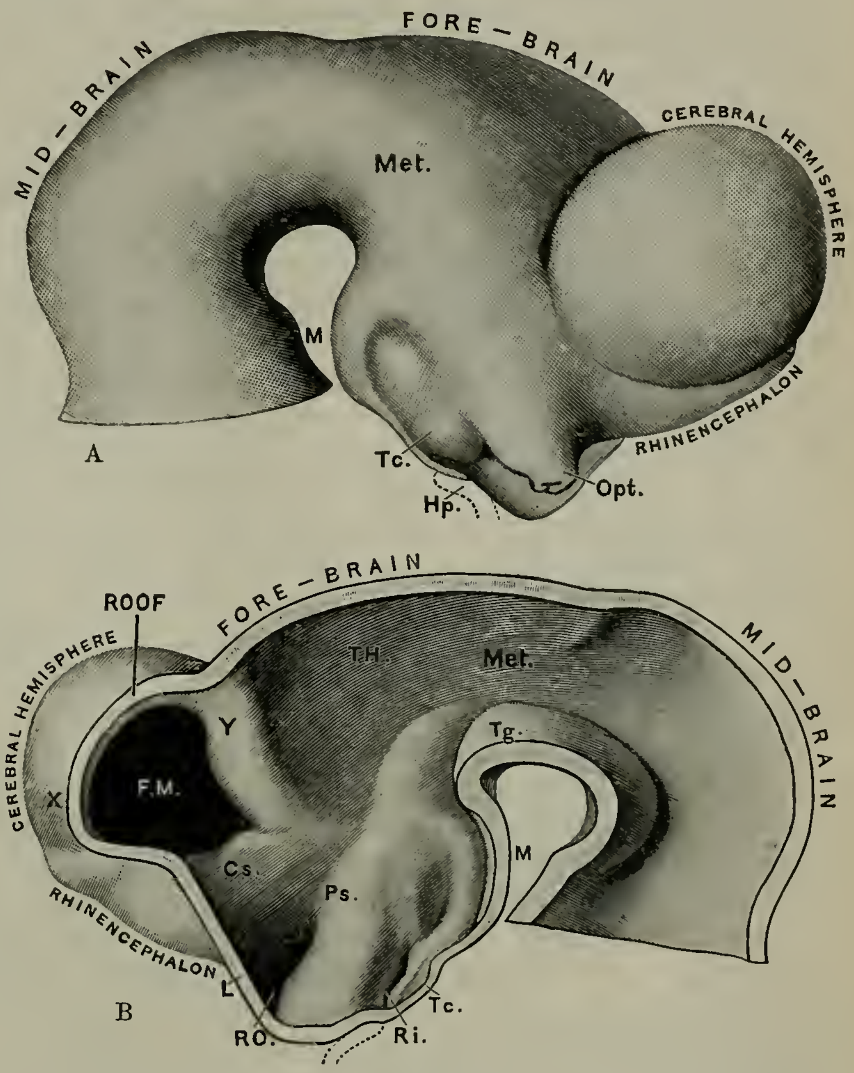


FIG. 433.—THE BRAIN OF A HUMAN EMBRYO IN THE FIFTH WEEK. (From His.)

A, Brain as seen in profile. B, Median section through the same brain. M, Mamillary eminence; Tc, Tuber cinereum; Hp, Hypophysis (hypophyseal diverticulum from buccal cavity); Opt, Optic stalk; TH, Thalamus; Tg, Tegmental part of mesencephalon; Ps, Hypothalamus; Cs, Corpus striatum; FM, Foramen interventriculare; L, Lamina terminalis; RO, Recessus opticus; Ri, Recessus infundibuli.

of a great mass of transverse fibres. At one time these strands of nerve-fibres were looked upon as a bridge between the two hemispheres of the cerebellum: hence the name **pons** was applied to them. This term is now applied not only to the fibres themselves, but also to the upward prolongation of the medulla oblongata, to the surface of which they are applied.

The subdivision of the rest of the encephalon into **mesencephalon** and **prosencephalon** develops later and is less fundamental than the primary demarcation between them and the rhombencephalon.

The visual apparatus is connected with both the mid-brain and the fore-brain, but at first more intimately with the former, to which nerve pathways are established to convey from the spinal medulla and medulla-oblongata sensory impressions of touch and hearing. From the alar laminæ of the mesencephalon there are developed four little hillocks **(colliculi)** — **corpora quadrigemina**—to receive these varied impressions and to enable them to influence the actions of the whole body. Special nerve paths are laid down from the corpora quadrigemina (Fig. 429) to the spinal medulla to enable the mid-brain to control the motor nuclei of the muscles of the trunk and limbs. These are called the **fasciculi tectospinales** (*tectum* being a synonym for corpora quadrigemina). A group of intercalated cells known as the **nucleus ruber** develops upon each side of the mesencephalon for the purpose of establishing connexions between the cerebellum and the mid-brain. When an impulse passes out of the mid-brain by the tecto-spinal bundle to excite some movement of the body, the red nucleus provides the link by which the cerebellum can co-ordinate the actions of the muscles involved. By means of a **fasciculus rubrospinalis** it can bring its influence to bear directly upon the nuclei of motor nerves in the brain and spinal medulla (Fig. 429).

The prosencephalon is at first, and in some of the lower fishes remains, the most insignificant of the three brain vesicles, but in the human brain (as also in that of most other vertebrates, though in varying degrees) a pair of enormous excrescences—the cerebral hemispheres—are budded off from it; and they become the dominant part of the nervous system (Fig. 433).

Each hemisphere is formed, however, from a relatively small part of the side wall of the prosencephalon, the rest of which goes to form the optic diverticula, the thalamus, and the hypothalamus, among other structures. The cerebral hemisphere is at first pre-eminently olfactory in function, the nerves of smell being inserted directly into it. But impressions of the associated sense of taste make their way into the cerebral hemisphere in the most primitive vertebrates: the gustatory nerves are inserted into the medulla oblongata, but fibre-paths are laid down to establish connexions with the hypothalamus, which in turn emits fibres to the cerebral hemisphere (Fig. 429). The thalamus is a greatly swollen part of the prosencephalic wall adjoining the mesencephalon. Its main part receives sensory impressions brought up from the spinal medulla and the terminal nuclei of the sensory cerebral nerves and transmits them to the cerebral hemisphere. Its caudal portion becomes specialised as a special receptive nucleus for visual and acoustic impressions for transmission to the cerebral hemisphere. It is called the **metathalamus** or **corpora geniculata.** Thus the cerebral hemisphere from being essentially a receptive organ for smell impressions ultimately becomes the terminus of all the sensory paths, and the structure that is concerned with the consciousness of all kinds of sensations. It also controls the voluntary movements of one-half of the body and emits a great strand of fibres—**pedunculus cerebri**—to establish relations with the cerebellum and all the motor nuclei on the other side of the encephalon and spinal medulla (Fig. 429, p. 514).

MEDULLA SPINALIS.

The **spinal medulla** is that part of the central nervous system which occupies the upper two-thirds of the vertebral canal. It is an elongated cylindrical structure, slightly flattened in front and behind, which extends from the margin of the foramen magnum to the level of the inferior border of the body of the first lumbar vertebra or to the superior border of the body of the second lumbar vertebra. Its average length in the male is 45 cm. and in the female 43 cm.

A considerable amount of variation within certain limits (viz., the mid-point of the body of the last thoracic vertebra and the superior border of the body of the third lumbar vertebra) is observed in different individuals as to the precise level at which the spinal medulla ends inferiorly, and in the female there would appear to be a tendency for the medulla to reach a slightly lower point in the canal than in the male. Further, the relation presented by the spinal medulla to the vertebral column differs in a marked degree in the fœtus and infant at different periods of development. Up to the third month of intra-uterine life the spinal medulla occupies the entire length of the vertebral canal; it extends downwards to the lowest limit of the vertebral canal. But from this time onwards, as growth proceeds, the vertebral column lengthens at a more rapid rate than the medulla. The spinal medulla, therefore, has the appearance of shrinking in an upward direction within its canal, and at birth its inferior end is usually found to be opposite the body of the third lumbar vertebra.

The attitude assumed by the individual affects to a small degree the position of the inferior end of the spinal medulla. Thus, when the trunk is bent well forwards, the terminal part of the spinal medulla rises slightly within its bony canal.

At the margin of the foramen magnum the spinal medulla becomes continuous with the medulla oblongata of the brain, whilst below, it tapers rapidly to a point and forms a conical extremity termed the **conus medullaris**. From the end of the conus medullaris a slender glistening thread is prolonged downwards within the vertebral canal, and finally anchors the spinal medulla to the back of the coccyx. This prolongation receives the name of the **filum terminale**.

The diameter of the spinal medulla is very much smaller than that of the vertebral canal within which it lies. A wide interval is left between its surface and the walls of its canal, and this excess of space is clearly a provision for allowing free movement of the vertebral column without producing any jarring contact between the delicate spinal medulla and the surrounding bones.

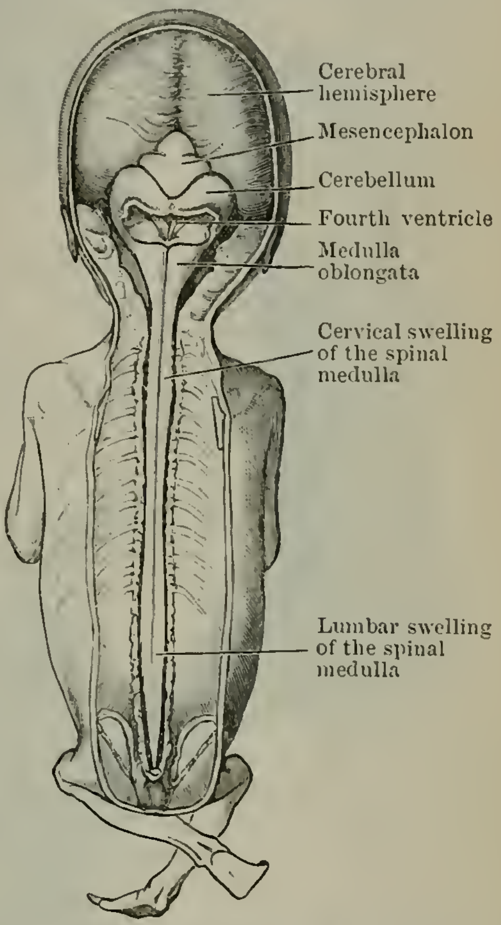

Cerebral hemisphere
Mesencephalon
Cerebellum
Fourth ventricle
Medulla oblongata
Cervical swelling of the spinal medulla
Lumbar swelling of the spinal medulla

Fig. 434.—Human Fœtus in the Third Month of Development, with the Brain and Spinal Medulla exposed from behind.

Three protective membranes are wrapped around the spinal medulla. From within outwards these are termed (1) the pia mater, (2) the arachnoid, and (3) the dura mater. The **pia mater** is a fibrous membrane which forms the immediate investment. It is closely applied to the spinal medulla, and from its deep surface numerous fine septa penetrate into the substance of the spinal medulla. The **arachnoid** is an exceedingly delicate transparent membrane which is loosely wrapped around the spinal medulla so as to leave a considerable interval, between itself and the pia mater, termed the subarachnoid space, in which there is always a varying amount of cerebro-spinal fluid. Outside the arachnoid, the **dura mater** forms a wide, dense, fibrous, tubular sheath, which extends downwards within the vertebral canal for a considerable distance beyond the conical extremity of the spinal medulla. The spinal medulla is suspended within its sheath or *theca* of dura mater by two lateral wing-like ligaments, termed the **ligamenta denticulata**. These extend laterally from the sides of the spinal medulla and are attached by a series of pointed or tooth-like processes to the inner surface of the theca of dura mater. Between the wall of the vertebral canal and the dura mater there is a narrow interval, which is filled up by soft areolo-fatty tissue and numerous thin-walled veins arranged in a plexiform manner.

Thirty-one pairs of spinal nerves arise from the sides of the spinal medulla. These are classified into eight cervical, twelve thoracic, five lumbar, five sacral, and one coccygeal; and according to the attachments of these groups of nerves the spinal medulla is arbitrarily subdivided into cervical, thoracic, lumbar, and sacral regions. In employing these terms, therefore, for different districts of the spinal medulla, it must be understood that the regions are determined by the nerve attachments and not by any direct relationship between these parts of the spinal medulla and the sections of the vertebral column which bear the same names.

Each spinal nerve is attached to the spinal medulla by an anterior or ventral and a posterior or dorsal root, and as these are traced to their central attachments they are seen to break up into a number of separate nerve fascicles or bundles, which spread out, in some cases very widely from each other, as they approach the side of the spinal medulla (Fig. 436). Each pair of nerves is therefore attached to a portion of spinal medulla of some length, and such a portion, with its pair of nerves, receives the name of a "segment of the spinal medulla." It must be clearly understood, however, that, in so far as the surface of the spinal medulla is concerned, there is no means of marking off one segment from another except by the nerve attachments.

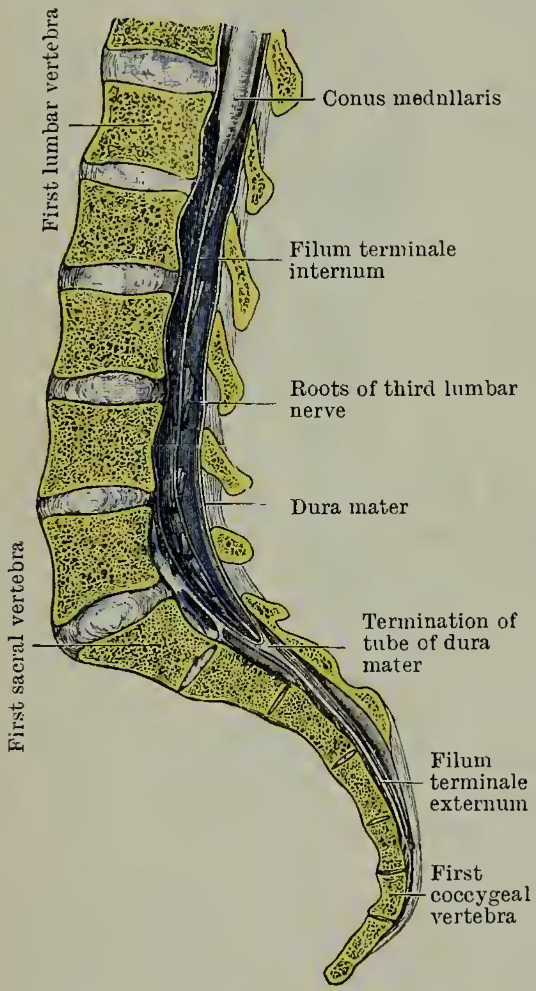


Fig. 435.—The Conus Medullaris and the Filum Terminale exposed within the Vertebral Canal.

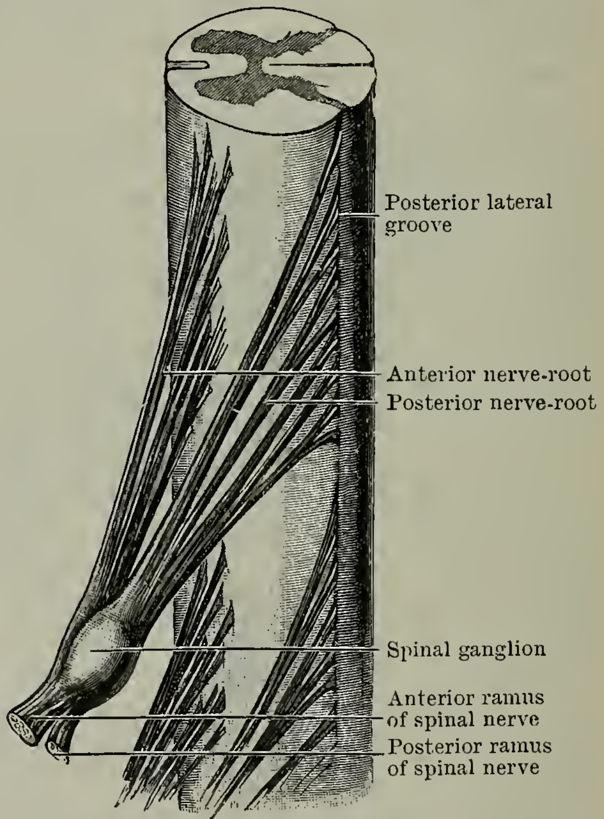


Fig. 436. — The Roots of Origin of the Seventh Thoracic Nerve (semi-diagrammatic).

In the cervical and lumbar regions of the spinal medulla the nerve-roots are somewhat crowded together, so that little or no interval is left between the adjoining root fila or fascicles of neighbouring nerves. In the thoracic region, however, distinct intervals may be observed, and the root fila are more loosely arranged. From this, it will be evident that the segments in different parts of the spinal medulla are not of equal length. In the cervical region the segments measure about 12 mm. in length, in the thoracic region from 20 to 24 mm., and in the lumbar region about 10 mm. The number of fila which attach the different nerve-roots to the spinal medulla is very different in different nerves, and is not necessarily the same in the same nerve-root in different individuals.

Owing to the great difference which exists between the length of the spinal medulla and the length of the vertebral column, the farther we pass down the greater the distance becomes between the attachment of the various nerve-roots to the spinal medulla and the intervertebral foramina through which the corresponding nerves leave the vertebral canal. The lower nerve-roots, therefore, have to traverse the vertebral canal for a considerable distance before they reach their apertures of emergence. It thus happens that the nerve-roots which spring from the lumbar and sacral regions of the spinal medulla attain a very great length and descend vertically in the lower part of the vertebral canal in a bunch or leash, in the midst of which lie the conus medullaris and the filum terminale. This great bundle of nerve-roots receives the appropriate name of the **cauda equina**.

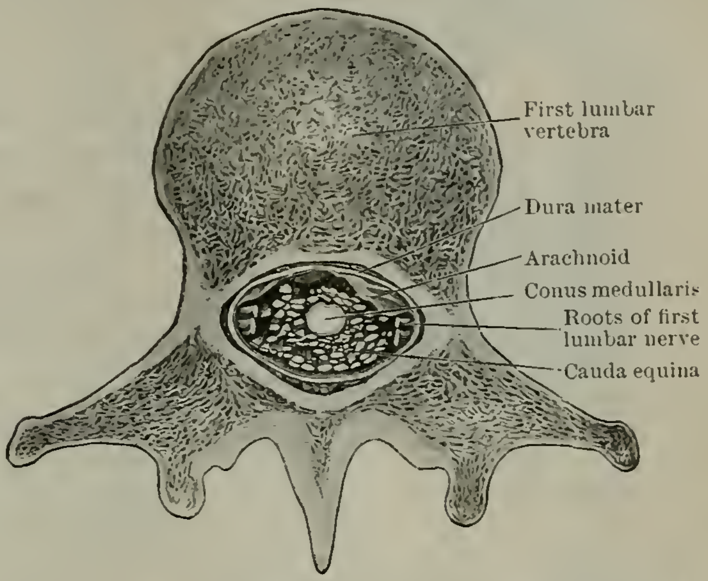


Fig. 437.—Section through the Conus Medullaris and the Cauda Equina as they lie in the Vertebral Canal.

Enlargements of the Spinal Medulla.—Throughout the greater part of the thoracic region, the spinal medulla presents a uniform girth and a very nearly circular outline when seen in transverse section. In the cervical and lumbar regions, however, it shows marked swellings. The **intumescentia cervicalis or cervical enlargement** is the more evident of the two. It begins very gradually at the upper end of the spinal medulla, attains its greatest breadth (12 to 14 mm.) opposite the fifth or sixth cervical vertebra, and finally subsides opposite the second thoracic vertebra. To this portion of the spinal medulla are attached the great nerves which supply the upper limbs. The **intumescentia lumbalis or lumbar enlargement** begins at the level of the tenth thoracic vertebra, and acquires its maximum transverse diameter (11 to 13 mm.) opposite the last thoracic vertebra. Below, it rapidly tapers away into

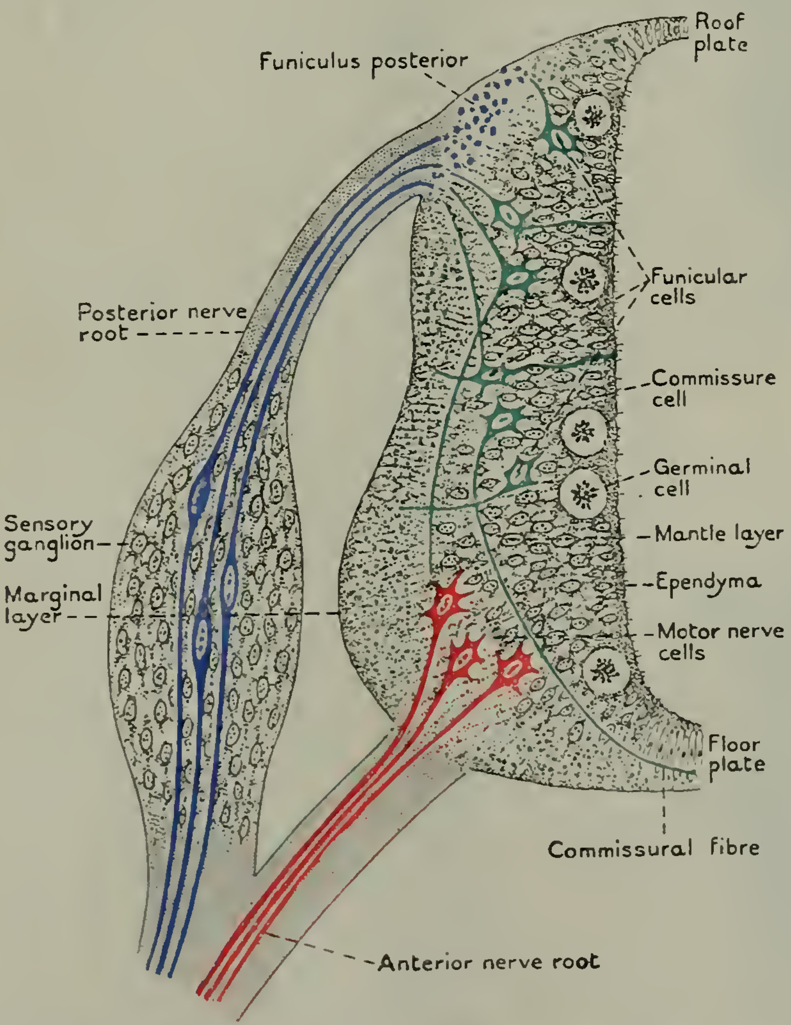


Fig. 438.—Diagram of Transverse Section of the left half of Early Neural Tube.

the conus medullaris. To the lumbar enlargement are attached the great nerves of the lower limbs.

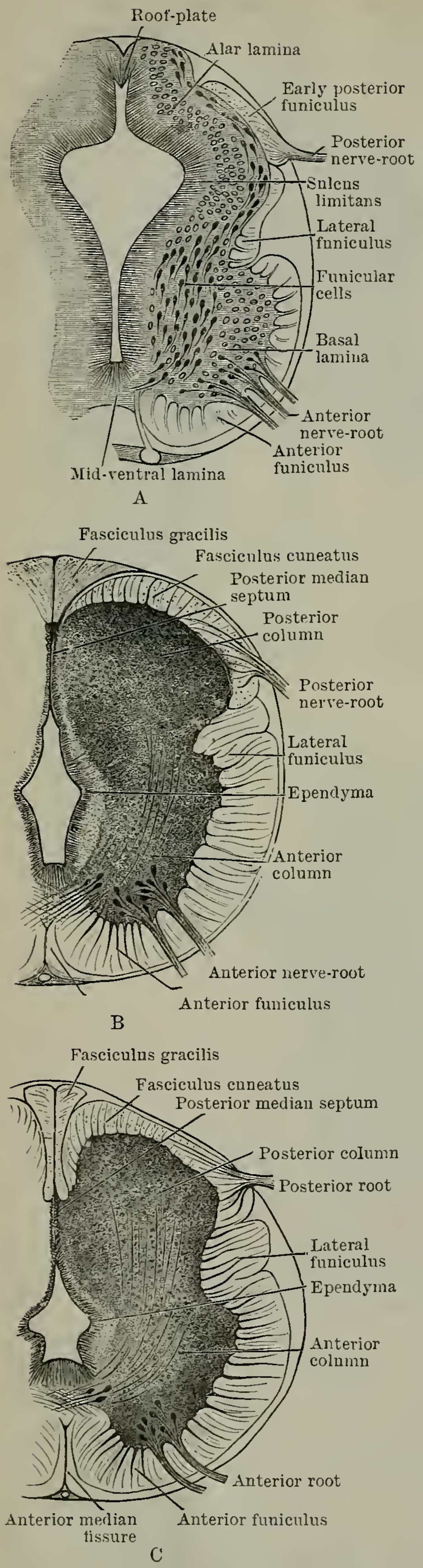


FIG. 439.—THREE STAGES IN THE DEVELOPMENT OF THE SPINAL MEDULLA. (His.)

These enlargements of the spinal medulla are associated with the outgrowth of the limbs. In the earlier developmental stages of the spinal medulla they are not present, and they take form only as the limbs become developed. In different animals their size corresponds with the degree of development of the limbs. Thus, in the long-armed orang and gibbon the cervical swelling stands out with a remarkable degree of prominence.

Development of the Spinal Medulla.—The early stages of the process by which the originally simple epithelial neural tube becomes converted into the central nervous system have already been considered. It remains to be explained how the features specially distinctive of the spinal medulla are produced.

In the early stages of the development of the spinal medulla (Fig. 438), the neuroblasts are found to be scattered in the intermediate of the three bands of which the thick side wall of the neural tube is composed — the mantle layer. The motor nerve-cells soon congregate in large numbers in the ventral part of the basal lamina (Fig. 439), so that the mantle layer expands there into a broad excrescence, which is the rudiment of the **columna anterior** or anterior cornu of gray matter. This anterior column contains the efferent or motor nerve-cells, the axons of which emerge as the **anterior root** of a spinal nerve. At this stage the rest of the mantle layer consists of a thin stratum of neuroblasts (Fig. 439), mainly intercalated cells, which receive the sensory impressions entering the spinal medulla through the **radix posterior**, and transmit impulses into axons passing (*a*) to the motor nuclei, (*b*) to the other side of the spinal medulla through the floor-plate (Fig. 438), or (*c*) into the superficial stratum (peripheral layer) of the spinal medulla, where they bend upwards or downwards as constituent elements of the **funiculi** (or white columns). As development proceeds (Fig. 438) the **substantia grisea** (gray substance) formed of these intercalated cells becomes much more abundant and forms a broad blunt boss (Figs. 439, B and C), which is the rudiment of the **columna posterior** (O.T. **posterior cornu**).

The surfaces of these gray columns become coated with a layer of white substance, composed at first mainly of the axons of cells in the root ganglia and intercalated cells in the spinal medulla; and as these funiculi increase in size they help to mould the form of the gray columns. This is displayed best in the case of the posterior column (O.T. posterior cornu). The major portion of the white substance, **funiculus posterior**, which accumulates behind (and afterwards lies on the medial side of) the posterior column, does not consist of fibres springing from intercalated cells, either of the spinal medulla or any other part of the central nervous system, but of the direct continuations of the central processes of the cells in the spinal ganglion on the posterior root (Figs. 438 and 439). A large proportion of the fibres of the posterior root do not enter the gray columns immediately after their insertion into the alar lamina, but bifurcate to form two vertical nerve-fibres, one passing upwards, and the other downwards, in the funiculus posterior before they end in the gray column, some distance above or below the place where they gained admission to the medulla spinalis. As the spinal medulla grows, the originally blunt posterior column becomes drawn backwards into an increasingly attenuated process, and the funiculus posterior, which was placed originally upon its lateral surface (Fig. 439, A), and then upon its posterior surface (Fig. 439, B), gradually assumes a wedge-shaped form (Figs. 439, C, and 441), upon the medial side of the gray matter.

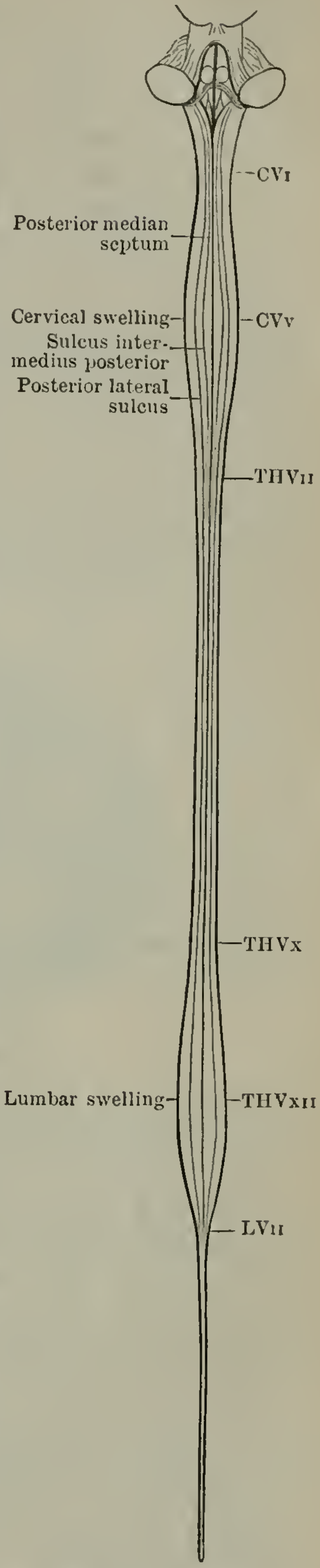


Fig. 440.—Diagram of the Spinal Medulla as seen from behind.

CVI shows the level of the 1st cervical vertebra; CVV of the 5th cervical vertebra; THVII of the 2nd thoracic vertebra; THVX of the 10th thoracic vertebra; THVXII of the 12th thoracic vertebra; LVII of the 2nd lumbar vertebra.

Development of the Anterior Median Fissure, Posterior Median Septum, and of the Central Canal.—As the anterior columns of gray matter and the anterior funiculi of white matter increase in size, the anterior surface of the spinal medulla, on each side of the median plane, bulges forwards, and the **fissura mediana anterior** (Fig. 439, A, B, and C) is produced as the natural result.

There has been considerable discussion as to the mode of formation of the **posterior median septum**; but there is now no doubt as to the essential facts. Early in the third month the walls of the posterior three-fourths (of the sagittal extent) of the **central canal** of the spinal medulla become approximated (Fig. 439), and later they fuse to obliterate that part of the canal. But the part of the septum thus formed is only an insignificant portion of the whole. For most of the septum is produced by the gradual elongation of the epithelial cells lining the remnant of the central canal as the fibre-masses of the posterior funiculi expand and separate the posterior surface of the spinal medulla further and further from the situation of the canal (see Fig. 428, p. 513).

Furrows of the Spinal Medulla.—When cross-sections of the adult spinal medulla are made, it is seen to be a bilateral structure which is partially subdivided into a right and a left half by a median cleft (fissura mediana anterior) in front and a septum (septum medianum posterius) behind. The anterior median fissure penetrates only for a distance corresponding to somewhat less than a third of the antero-posterior diameter of the spinal medulla. The pia mater dips down into it and forms a fold or reduplication within it. The posterior median septum in the cervical and thoracic regions penetrates into the spinal medulla until it reaches a point somewhat beyond its centre. It is extremely narrow, and consists of ependymal and neuroglial elements, and is intimately connected with the adjacent sides of the two halves of the spinal medulla, between which it intervenes. The pia mater, which invests the surface of the spinal medulla, passes continuously over the posterior median septum and sends no prolongation of any kind into it. In the lumbar region of the spinal medulla the septum becomes shallower, whilst the anterior median fissure deepens, and ultimately in the inferior part of the spinal medulla the fissure and septum present a very nearly equal depth.

The two halves of the spinal medulla may show trifling differences in the arrangement of the parts which compose them; but to all intents and purposes they are symmetrical. They are joined together by a more or less broad band or commissure, which intervenes between the median fissure and the septum.

An inspection of the surface of each half of the spinal medulla brings into view a longitudinal groove or furrow, at some little distance from the posterior median septum, which extends along the whole length of the spinal medulla. Along the bottom of this groove the fila of the posterior nerve-roots enter the spinal medulla in accurate linear order. It is called the **sulcus lateralis posterior.** There is no corresponding furrow on the anterior part of each half of the spinal medulla in connexion with the emergence of the fila of the anterior nerve-roots. These fila emerge irregularly over a broad strip of the surface of the spinal medulla, which corresponds in its width to the thickness of the subjacent anterior surface of the anterior column of gray matter.

The sulcus lateralis posterior subdivides each half of the spinal medulla into a small **funiculus posterior** and a much larger **antero-lateral funiculus**, and it is customary to map the latter arbitrarily off into a **funiculus lateralis** and a **funiculus anterior** by a line corresponding to the emergence of the most lateral of the fila or fascicles of the anterior nerve-roots.

In the cervical region a distinct longitudinal groove may be observed on the surface of the posterior funiculus. It is placed rather nearer to the posterior median septum than to the posterior lateral sulcus, and as it is traced down into the thoracic region it gradually becomes indistinct and finally disappears. This is called the **sulcus intermedius posterior**, and it marks on the surface the position of a septum of pia mater which dips into the spinal medulla and subdivides the posterior funiculus into a lateral part, termed the **fasciculus cuneatus** (O.T. **column of Burdach**), and a medial portion, which receives the name of the **fasciculus gracilis** (O.T. **column of Goll**).

Internal Structure of the Spinal Medulla.

The spinal medulla is composed of a central core of gray matter thickly coated on the outside by white matter. At only one spot does the gray matter come close to the surface, viz., at the bottom of the sulcus lateralis posterior.

Gray Matter of the Spinal Medulla.—The gray matter in the interior of the spinal medulla has the form of a fluted column, but it is customary to describe it as it appears in transverse sections. It then presents the appearance of the capital letter H. In each half of the spinal medulla there is a semilunar or crescentic mass, shaped somewhat like a comma, the concavity of which is directed laterally and the convexity medially. The two crescents of opposite sides are connected across the median plane by a transverse band, which receives the name of the **commissura grisea** (gray commissure). The posterior median septum extends forwards in the spinal medulla until it reaches the gray commissure. The bottom of the anterior median fissure, however, is separated from it by an intervening strip of white matter, which is termed the **commissura anterior alba**, or anterior white commissure. In the gray commissure may be seen the central canal of the spinal medulla (**canalis centralis**), which tunnels the entire length of the spinal medulla and is just visible to the naked eye as a minute speck. The portion of the gray commissure which lies behind the central canal is called the *commissura posterior*; whilst the portion in front receives the name of the *commissura anterior grisea.*

Each crescentic mass of gray matter presents certain well-defined parts. The projecting portions which extend behind and in front of the connecting transverse gray commissure are termed respectively the posterior and the anterior columns of gray matter (**columnæ griseæ**). These stand out in marked contrast to each other. In section the **columna anterior** is short, thick, and very blunt at its extremity.

Further, its extremity falls considerably short of the surface of the spinal medulla and is separated from it by a moderately thick coating of white matter. Through this the fila of the anterior nerve-roots, as they emerge from the gray matter of the anterior column, pass on their way to the surface. Throughout the greater part of the spinal medulla the **columna posterior** (O.T. **posterior cornu**) is elongated and narrow, and is drawn out to a fine point, which almost reaches the bottom of the posterior lateral sulcus. This pointed extremity receives the name of the **apex columnæ posterioris**; the slightly swollen part which succeeds it is the **caput columnæ**; whilst the slightly constricted part adjoining the gray commissure goes under the name of the **cervix columnæ posterioris.**

The apex or tip of the posterior column differs considerably in appearance from the general mass of the gray matter. It is composed of a material which presents a lighter hue and has a somewhat translucent look. It is called the **substantia gelatinosa [Rolandi]**, and, when seen in transverse section, it exhibits a V-shaped outline and fits on the posterior column like a cap.

A pointed and prominent triangular projection juts out from the lateral aspect of the gray matter nearly opposite the gray commissure. This is the **columna lateralis** (O.T. **lateral cornu**), and it is best marked in the upper thoracic region (Fig. 442, B). Traced upwards it becomes absorbed in the greatly expanded anterior column of the cervical swelling, but it reappears again in the upper part of the spinal medulla, and is particularly noticeable in the second and third cervical segments; followed in a downward direction it blends with the anterior column in the lumbar swelling and contributes to the thickening of that column.

The gray matter is for the most part mapped off from the surrounding white matter with a considerable degree of sharpness; but in the cervical region, on the lateral aspect of the crescentic mass and in the angle between the anterior and posterior columns, fine bands of gray matter penetrate the white matter, and, joining with each other, form a network, the meshes of which enclose small islands of white matter. This constitutes what is called the **formatio reticularis.** Although best marked in the cervical region, traces of the same reticular formation may be detected in lower segments of the spinal medulla.

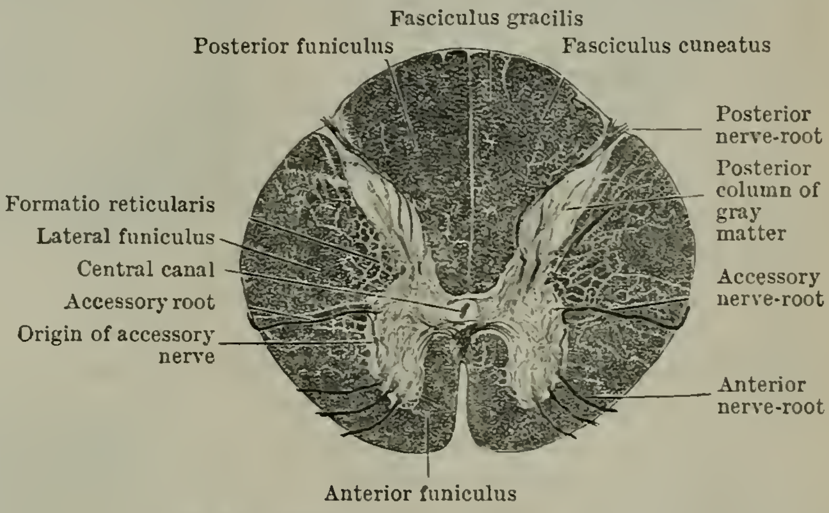


Fig. 441.—Transverse Section through the Superior Part of the Cervical Region of the Spinal Medulla. (From a specimen prepared by the Weigert-Pal method, by which the white matter is rendered dark whilst the gray matter is bleached.)

Characters presented by the Gray Matter in Different Regions of the Spinal Medulla.—The gray matter is not present in equal quantity nor does it exhibit the same form in all regions of the spinal medulla. Indeed, each segment presents its own special characters in both of these respects. It is not necessary, however, in the present instance, to enter into this matter with any degree of minute detail. It will be sufficient if the broad distinctions which are evident in the different regions are pointed out.

It may be regarded as a general law that, wherever there is an increase in the size of the nerves attached to a particular part of the spinal medulla, a corresponding increase in the amount of gray matter will be observed. It follows from this that the regions where the gray matter bulks most largely are the lumbar and the cervical swellings. The great nerve-roots which go to form the nerves of the large limb-plexuses enter and pass out from those portions of the spinal medulla. In the thoracic region there is a reduction in the quantity of gray matter in correspondence with the smaller size of the thoracic nerves.

In the *thoracic region* (Fig. 442, B) both columns of gray matter are narrow, although the distinction between the anterior column and the still more attenuated posterior column is sufficiently manifest. In this region the lateral column of gray matter also is characteristic, and the substantia gelatinosa in transverse section is pointed and spear-shaped.

In the **upper three segments** of the *cervical region* the anterior columns of gray matter are not large and they resemble the corresponding columns in the thoracic region. A lateral column also is present. But in these segments (and more especially in the first and second) there is a marked attenuation of the neck of the posterior column, and the posterior commissure is very broad.

In the **cervical swelling** the contrast between the two columns is most striking; the anterior column is of great size and presents a very broad surface towards the anterior aspect of the spinal medulla, whilst the posterior column remains narrow. This great increase in the bulk of the anterior column is due to a marked addition of gray matter on the lateral side of the column, and seeing that this additional matter is traversed by a greater number of fibres, it stands out, in well-prepared specimens, more or less distinctly from the part of the column which lies to the medial side, and which may be considered to represent the entire anterior column in the thoracic and upper cervical segments. Within this lateral addition to the anterior column are placed those collections of cells which constitute the nuclei of origin of the motor nerves of the muscles of the upper limb. The characteristic thickening of the anterior column of gray matter is evident, therefore, in those segments of the spinal medulla to which the nerves which enter the brachial plexus are attached, viz., the lower five cervical segments and the first thoracic segment.

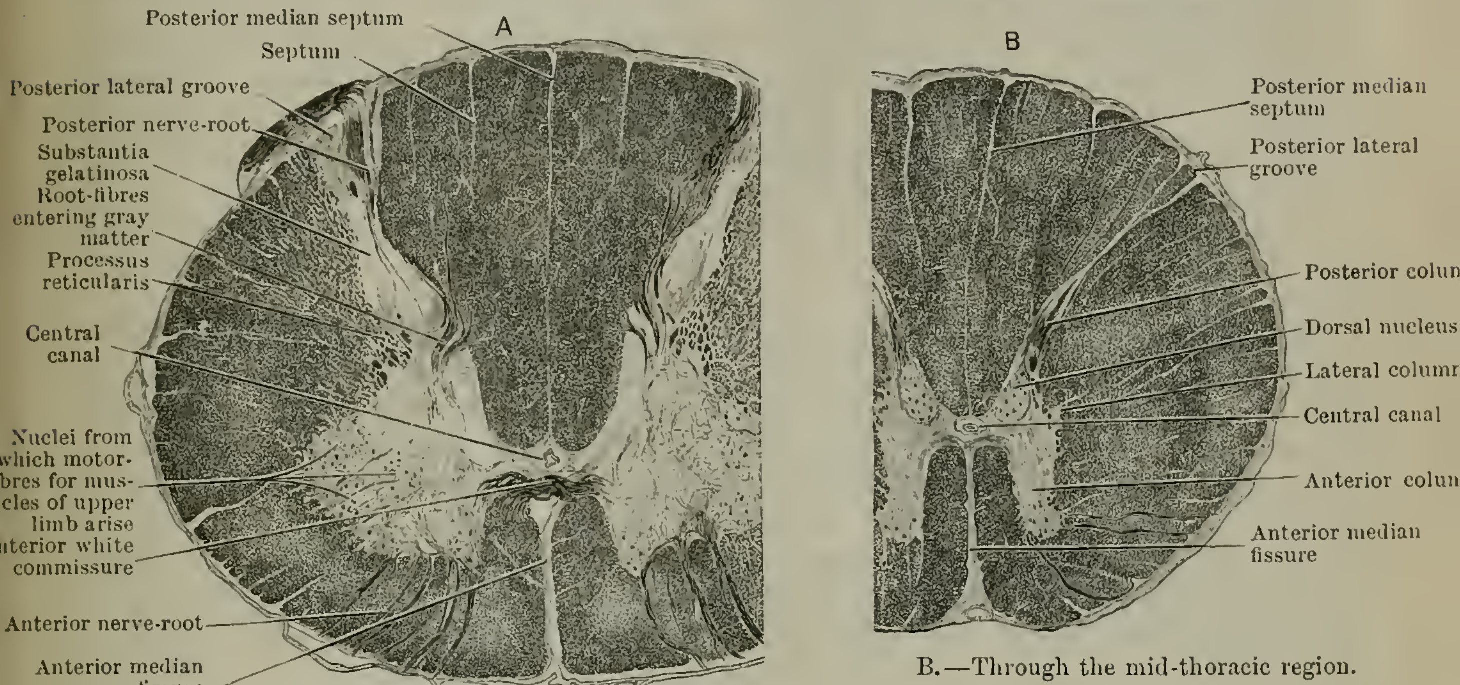
In the **lumbar swelling** the anterior columns again broaden out, and for the same reason as in the case of the corresponding columns in the cervical swelling. The nuclear masses which contain the cells from which the motor fibres which supply the muscles of the lower limbs take origin are added to the lateral aspect of the columns and give them a very characteristic appearance. In this region of the spinal medulla, however, the posterior columns also are broad and are capped by substantia gelatinosa which in transverse section presents a semilunar outline. There is consequently no difficulty in distinguishing, from an inspection of the gray matter alone, between transverse sections of the spinal medulla taken from the cervical and lumbar swellings of the spinal medulla.

In the lower part of the **conus medullaris** the gray matter in each half of the spinal medulla assumes the form of an oval mass joined to its fellow of the opposite side by a thick gray commissure. Here, almost the entire bulk of the spinal medulla consists of gray matter, seeing that the white matter is reduced to such an extent that it forms only a thin coating on the outside.

White Matter of the Spinal Medulla.—In transverse sections of the spinal medulla the three funiculi into which the white matter is subdivided become very apparent. The **posterior funiculus** is wedge-shaped, and lies between the posterior median septum and the posterior column of gray matter. The **lateral funiculus** occupies the concavity of the gray crescent. Behind, it is bounded by the posterior column of gray matter and the sulcus lateralis posterior, whilst in front it extends as far as the most lateral fasciculi of the anterior nerve-roots as they pass out from the anterior column. The **anterior funiculus** includes the white matter between the anterior median fissure and the anterior column of gray matter, and also the white matter which separates the broad extremity of the anterior column from the surface of the spinal medulla. This latter portion of the anterior funiculus is traversed by the emerging fila of the anterior nerve-roots.

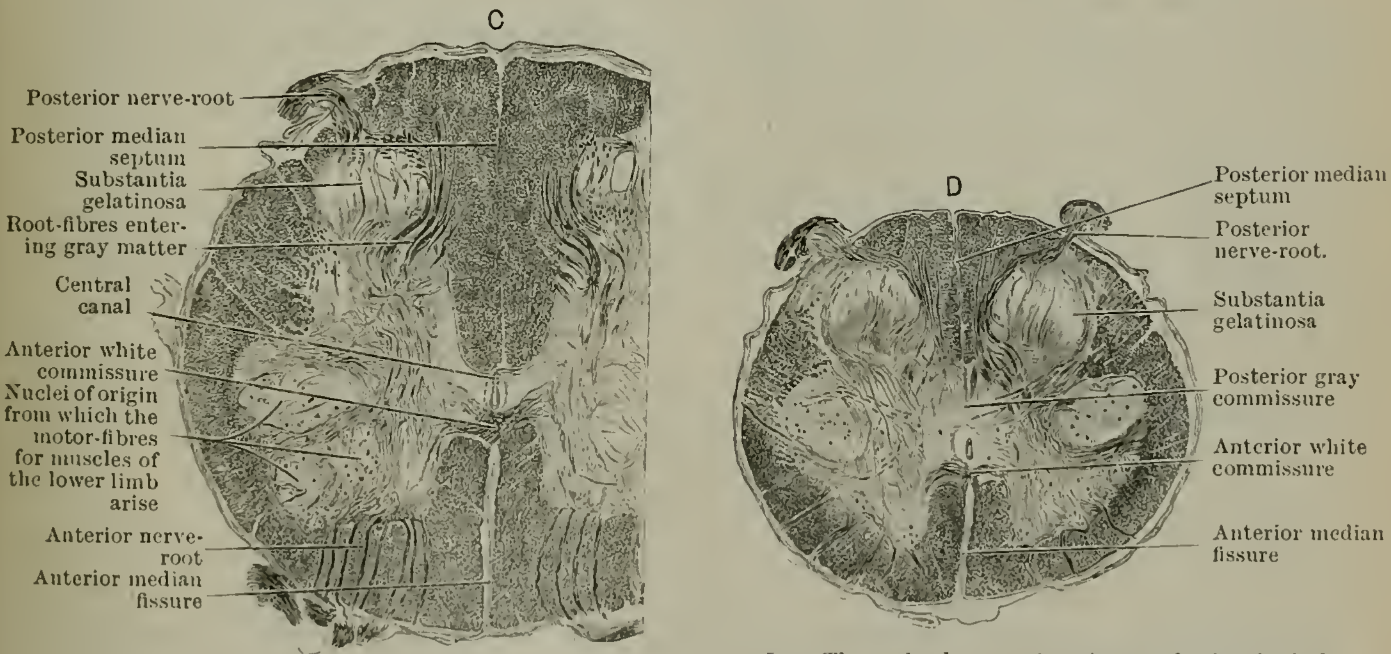
In cross-sections of the spinal medulla the partition of pia mater, which dips in at the sulcus intermedius posterior and divides the posterior funiculus into the medial **fasciculus gracilis** and the lateral **fasciculus cuneatus**, is very strongly marked in the cervical regions, but as it is traced downwards into the thoracic region it becomes shorter and fainter, and finally disappears altogether at the level of the eighth thoracic nerve. Below this point there is no visible demarcation of the posterior funiculus into two parts.

The white matter is not present in equal quantity throughout the entire length of the spinal medulla. It increases steadily from below upwards, and this increase is most noticeable in the lateral and posterior funiculi. In the lower part of the conus medullaris the amount of gray matter is actually greater than that of the white matter: but very soon this state of affairs is changed, and in the lumbar region the proportion of gray to white matter is approximately as 1 : 2·1; in the thoracic region as 1 : 5; and in the cervical region as 1 : 5·1. When it is remembered how the gray matter expands in the lumbar and cervical regions, and how greatly it becomes reduced in the thoracic region, the significance of these figures will become more apparent.



A.—Cervical region—at the level of the fifth cervical nerve. (From a specimen prepared by Dr. A. Bruce.)

B.—Through the mid-thoracic region.



C.—Through the lumbar region at the level of the fourth lumbar nerve.

D.—Through the sacral region at the level of the third sacral nerve. (From a specimen prepared by Dr. A. Bruce.)

FIG. 442.—SECTION THROUGH EACH OF THE FOUR REGIONS OF THE MEDULLA SPINALIS. (From specimens prepared by the Weigert-Pal method; by which the white matter is rendered dark in colour whilst the gray matter is bleached.)

Canalis Centralis.—As previously stated, the **central canal** is found in the gray commissure. It is a very minute tunnel, barely visible to the naked eye when seen in transverse section, and it traverses the entire length of the spinal medulla. Above, it passes into the medulla oblongata, and finally opens into the fourth ventricle of the brain; below, it is continued for a variable distance into the filum terminale, and in this it ends blindly. Only in the lumbar region does the central canal occupy the centre of the spinal medulla. Above this level, in the thoracic and cervical regions, it lies much nearer the anterior than the posterior aspect of the spinal medulla; whilst below the lumbar region, as it is traced down into the conus medullaris, it inclines backwards and approaches the posterior aspect of the spinal medulla. The calibre of the canal also varies somewhat in different parts of the spinal medulla. It is narrowest in the thoracic region; and in the lower part of the conus medullaris it expands into a distinct fusiform dilatation (very nearly 1 mm. in transverse diameter), which is termed the **ventriculus terminalis** (Krause).

The central canal is lined with a layer of ciliated columnar cells, the deep tapering ends of which are prolonged into slender processes which penetrate into the substance of the spinal medulla. These cells constitute the lining ependymal cells of the canal. The cilia of the epithelial cells are very early lost, and it is not uncommon to find the canal blocked up by epithelial debris.

The central canal is of interest because it represents in the adult the relatively wide lumen of the early ectodermal neural tube from which the spinal medulla is developed.

Filum Terminale.—The delicate thread to which this name is applied is continuous with the inferior tapered end of the conus medullaris. It is easily distinguished, by its silvery and glistening appearance, from the numerous long nerve-roots (**cauda equina**) amidst which it lies. It is about six inches long, and down to the level of the second sacral vertebra it is enclosed with the surrounding nerve-roots within the dura mater. Below this point the dura mater is applied directly to the surface of the filum terminale and is called **filum duræ matris spinalis.** The filum terminale proceeds downwards in the sacral canal, and finally receives attachment to the periosteum on the posterior aspect of the coccyx (Fig. 435, p. 520). It is customary to speak of the filum as consisting of two parts, viz., the filum terminale internum and the filum terminale externum, or the part inside and the part outside the tube of dura mater.

The **filum terminale externum** is simply a fibrous thread, strengthened by the prolongation it receives from the dura mater. The **filum terminale internum** is composed largely of pia mater; but in its superior half it encloses the terminal part of the central canal, and around this a variable amount of the gray substance of the spinal medulla is prolonged downwards into the filum. When transverse sections are made through the superior part of the filum terminale internum some bundles of medullated nerve-fibres are observed clinging to its sides, and with these are associated some nerve-cells identical with those in the spinal ganglia. These represent rudimentary or aborted caudal nerves (Rauber).

Summary of the Chief Characters presented by the Spinal Medulla in its Different Regions.

Cervical Region.	Thoracic Region.	Lumbar Region.	Sacral Region.
In transverse section, **outline of spinal medulla** transversely oval; in the middle of the cervical swelling the transverse diameter being nearly one-third longer than the antero-posterior diameter.	In transverse section, **outline of spinal medulla** more nearly circular; but still the transverse diameter is greater than the antero-posterior diameter.	In transverse section, **outline of spinal medulla** more nearly circular than in thoracic region.	In transverse section, **outline of spinal medulla** nearly circular, but still somewhat compressed from before backwards.
Postero-median septum very deep, extending beyond the centre of the spinal medulla; **antero-median fissure** shallow.	**Postero-median septum** very deep, extending beyond centre of the spinal medulla: **antero-median fissure** shallow.	**Postero-median septum** not nearly so deep as in regions above: **antero-median fissure**, on the other hand, much deeper.	**Postero-median septum** and **antero-median fissure** of equal depth.

SUMMARY OF THE CHIEF CHARACTERS PRESENTED BY THE SPINAL MEDULLA IN ITS DIFFERENT REGIONS—(*Continued*).

Cervical Region.	Thoracic Region.	Lumbar Region.	Sacral Region.
Gray matter greatly increased in quantity in the cervical swelling: anterior column thick and massive; posterior column slender in comparison. Lateral column evident only above the level of the fourth cervical nerve. Processus reticularis strongly marked.	**Gray matter** greatly reduced in quantity. Both columns slender. Lateral column well marked. Processus reticularis scarcely apparent.	**Gray matter** greatly increased in the lumbar swelling. Both columns very thick and massive. Lateral column absorbed in anterior column. Processus reticularis absent.	Both columns of **gray matter** very thick and massive. Lateral column apparent. No processus reticularis.
White matter in great quantity, and especially massed in the lateral and posterior funiculi.	**White matter** less in quantity than in cervical region, but bulking largely in comparison with the quantity of gray matter.	**White matter** small in quantity compared with higher regions, and very small in amount in relation to increased quantity of gray matter.	**White matter** very small in quantity in comparison with the gray matter.
Sulcus intermedius posterior and corresponding septum well marked.	**Sulcus intermedius posterior** absent; but the corresponding septum can be traced as low down as the eighth thoracic nerve.	No **sulcus intermedius posterior** or corresponding septum.	No **sulcus intermedius posterior** and no corresponding septum.
Central canal considerably nearer the anterior surface than the posterior surface of the spinal medulla.	**Central canal** considerably nearer the anterior surface than the posterior surface of the spinal medulla.	**Central canal** in the centre of the spinal medulla.	**Central canal** in the centre of the spinal medulla.

COMPONENT PARTS OF THE GRAY MATTER OF THE SPINAL MEDULLA.

Neuroglia enters largely into the constitution of the gray matter of the spinal medulla. It forms a bed within which the nervous elements are distributed. These nervous elements consist of (1) nerve-cells and (2) nerve-fibres—both medullated and non-medullated. The nerve-cells lie in small spaces in the neuroglia, whilst the nerve-fibres traverse fine passages the walls of which are formed of the same substance. The neuroglia is thus an all-pervading basis substance which isolates the nervous elements one from the other more or less completely, and at the same time binds them together into a consistent solid mass. In two situations the gray matter presents peculiar features, viz., the apex of the posterior column and the tissue surrounding the central canal. In both situations the gray matter stains more deeply with carmine and presents a more translucent appearance; in other respects the substantia grisea centralis and the substantia gelatinosa are very different.

The **substantia grisea centralis** forms a thick ring around the central canal. It is traversed by the fine processes which proceed from the deep ends of the ependymal cells which line the canal. It is composed almost entirely of neuroglia.

In transverse sections of the spinal medulla the **substantia gelatinosa**, in the cervical and thoracic regions, presents the appearance of a V-shaped mass, embracing the extremity of the posterior column of gray matter; in the lumbar region this cap assumes a semilunar outline.

In the substantia gelatinosa the neuroglia is present in small quantity, and small nerve-cells are developed within it in considerable numbers.

Nerve-Cells.—The nerve-cells are scattered plentifully throughout the gray matter, but perhaps not in such great numbers as might be expected when we note the enormous number of nerve-fibres with which they stand in relation. They are all, without exception, multipolar, and send off from their various aspects several branching protoplasmic processes or dendrites, and one axon, which becomes the axis-cylinder of a nerve-fibre. In size they vary considerably, and as a rule (to which, however, there are many exceptions) the bulk of a nerve-cell has a more or less definite relation to the length of the axis-cylinder which proceeds from it.

When the nerve-cells are studied in a series of transverse sections of the spinal medulla, it will be noticed that a large proportion of them are grouped in clusters in certain districts of the gray matter; and as these groups are seen in very much the same position in successive sections, it is clear that these cells are arranged in longitudinal columns of greater or less length. Thus we recognise—(1) a ventral group or column of cells in the anterior column of gray matter; (2) an intermedio-lateral group or column in the lateral column of gray matter, where this exists; and (3) a posterior vesicular column of cells (nucleus dorsalis), forming a most conspicuous group in the medial part of the neck of the posterior column in the thoracic region of the spinal medulla.

Other cells, besides those forming these columns, are scattered somewhat irregularly throughout the gray matter of the posterior column and the part of the gray crescent which lies between the two columns; and although these also in some measure may be classified into groups, the arrangement thus effected is not of so definite a character as to justify us in dwelling upon it in the present instance.

Ventral Cell-Column and the Origin of the Fibres of the Anterior Nerve-roots.—The ventral cell-group occupies the anterior column of gray matter, and in it are found the largest and most conspicuous cells in the spinal medulla. It extends from one end of the spinal medulla to the other. These ventral nerve-cells have numerous wide-spreading dendritic processes, and it is to be noticed that certain of these dendrites do not confine their ramifications to the gray matter. Thus, some of the cells along the medial border of the anterior column of gray matter send dendrites across the median plane in the anterior commissure to end in the anterior gray column of the opposite side; whilst others, lying along the lateral margin of the anterior column of gray matter, send dendrites in amongst the nerve-fibres of the adjoining white matter.

The axons or axis-cylinder processes of a large proportion of the ventral cells converge together; and, becoming medullated, they form bundles which pass out from the gray matter, and through the white matter which separates the thick end of the anterior column from the surface of the spinal medulla, to emerge finally as the fila of the anterior nerve-roots. These cells, then, are the sources from which the nerve-fibres of the anterior nerve-roots proceed, and in consequence they are frequently spoken of as the "motor cells" of the spinal medulla. Whilst this is the arrangement of the axons of the great majority of the motor cells, it should be noted that a few cross the median plane in the anterior white commissure and emerge in the fila of origin of the opposite anterior nerve-root.

The ventral cells are not scattered uniformly throughout the anterior column of gray matter. They are aggregated more closely together in certain parts of the anterior column, and thus form sub-groups or columns more or less perfectly marked off from each other.

Thus, one sub-group or column of ventral cells occupies the medial part of the anterior column of gray matter throughout almost its whole length. In only two segments of the medulla is it absent, viz., the fifth lumbar and the first sacral; at this level in the spinal medulla alone is its continuity broken (Bruce). It is termed the *antero-median column* or *group* of ventral cells. Behind this cell-column there is another classed with it to which the name of *postero-median column* or *group* is given, but this column of cells is not continuous throughout the entire length of the medulla. It is present in the thoracic region of the spinal medulla, where the motor nuclei for the muscles of the limbs are absent; and it is seen also in two or three of the segments of the cervical region and in the first lumbar segment (Bruce); elsewhere it is not represented.

In the cervical and lumbar swellings of the medulla, where the marked lateral outgrowth is added to the lateral side of the anterior column of gray matter, certain groups of large multipolar cells are visible. These are the nuclei of origin of the motor-fibres which supply the muscles of the limbs, and consequently they are not represented in the upper three cervical segments of the spinal medulla; nor in any of the thoracic segments, with the exception of the first thoracic segment; nor in the lowest two sacral segments.

These *lateral cells* are arranged in several columns, which extend for varying distances in the superadded lateral parts of the anterior column of gray matter. The two main columns are an *antero-lateral* and a *postero-lateral column*; in certain segments there is likewise a *retro-postero-lateral column*, and in a number of segments in the lumbar and sacral regions a *central column* of cells (Bruce).

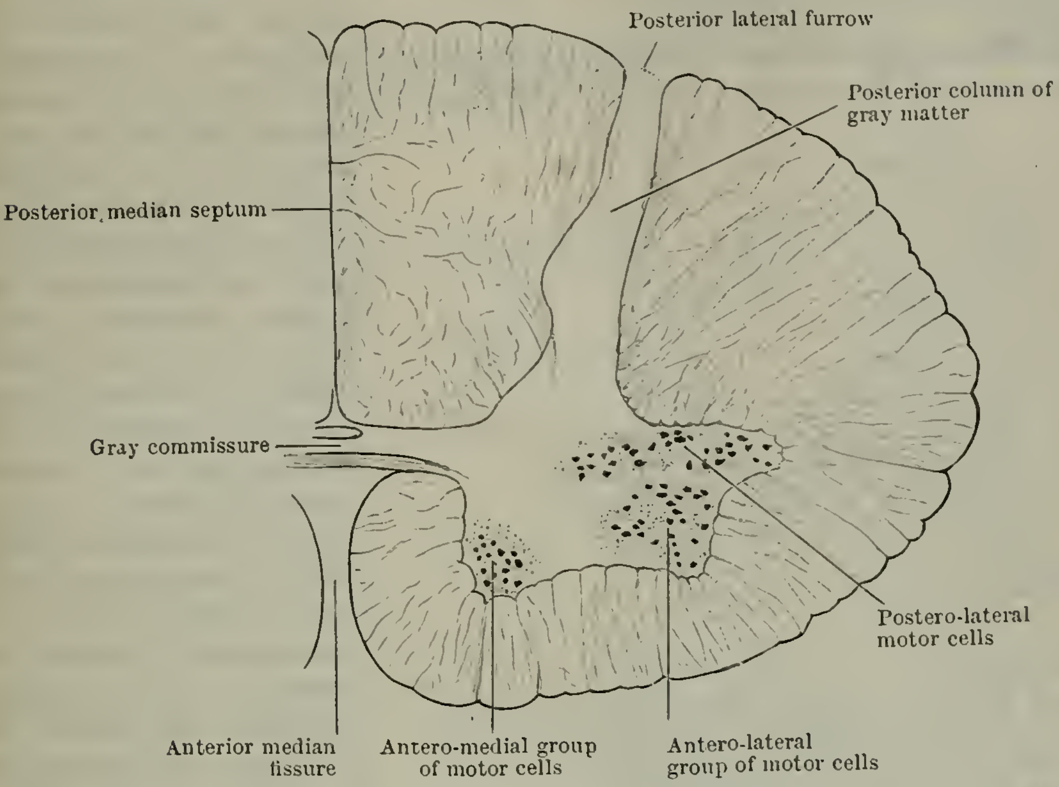

Posterior lateral furrow
Posterior column of gray matter
Posterior median septum
Gray commissure
Postero-lateral motor cells
Anterior median fissure
Antero-medial group of motor cells
Antero-lateral group of motor cells

FIG. 443.—SECTION THROUGH THE FIFTH CERVICAL SEGMENT OF THE SPINAL MEDULLA. (To a large extent founded on Plates in Dr. Bruce's *Atlas.*)

There cannot be a doubt that the grouping of the motor cells in the anterior column of gray matter of the medulla stands in relation to the muscle groups to which their axis-cylinder processes are distributed; but from what has been said it will be apparent that sharply defined cell-clusters associated with particular muscles do not exist. Still, much can be learned regarding the localisation of the motor nuclei in the anterior column of gray matter of the medulla from the study of the changes which occur in the cell-columns after atrophy of isolated muscles or groups of muscles, and after complete or partial amputations of limbs. It has been pointed out that the long muscles of the trunk (as, for example, the different parts of the sacro-spinalis muscle) receive nerve-fibres from all the segments of the spinal medulla. Now, we have noted that there is only one cell-column, the ventro-median column, which pursues an almost uninterrupted course throughout the entire length of the medulla. It may be assumed, therefore, that the nerve-fibres which go to these long trunk-muscles take origin in these medial cells.

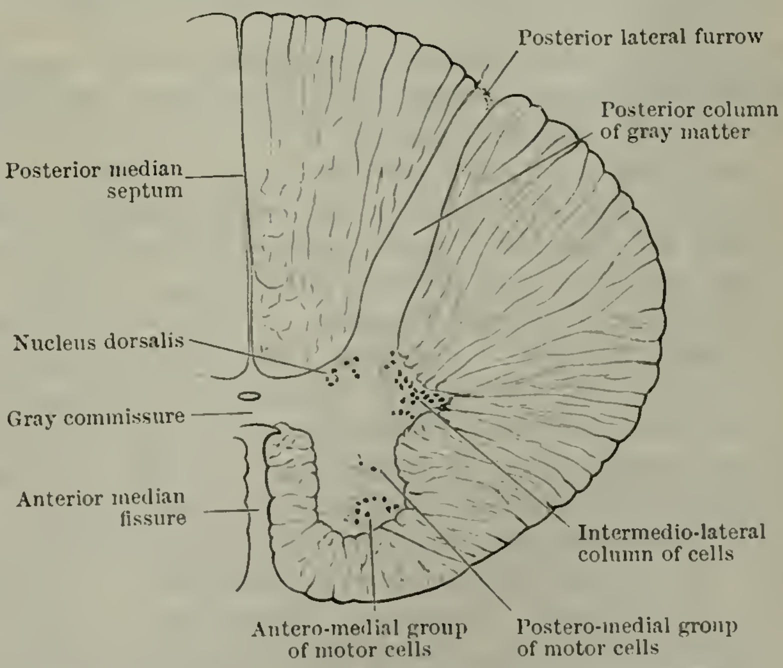

Posterior lateral furrow
Posterior column of gray matter
Posterior median septum
Nucleus dorsalis
Gray commissure
Anterior median fissure
Intermedio-lateral column of cells
Antero-medial group of motor cells
Postero-medial group of motor cells

FIG. 444.—SECTION THROUGH THE EIGHTH THORACIC SEGMENT OF THE SPINAL MEDULLA. (To a large extent founded on Plates in Dr. Bruce's *Atlas.*)

Edinger states that in the anterior column of gray matter the nuclei of origin of the nerves which supply the proximal muscles are medially placed: that those for the distal muscles are in general situated laterally. If this is the case, the cells connected with the shoulder muscles will lie nearer the middle of the anterior column of gray matter than those which are connected with the hand-muscles. In cases where the forearm and hand, or the leg and the foot, are amputated, it would appear that it is the postero-lateral column of cells that shows changes in consequence of its separation from the muscles to which its fibres are distributed.[1]

Intermedio-lateral Cell-column.—The intermedio-lateral cells form a long slender column which extends throughout the entire thoracic region of the medulla in the lateral column of gray matter. It is also prolonged downwards into the first and second lumbar segments, where it disappears. In transverse sections through the spinal medulla this cell-group presents a very characteristic appearance, because the cells which compose it are small and are closely packed together. Although these cells, as a continuous column, are restricted to the region indicated, it should be noted that the same group of cells reappears above, in certain of the cervical segments, and also in the third and fourth sacral segments. From these cells very fine fibres arise and leave the spinal medulla, intermingled with the motor fibres of the anterior nerve-roots; they pass into the sympathetic ganglia, of which they constitute the white rami communicantes. They represent the splanchnic efferent fibres of the medulla spinalis.

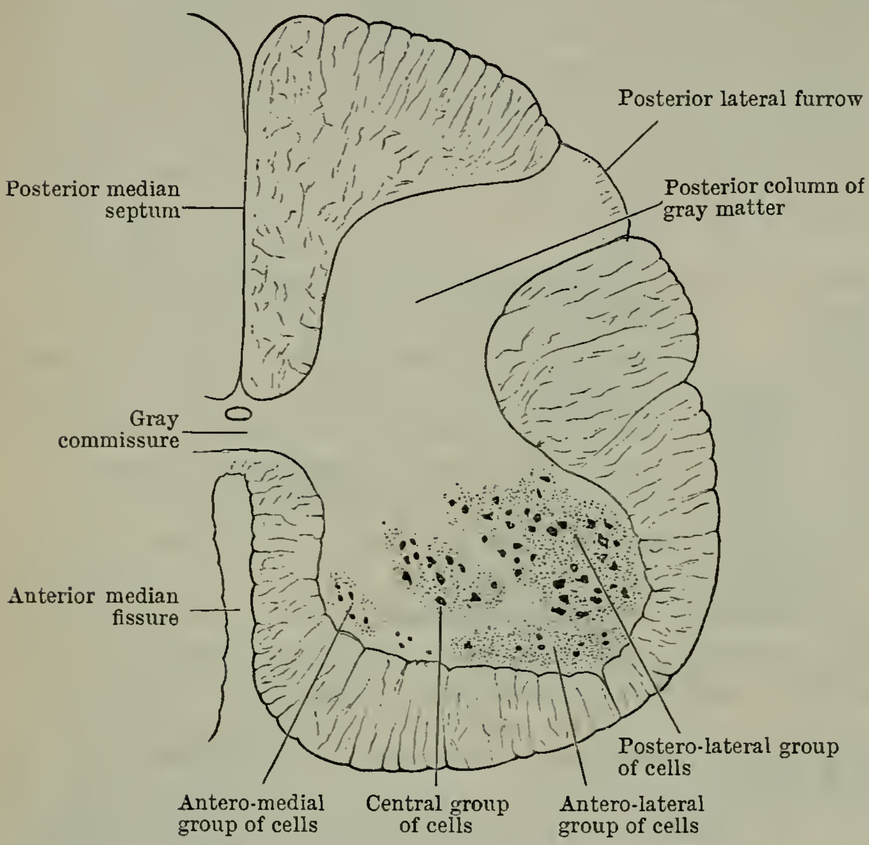

Posterior lateral furrow
Posterior median septum
Posterior column of gray matter
Gray commissure
Anterior median fissure
Postero-lateral group of cells
Antero-medial group of cells
Central group of cells
Antero-lateral group of cells

Fig. 445.—Section through the Third Lumbar Segment of the Spinal Medulla to show the grouping of the Motor Cells. (To a large extent founded on Plates in Dr. Bruce's *Atlas.*)

Nucleus Dorsalis (O.T. Clarke's Column).—This occupies the posterior column of gray matter and is the most conspicuous of all the cell-groups in the medulla. It does not, however, extend along the whole length of the medulla; indeed it is almost entirely confined to the "dorsal" region, which is the reason for the designation "nucleus dorsalis." (*When, in the recent revision of nomenclature, the term "thoracic" was substituted for "dorsal" the revisers omitted to change the name of this structure to "thoracic."*) Above, it begins opposite the seventh or eighth cervical nerve, whilst below, it may be traced to the level of the second lumbar nerve, where it disappears. In transverse section of the spinal medulla it presents an oval outline, and is seen in the median part of the cervix of the posterior column of gray matter, immediately behind the gray commissure (Fig. 444, p. 531). On the lateral side it is circumscribed by numerous curved fibres from the entering posterior nerve-root, and in the lower thoracic region of the spinal medulla (opposite the eleventh and twelfth thoracic nerves) it becomes so marked that it forms a bulging on the median aspect of the posterior gray column.

The cells of the nucleus dorsalis are large, and possess several dendritic processes. The axons enter the lateral funiculus of white matter and there form a strand of fibres, which will be described later under the name of the **fasciculus spino-cerebellaris** (*wrongly called "cerebellospinalis" in the B.N.A.*).

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[1] Those who seek further information regarding the grouping of the ventral cells of the medulla may with advantage study Dr. Alexander Bruce's *Atlas of the Spinal Cord.*

Nerve-fibres in the Gray Matter of the Medulla Spinalis.—Nerve-fibres of both the medullated and the non-medullated variety pervade every part of the gray matter. They are of three kinds, viz., (1) collaterals, (2) terminations of nerve-fibres, (3) axons given off by the cells. Many of the nerve-fibres which compose the funiculi of the medulla give off numerous fine collateral branches, which pass into the gray matter from all sides and finally end in relation with the nerve-cells. The majority of the nerve-fibres themselves, which thus give off collaterals, finally enter the gray matter, and end similarly. The axons of the majority of the cells leave the gray matter and emerge either for the purpose of entering a peripheral nerve or for the purpose of entering a strand of fibres in the white matter of the spinal medulla.

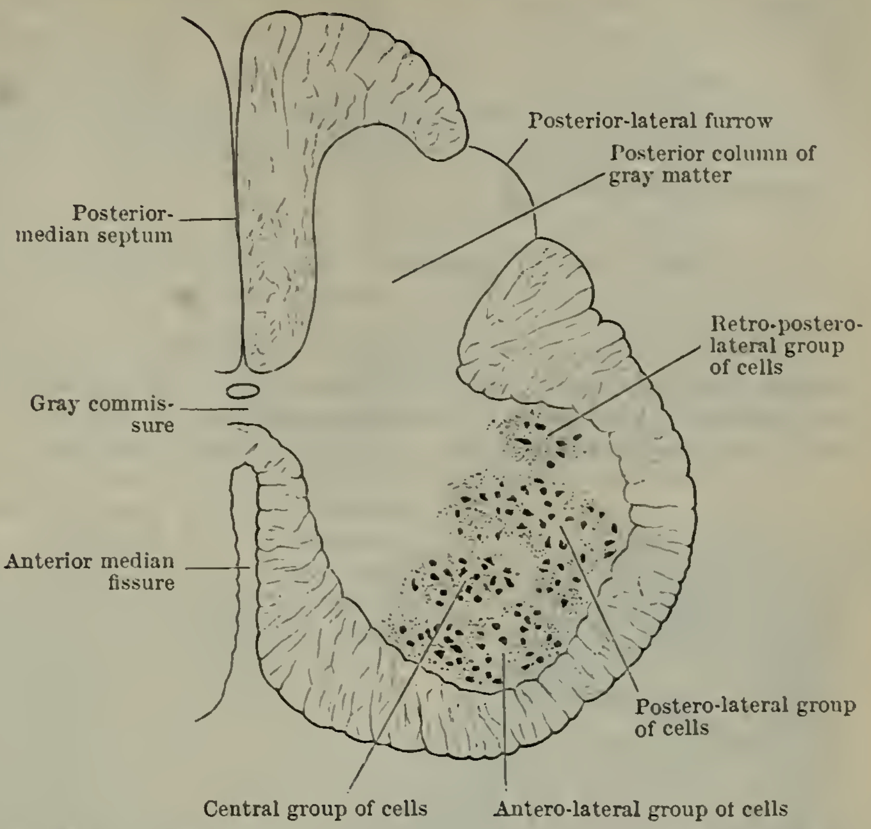
Posterior-lateral furrow
Posterior column of gray matter
Posterior-median septum
Retro-postero-lateral group of cells
Gray commissure
Anterior median fissure
Postero-lateral group of cells
Central group of cells
Antero-lateral group of cells

Fig. 446.—Section through the First Sacral Segment of the Spinal Medulla to show the grouping of the Motor Nerve-cells. (To a large extent founded on Plates in Dr. Bruce's *Atlas.*)

The nerve-fibres thus derived are interwoven together in the gray matter in a dense inextricable interlacement.

Component Parts of the White Matter of the Spinal Medulla.

The white matter of the spinal medulla is composed of medullated nerve-fibres, embedded in neuroglia. The fibres, for the most part, pursue a longitudinal course; and, from the deep surface of the pia mater which surrounds the medulla, fibrous septa or partitions are carried in along vertical planes between the fibres so as to form an irregular and very imperfect fibrous framework of support. The neuroglia is disposed in a layer of varying thickness around the medulla, subjacent to the pia mater, and is carried into the medulla so as to give a coating to both sides of the various pial septa. The neuroglia is disposed also around the various nerve-fibres, so that each of these may be said to lie in a canal or tunnel of this substance. The nerve-fibres are all medullated, but they are not provided with primitive sheaths. It is the medullary substance of the nerve-fibres which gives to the white matter its opaque, milky-white appearance. When a thin transverse section of the medulla is stained in carmine and examined under the microscope the white matter presents the appearance of a series of closely applied circles, each with a dot in the centre. The dot is the transversely divided axis-cylinder of a nerve-fibre, and the dark ring which forms the circumference of the circle represents the wall of the neuroglial canal which is occupied by the fibre. The medullary substance is very faintly seen. It presents a filmy or cloudy appearance between the axis-cylinder and the neuroglial ring.

Arrangement of the Nerve-fibres of the White Matter in Fasciculi or Tracts.—When the white matter of a healthy adult spinal medulla is examined, the fibres which compose it are seen to vary considerably in point of size; and although there are special places where large fibres—or it may be small fibres—are present in greater numbers than elsewhere, yet, as a rule, both great and small fibres are mixed up together. No conclusive evidence can be obtained in such a spinal medulla, by any means at our disposal, of the fact that the longitudinally arranged fibres are grouped together in more or less definite tracts or fasciculi, the fibres of which run a definite course and present definite connexions. Yet this is known to be the case, and the existence of these separate tracts has been proved both by embryological investigation, as well as by the examination of the effects of injuries produced experimentally or accidentally on the nervous system in living beings.

By the **experimental method** it has been shown that when a nerve-fibre is severed the part which is detached from the nerve-cell from which it is an offshoot degenerates, whilst the part which remains connected with the nerve-cell undergoes little or no change. This is called the law of "Wallerian" degeneration. Thus, if in a living animal one-half of the spinal medulla is cut across, and after a few weeks the animal is killed and the medulla examined, it will be seen that there are degenerated tracts of fibres in the white matter, both above and below the plane of division; but, still further, it will also be manifest that the tracts which are degenerated above the plane of division are not the same as those which are degenerated in the part of the medulla which lies below this level. The interpretation of this is obvious. The nerve-tracts which have degenerated above the plane of section are the offshoots of nerve-cells which lie in lower segments of the medulla or in spinal ganglia below the plane of section. Severed from these nerve-cells, they undergo what is called *ascending degeneration.* The nerve-tracts, on the other hand, which have degenerated in the portion of the medulla below the plane of division are the axons of cells which lie at a higher level than the plane of section, either in higher segments of the spinal medulla or in the brain itself. Cut off from the nerve-cells from which they proceed, they present an example of *descending degeneration.*

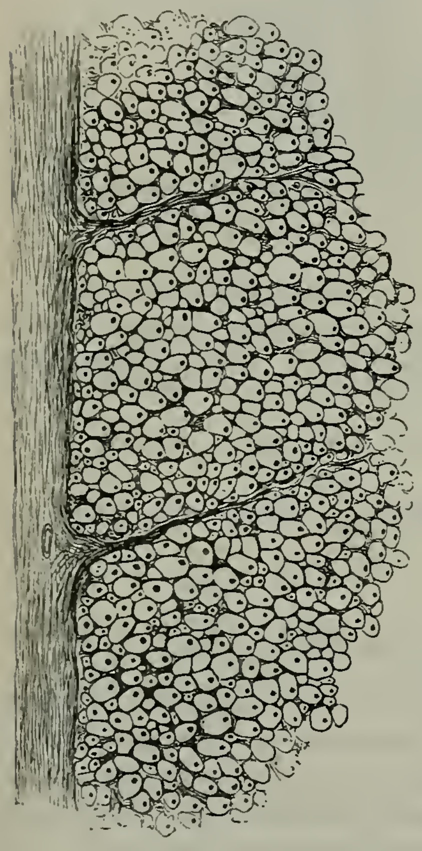
FIG. 447.—TRANSVERSE SECTION THROUGH THE WHITE MATTER OF THE MEDULLA SPINALIS, as seen through the microscope.

The **embryological method** was first employed by Flechsig, and it is often referred to as Flechsig's method. It is based upon the fact that nerve-fibres in the earliest stages of their development consist of naked axis-cylinders, and are not provided with medullary sheaths. Further, the nerve-fibres of different strands assume the medullary sheaths at different periods. If the fœtal central nervous system is examined at different stages of its development, it is a comparatively easy matter to locate the different tracts of fibres by evidence of this kind. Speaking broadly, the tracts which myelinate first are those which bring the central nervous system into relation with the peripheral parts (skin, muscles, etc.); then those fibres which bind the various segments of the central nervous system together; next, those which connect the spinal medulla with the cerebellum; and, lastly, the tracts which connect the spinal medulla with the cerebral hemispheres. The nervous apparatus for the performance of automatic movements is fully provided, therefore, before this is put under the control and direction of the higher centres. It by no means follows that in all the higher animals corresponding strands myelinate at relatively corresponding periods. Take the case of a young animal which from the time of its birth is able to move about and perform voluntary movements of various kinds in a more or less perfect manner, and compare it with the helpless new-born infant which is capable of exhibiting automatic movements only. In the former, the cerebro-spinal tracts, or motor tracts, which descend from the cerebrum into the spinal medulla, and which are the paths along which the mandates of the will travel, myelinate at an early period; whilst in the infant the corresponding fibres do not obtain their medullary sheaths until after birth. The study of the dates, therefore, at which the various strands of nerve-fibres myelinate not only gives the anatomist a means of locating their position in the white matter of the central nervous system, but it also affords the physiologist most important information regarding their functions, and also the periods at which these functions are called into play.

It is a matter of interest to note that influences which either accelerate or retard the periods at which nerve-fibres are brought into functional activity have also an effect in determining the dates at which these fibres assume their sheaths of myelin. Thus, when a child is prematurely born the whole process of myelinisation is, as it were, hurried up; and further, when in new-born animals light is freely admitted to one eye whilst it is carefully excluded from the other, the fibres of the optic nerve of the former myelinate more rapidly than those of the opposite nerve.

Study of the minute structure (Anatomical method) of the central nervous system, especially of material that has been stained by the methods of Golgi and Ramon y Cajal or by the use of methylene blue, completes the results attained by these other methods, by demonstrating the precise mode of origin and termination of the various fasciculi.

Posterior Funiculus and the Posterior Roots of the Spinal Nerves.—In the cervical and upper thoracic regions of the spinal medulla the posterior funiculus is divided by the posterior intermediate sulcus and septum into the **fasciculus cuneatus**, which lies laterally and next to the posterior column of gray matter, and the **fasciculus gracilis**, which lies medially and next to the posterior-median septum. The fasciculus cuneatus is composed of nerve-fibres which are for the most part larger than those entering into the formation of the fasciculus gracilis, and both tracts have a most intimate relation to the posterior nerve-roots; indeed, they are both composed almost entirely of fibres which enter the medulla by these roots, and then pursue a longitudinal course.

The nerve-fibres which form the posterior nerve-roots, on entering the medulla along the sulcus lateralis posterior, divide within the fasciculus cuneatus into ascending and descending branches which diverge abruptly as they pass respectively upwards and downwards. The **descending fibres** are, as a rule, short, and soon end in the gray matter of the spinal medulla. These descending fibres occupy an area in the posterior funiculus along the line of separation of the fasciculus gracilis and the fasciculus cuneatus, and, hence, may be called the **fasciculus interfascicularis (comma tract of Schultze)**. This area, when the spinal medulla is divided, undergoes descending degeneration and then presents a comma-shaped outline (Fig. 448).

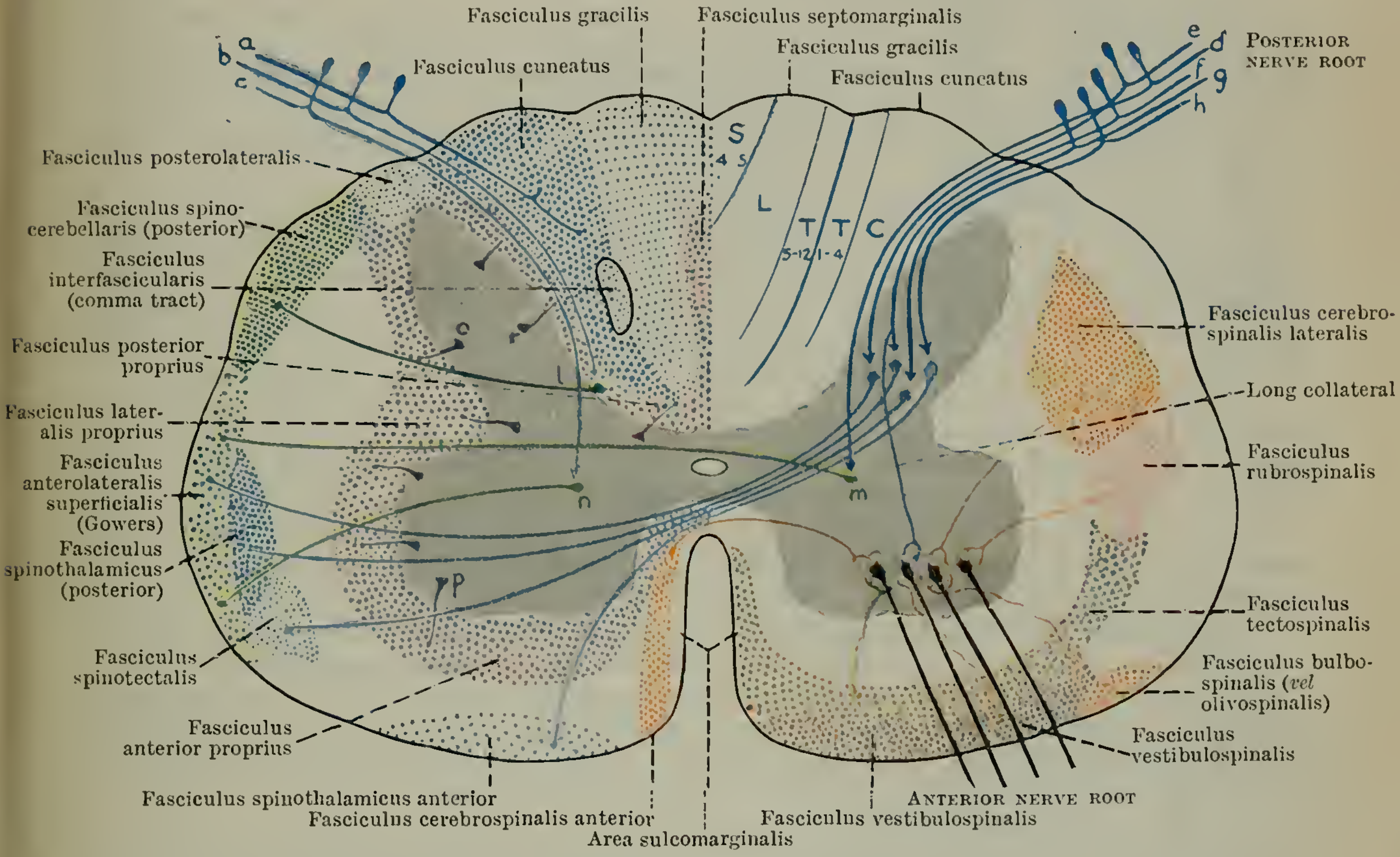
Fasciculus gracilis
Fasciculus septomarginalis
Fasciculus gracilis
Fasciculus cuneatus
Fasciculus cuneatus
a
b
c
e
d
f
g
h
Posterior nerve root
Fasciculus posterolateralis
Fasciculus spino-cerebellaris (posterior)
Fasciculus interfascicularis (comma tract)
Fasciculus posterior proprius
Fasciculus lateralis proprius
Fasciculus anterolateralis superficialis (Gowers)
Fasciculus spinothalamicus (posterior)
Fasciculus spinotectalis
Fasciculus anterior proprius
S
4 5
L
T
T
C
5-12
1-4
c
r
l
n
m
P
Fasciculus cerebro-spinalis lateralis
Long collateral
Fasciculus rubrospinalis
Fasciculus tectospinalis
Fasciculus bulbo-spinalis (vel olivospinalis)
Fasciculus vestibulospinalis
Fasciculus spinothalamicus anterior
Fasciculus cerebrospinalis anterior
Area sulcomarginalis
Anterior nerve root
Fasciculus vestibulospinalis

Fig. 448.—A Diagram to illustrate the Grouping of the various Fasciculi in the Spinal Medulla (in transverse section).

The **ascending fibres** vary greatly in length, and at differing distances from the point where the parent fibres enter the medulla they end in the gray matter. A small contribution, however, of ascending fibres, from each posterior nerve-root, extends upwards to the upper end of the spinal medulla, to end in the medulla oblongata (Figs. 429 and 449).

As each posterior nerve-root enters, its fibres range themselves in the lateral part of the posterior funiculus close up against the posterior column of gray matter. The nerve-fibres of the nerve-root next above take the same position, and consequently those which entered from the nerve immediately below are displaced medially, and come to lie in the posterior funiculus nearer to the median plane. This process goes on as each nerve-root enters, and the result is that the fibres of the lower nerves are gradually pushed nearer and nearer to the posterior median septum in a successive series of lamellar tracts. Of course, the greater proportion of the fibres which are thus carried upwards from the posterior nerve-roots sooner or later leave the posterior funiculus and enter the gray matter, to end there in relation to some of its cells; but, as we have said, every posterior nerve-root sends a few fibres up the whole length of that portion of the spinal medulla which lies above, and thus the posterior funiculus gradually increases in bulk as it is traced upwards, and in all except the lowest part of the spinal medulla, the posterior funiculus is separable into a fasciculus gracilis and a fasciculus cuneatus. The fasciculus gracilis is composed of the long ascending fibres of the posterior nerve-roots, which have entered the lower segments of the spinal medulla. To put the matter differently, the fibres of the sacral roots are displaced medially by the entering lumbar fibres, while the fibres of the lumbar roots are in their turn pushed medially by the entering thoracic fibres, and, lastly, the fibres of the cervical roots displace the thoracic fibres. The difference between the fasciculus gracilis and the fasciculus cuneatus consists simply in this, that the former is composed of the fibres of posterior nerve-roots which have entered the medulla at a lower level than those which enter into the formation of the fasciculus cuneatus. The fibres of the fasciculus gracilis, taking them as a whole, must therefore necessarily run a very much longer course.

Our knowledge of the constitution of the posterior columns of the spinal medulla is derived largely from the study of the course of degeneration in monkeys, after the medulla has been cut across—either partially or completely. But we have also a direct knowledge of the lamination of the posterior columns of the human spinal medulla (Fig. 448) that has been acquired from the examination of cases in which the medulla or its nerve-roots had been injured during life.

Numerous collateral fibrils stream into the gray matter of the posterior column both from the ascending and descending branches of the entering fibres of the posterior nerve-roots. These are classified into long and short collaterals. The **long collaterals** extend forwards into the anterior column of gray matter and end in relation to the ventral nerve-cells. The **short collaterals** end in relation to the nerve-cells in the substantia gelatinosa, and other nerve-cells of the posterior column of gray matter.

The majority of the fibres of the posterior nerve-root enter the spinal medulla on the medial side of the apex of the posterior column of gray matter. The manner in which these are related to the fasciculus cuneatus and the fasciculus gracilis has been noticed; but a certain number of those fibres which lie most laterally take a curved course forwards on the medial side of the posterior column of gray matter and then pass into it. In the thoracic region these curved fibres end in connexion with the cells of the nucleus dorsalis (Fig. 442, B, p. 527, and Fig. 429).

Fasciculus Posterolateralis (O.T. **Tract of Lissauer**).—The postero-lateral fasciculus is a small tract of nerve-fibres of minute calibre which assume their medullary sheaths at a comparatively late period. It is placed at the surface of the medulla close to the sulcus lateralis posterior. It is formed by some of the lateral fibres of the posterior nerve-roots which do not enter the fasciculus cuneatus, but pass upwards in the medulla close to the substantia gelatinosa, in which they ultimately end.

It must now be evident that the fibres which enter the medulla spinalis through each posterior nerve-root have three main modes of distribution: (1) the majority take part in the formation of the fasciculus cuneatus, and pass upwards or downwards to end in the gray matter at some other level in the central nervous system; (2) some fibres, and many collaterals of fibres in the fasciculus cuneatus, lie close to the posterior column and describe a series of graceful curves as they pass forwards, prior to turning laterally into all regions of the gray matter to end at the same level as they enter the medulla spinalis; (3) a third series form the postero-lateral fasciculus and end in connexion with the cells of the substantia gelatinosa and other cells in the posterior and anterior columns of gray matter (Fig. 429).

The fibres derived from the posterior nerve-roots which ascend in the posterior funiculi of the medulla spinalis to the medulla oblongata of the brain constitute a direct sensory tract; other fibres are described which give rise to a crossed sensory tract termed the **fasciculus spino-thalamicus**. These latter fibres arise as the axons of certain of the cells in the posterior column in connexion with which fibres from the posterior nerve-roots have ended, and crossing to the opposite side of the medulla spinalis through the anterior commissure they ascend in the antero-lateral funiculus to the brain, where they ultimately reach the thalamus. As the spino-thalamic tract ascends in the spinal medulla its fibres are not gathered into a compact strand, but are more or less loosely scattered in the lateral funiculus.

Association Fibres in the Posterior Funiculus.—But the whole of the fibres of the posterior funiculus are not derived from the posterior nerve-roots. A few fibres exist in this funiculus which have a different origin. They are derived from certain of the cells of the gray matter, and, entering the posterior funiculus, they divide into ascending and descending branches which pass upwards and downwards in the funiculus for a varying distance, before they finally turn in to end in the gray matter at higher and lower levels. These fibres, therefore, constitute links of connexion between different segments of the spinal medulla, and they constitute the **fasciculus posterior proprius.** Our information regarding these fibres at present is somewhat defective; but it is believed that the deepest part of the funiculus, *i.e.* the part next the posterior gray commissure, and the **fasciculus septomarginalis** of Bruce, placed in apposition with the posterior-median septum and in the adjoining part of the surface, belong mainly to this category.

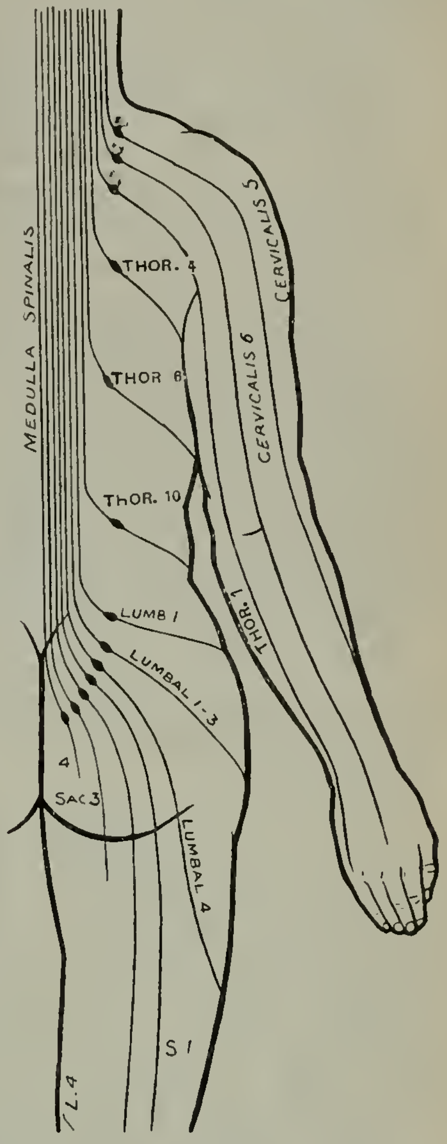

FIG. 449.—DIAGRAM TO SHOW THE MANNER IN WHICH THE FIBRES OF THE POSTERIOR NERVE-ROOTS ENTER AND ASCEND IN THE POSTERIOR FUNICULUS OF THE SPINAL MEDULLA. (From Edinger.)

Funiculus Lateralis and Funiculus Anterior.—It is convenient to consider the anterior along with the lateral funiculus and to call the whole mass of white substance that is left, after eliminating the posterior funiculus, the **antero-lateral funiculus.** In contact with the surface of the gray columns there is a broad band of white matter the parts of which are known respectively as the **fasciculus proprius anterior** and **lateralis** (O.T. the ground bundles of the antero-lateral funiculus). It is composed wholly of fibres which spring from nerve-cells in the gray columns, and, after passing for varying distances upwards or downwards, end in the gray matter of the spinal medulla. Thus they constitute an intrinsic system of fibres linking together different levels of the spinal medulla. They become medullated before any other fibres, except the root-fibres and their continuations in the posterior funiculus. When cut across some of the fibres degenerate above, others below, the injury, and the degeneration extends for varying distances upwards and downwards respectively.

The best-known long or extrinsic systems of fibres in the antero-lateral funiculus are those known as the **fasciculus cerebrospinalis lateralis** (O.T. **crossed pyramidal tract**), the **fasciculus cerebrospinalis anterior** (O.T. **direct pyramidal tract**), the **fasciculus cerebellospinalis** (O.T. **direct cerebellar tract**) (*which goes from the spinal medulla to the cerebellum, and ought therefore to be called spinocerebellaris, as it will be subsequently named in this account*), and the **fasciculus anterolateralis superficialis** (O.T. **Gowers' tract**).

There are, however, many other fasciculi at least as important as these, but there is as yet no close agreement as to their precise limits or connexions. One reason for this is that some of the elements of one tract may become intermingled with those of another; moreover, the position and relations of certain of them vary considerably at different levels of the spinal medulla. In Fig. 429 an attempt has been made to present the present state of our knowledge of these great strands of white fibres. This diagram is not intended to represent any definite level of the spinal medulla, though certain features are shown which occur only in the cervical region; and in respect of other features, the arrangement found in lower regions of the spinal medulla has been introduced to render the diagram more serviceable.

Much of the apparent complexity of this chart will disappear if the reader recalls some general statements (p. 513) made with regard to the outstanding features of the brain. It was then explained that when afferent nerves, coming from the skin and muscles, enter the spinal medulla, they not only establish relations with the motor nuclei and other spinal structures in the neighbourhood of their insertion, but also give rise, directly or indirectly (see Fig. 429), to many fasciculi which pass upwards in the spinal medulla to reach the medulla oblongata, the pons and cerebellum, the mesencephalon (corpora quadrigemina), the thalamus, and the cerebral hemisphere. In the neighbourhood of each level where these ascending sensory tracts end, such as for example the region of the vestibular nucleus and cerebellum, the tectum mesencephali, the corpus striatum, and the cerebral hemisphere, great descending tracts originate and pass downwards in the spinal medulla (Fig. 429—*the red lines*). Thus we have cerebro-spinal, rubro-spinal, tecto-spinal, vestibulo-spinal, and bulbo-spinal fasciculi passing down the spinal medulla; and each system eventually ends around the series of motor nuclei (Fig. 429), many of them in the spinal medulla.

In the antero-lateral funiculus the various fasciculi will be found to be grouped roughly into three bands:—Next to the gray columns is the fasciculus proprius; then comes a band of descending (motor) fasciculi; and then, upon the surface, a series of ascending (sensory) fasciculi. This arrangement, however, is not maintained with any degree of exactitude in the anterior funiculus, where the sharp demarcation between ascending and descending fasciculi is in great part destroyed by the intermingling of fibres passing in opposite directions.

The fibres of the posterior nerve-root have already been studied so far as their relation to the posterior funiculus is concerned. No clear conception of the nature and significance of the ascending fasciculi in the antero-lateral funiculus can be obtained unless they also are studied in relationship with the fibres of the posterior root.

It has already been explained that of the fibres which enter the spinal medulla in the posterior root the great majority enter the posterior funiculus, where they bifurcate (Fig. 448, *a*); one branch of each fibre passes upwards either in the funiculus gracilis or in the funiculus cuneatus, or it may pass from the latter into the former; the other descends in the fasciculus interfascicularis (O.T. comma tract). Other fibres perhaps enter the postero-lateral fasciculus (O.T. Lissauer's bundle). But all the other fibres of the posterior root, together with the majority of the fibres of the fasciculus cuneatus, sooner or later enter the gray matter (Fig. 448, *b* to *h*) of the spinal medulla.

Some of them (*b*) pass directly to end in the nucleus dorsalis of their own side, and from its cells fresh fibres arise, which pass laterally through the posterior column and lateral funiculus to reach the surface, where they bend upwards as constituent fibres of the spino-cerebellar fasciculus. These pass upwards throughout the whole length of the spinal medulla (above their place of origin), into the medulla oblongata, thence into the cerebellum through the restiform body.

Other fibres on the same side (*c*), and perhaps also on the other side (*d*), end amidst cells of the gray matter, the axis-cylinder processes of which pass into the antero-lateral superficial fasciculus (O.T. Gowers' tract). In this tract they ascend throughout the spinal medulla, medulla oblongata, and pons, to enter the cerebellum alongside the brachium conjunctivum (superior peduncle). This element in the antero-lateral fasciculus is sometimes designated the **fasciculus spinocerebellaris anterior**, to distinguish it both from the non-cerebellar fibres of the parent fasciculus and from the **fasciculus spinocerebellaris [posterior]** (O.T. **the direct cerebellar tract**). These two spino-cerebellar tracts convey to the cerebellum information from the muscles and overlying skin which assists it to co-ordinate the muscles for carrying on precisely adjusted movements.

Other fibres of the posterior nerve-root (*e*, *f*, *g*, and *h*) terminate in relationship with cells in the gray columns of their own side of the spinal medulla, the axons of which cross the median plane in the anterior commissure to pass respectively (*e*) into the antero-lateral superficial fasciculus [not to be confused with the cerebellar constituents of this bundle]; (*f*) into the real **fasciculus spinothalamicus [posterior]**, of which the last-mentioned fibres are merely outlying members; (*g*) into the **fasciculus spinotectalis**, to ascend to the mesencephalon; and (*h*) into the marginal area of the anterior funiculus to form a group which may be called the **fasciculus spinothalamicus anterior.**

The careful investigations of the late Dr. Page May led him to attach a definite physiological significance to this grouping of the ascending paths. The **fasciculus spinothalamicus [posterior]** is supposed to convey upwards to the thalamus (for transmission to the cerebral cortex, which is concerned with the conscious appreciation of sensations) all impulses of *pain, heat, and cold* coming from the skin upon the opposite side of the body. The **fasciculus spinothalamicus anterior** conveys impulses of *touch* and *pressure* from the opposite side.

The **spino-cerebellar fasciculi [anterior** and **posterior]** convey to the cerebellum respectively homolateral and bilateral unconscious afferent impulses underlying muscular co-ordination and reflex tone.

Among the descending tracts that establish connexions between various parts of the brain (see Fig. 429) and the motor nerve-cells in the anterior column may be mentioned the **cerebro-spinal**, the **rubro-spinal** (from the red nucleus), the **tecto-spinal** (from the corpora quadrigemina), the **vestibulo-spinal** (from the terminal nucleus of the vestibular nerve), and the **bulbo-spinal tracts.** The last-mentioned forms a peculiar triangular area upon the surface immediately to the lateral side of the anterior nerve-roots (Fig. 448), but there is great uncertainty as to its mode of origin: it is often called the **fasciculus olivospinalis**, from the fact that its discoverer, Helweg, believed it to originate from the olivary nucleus in the bulb or medulla oblongata. It may be regarded as an outlying part of the vestibular (or cerebellar) tract to the motor nuclei of the spinal medulla.

The **fasciculus cerebrospinalis lateralis** (O.T. **crossed pyramidal tract**) is a large well-defined descending tract which lies immediately in front of the posterior column of gray matter, and subjacent to the posterior spino-cerebellar fasciculus, which shuts it out from the surface. Below the point where the posterior spino-cerebellar fasciculus begins the cerebro-spinal fasciculus becomes superficial, and in this position it can be traced as low as the fourth sacral nerve, at which level it ceases to exist as a distinct strand. The cerebro-spinal fasciculus is composed of an admixture of both large and small fibres. These arise in the brain from the large pyramidal cells of the motor or precentral area of the cerebral cortex, and pass downwards through various subdivisions of the brain to gain the spinal medulla. As they enter the spinal medulla they cross the median plane from one side to the other, and it thus happens that the cerebro-spinal tract in the right lateral funiculus of the spinal medulla has its origin in the cortex of the left cerebral hemisphere, and *vice versa.* As the tract descends in the spinal medulla it gradually diminishes in size; and this is due to the fact that, as it traverses each spinal segment, numerous fibres leave it to enter the anterior column of gray matter, and end in connexion with the anterior motor cells from which the fibres of the anterior nerve-roots arise. The entire strand is ultimately exhausted in this way. Numerous collateral fibrils spring from the cerebro-spinal fibres, and, entering the gray matter, end in a similar manner. In this way a single cerebro-spinal fibre may be connected with several spinal segments before it finally ends. The lateral cerebro-spinal fasciculus must be regarded as a great motor strand which brings the spinal motor apparatus under the control of the will.

Sharpey Schafer believes that many of the fibres of the cerebro-spinal fasciculus end in connexion with the cells of the nucleus dorsalis.

In many marsupials, rodents, and ungulates the lateral cerebro-spinal fasciculus lies in the posterior funiculus of the spinal medulla.

The **fasciculus lateralis proprius** represents the remainder of the lateral funiculus. Its fibres are largely derived from the cells situated in all parts of the gray matter, and also from the nerve-cells of the opposite side of the spinal medulla. After a course of very varying length in the fasciculus lateralis, these fibres turn medially and re-enter the gray matter. Such fibres may thus be regarded as **inter-segmental association fibres** binding two or more segments of the spinal medulla together. It may be mentioned that the association fibres which link together segments of the spinal medulla which are near to each other lie close to the gray matter, whilst those which connect the more distant segments are situated further out in the lateral funiculus.

Funiculus Anterior.—One well-defined tract is situated in the funiculus anterior. This is termed the **fasciculus cerebrospinalis anterior.** The remainder of the funiculus receives the name of the **fasciculus anterior proprius.**

The **fasciculus cerebrospinalis anterior** (O.T. **direct pyramidal tract**) is usually a nerve-strand of small size which lies near the anterior median fissure. As a rule it cannot be traced lower than the middle of the thoracic region of the spinal medulla. It is a descending tract and must be associated with the lateral cerebro-spinal fasciculus of the opposite side, seeing that both of these strands arise from the motor area of the cortex of the same cerebral hemisphere. From this it must be clear that the anterior cerebro-spinal fasciculus does not cross the median plane as it enters the spinal medulla, but descends on the side of the spinal medulla corresponding to the cerebral hemisphere in which it arises. Nevertheless, its fibres do not end in the same side of the spinal medulla, but at every step along the path of the strand they make use of the anterior commissure, and cross to the opposite side of the spinal medulla, to terminate in relation to the opposite ventral motor cells in the same manner as the lateral cerebro-spinal fibres.

From this crossing of the cerebro-spinal fasciculi, it follows that the destruction of the fibres which compose them as they descend in one side of the brain must result in paralysis of the muscles supplied by the efferent nerves of the opposite side of the spinal medulla.

In cases of old brain lesion it is sometimes possible to detect some degenerated fibres in the lateral cerebro-spinal fasciculus of the sound side of the spinal medulla, and from this it is supposed that this tract contains a few uncrossed fibres. If this is the case, each side of the spinal medulla stands in connexion with the motor area of both cerebral hemispheres.

It is well to note that the fibres of both lateral cerebro-spinal fasciculi are not medullated until the time of birth. They are the latest of all the fasciculi of the spinal medulla to myelinate.

Commissura Anterior Alba.—The anterior white commissure is composed of medullated nerve-fibres passing from one side of the spinal medulla to the other and entering the anterior column of gray matter, and also the anterior funiculus of white matter. It is to be regarded more as a decussation than as a commissure, and its width, which varies somewhat in different regions, fluctuates in correspondence with the diameter of the spinal medulla.

Amongst the fibres which cross in the anterior commissure may be mentioned: (1) The fibres of the fasciculus cerebrospinalis anterior; (2) collaterals from both the anterior and lateral funiculi; (3) axons of many of the cells of the gray matter; (4) the dendritic processes of some of the medial anterior cells.

Commissura Grisea.—Although this is composed of gray matter with a large admixture of neuroglia, numerous nerve-fibres pass transversely through it, so as to establish relations between the cells in the gray matter on the two sides of the spinal medulla.

THE ENCEPHALON OR BRAIN.

The **brain** is the enlarged and greatly modified upper part of the cerebro-spinal nervous axis. It is surrounded by the same membranes that envelop the medulla spinalis (viz., the dura mater, the arachnoid, and the pia mater), and it almost completely fills up the cavity of the cranium. So closely, indeed, is the skull capsule moulded upon the brain that the impress of the latter is almost everywhere evident upon the inner surface of the cranial wall. The relations, therefore, of cranium to brain are totally different from those presented by the vertebral canal to the spinal medulla. As we have noted, the medulla spinalis occupies only a part of its bony case; and there is not only a wide and roomy space between the arachnoid and the pia mater, but also an interval of some width between the dura mater and the walls of the vertebral canal.

General Appearance of the Brain.—When viewed from above the brain presents an ovoid figure, the broad end of which is directed backwards. Its greatest transverse diameter is usually found in the neighbourhood of that part which lies between the two parietal tuberosities of the cranium. The only parts which are visible when the brain is inspected from this point of view are the two convoluted **cerebral hemispheres.** These present an extensive convex surface, which is closely applied to the internal aspect of the cranial vault, and are separated from each other by a deep median cleft, termed the **fissura longitudinalis cerebri,** which extends from the front to the back of the brain.

The inferior aspect of the brain is usually termed the **basis cerebri.** It presents an uneven and irregular surface, which is more or less accurately adapted to the inequalities on the floor of the cranial cavity. Upon this aspect of the brain some of its main subdivisions may be recognised. Thus, posteriorly, is seen the short cylindrical portion, called the **medulla oblongata,** through which, at the foramen magnum, the brain becomes continuous with the medulla spinalis. The medulla oblongata lies on the ventral aspect of the cerebellum, and occupies the vallecula or hollow which intervenes between the two cerebellar hemispheres. The **cerebellum** is a mass of considerable size which is placed below the posterior portions of the two cerebral hemispheres. It is easily recognised on account of the closely set, curved, and parallel fissures which traverse its surface and give it a foliated appearance. Above the medulla oblongata, and in close connexion with it, is a prominent white elevation called the **pons.** Immediately in front of the pons there is a deep hollow or recess. This is bounded behind by the pons, on each side by the projecting temporal lobe of the cerebral hemisphere, and in front by the orbital portions of the frontal lobes of the cerebral hemispheres. Passing out from each side of the anterior part of this recess is the deep **lateral fissure** of the brain which intervenes between the pointed and projecting extremity of the temporal lobe and the frontal lobe of the cerebrum, whilst, in the median plane in front, the longitudinal fissure, which separates the frontal portions of the cerebral hemispheres, opens into it.

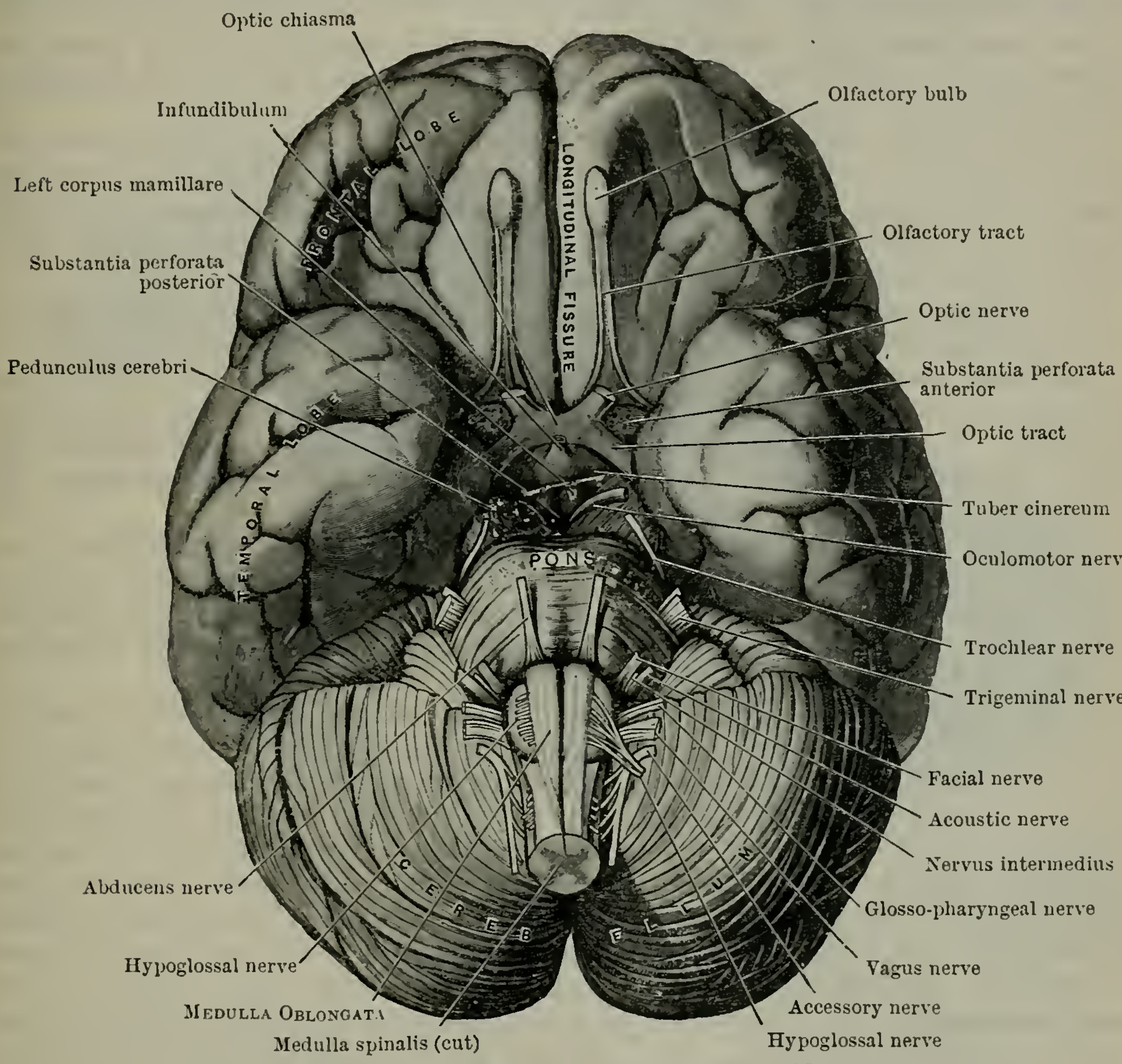

FIG. 450.—THE BASE OF THE BRAIN WITH THE CEREBRAL NERVES ATTACHED.

Within the limits of this deep hollow, on the base of the brain, two large rope-like strands, the **pedunculi cerebri**, may be seen issuing from the inferior surface of the cerebral hemispheres. As they pass downwards these peduncles are inclined obliquely towards the median plane, so that when they plunge into the pons they are situated in close apposition the one to the other (Fig. 452). Turning round the lateral side of each peduncle, where it emerges from the cerebrum, a flattened band termed the **optic tract** may be observed. These bands come from the anterior part of the hollow, where they are joined together by a short connecting piece termed the **optic chiasma**. The **optic nerve** is inserted, on each side, into the antero-lateral angle of the chiasma.

The pedunculi cerebri, the optic tracts, and the optic chiasma enclose a deep rhomboidal or lozenge-shaped interval on the base of the brain, which is termed the **fossa interpeduncularis**. Within the limits of this area the following parts may be seen as we pass from behind forwards: (1) the substantia perforata posterior; (2) the corpora mamillaria; (3) the tuber cinereum and the stalk of the hypophysis cerebri (O.T. pituitary body).

At its posterior angle, immediately in front of the pons, the interpeduncular fossa is very deep and is floored by a layer of gray matter, in which are numerous small apertures. This is the **substantia perforata posterior**. Through the apertures which are dotted over its surface the small postero-medial basal branches of the posterior cerebral artery enter the brain.

The **corpora mamillaria** are two small white pea-like eminences placed side by side in front of the substantia perforata posterior.

The **tuber cinereum** is a slightly-raised field of gray matter, which occupies the interval between the anterior portions of the optic tracts in front of the corpora mamillaria. Springing from the anterior part of the tuber cinereum, immediately behind the optic chiasma, is the **infundibulum**, or the stalk which connects the hypophysis cerebri with the base of the brain (Fig. 452).

Lateral to the limits of the anterior part of the interpeduncular space there is, on each side, a small depressed triangular field of gray matter, which leads laterally into the lateral cerebral fissure. It is perforated by the antero-medial and the antero-lateral groups of basal arteries, and receives the name of the **substantia perforata anterior**.

General Connexions of the Several Parts of the Brain.—The medulla oblongata, the pons, and the cerebellum occupy the posterior cranial fossa, and they are separated from the cerebral hemispheres, which lie above them, by a partition of dura mater, termed the tentorium cerebelli. Further, they surround a cavity, a portion of the primitive cavity of the early neural tube, which is termed the **fourth ventricle** of the brain, and they all stand in intimate connexion, one with the other. The medulla oblongata is for the most part carried upwards into the pons; but at the same time two large strands from its dorsal aspect, termed the **restiform bodies**, are prolonged into the cerebellum, and constitute its **inferior peduncles**, or the chief bonds of union between the medulla (oblongata and spinalis) and the cerebellum. The pons has large numbers of transverse fibres entering into its composition, and the great majority of these are gathered together on each side in the form of a large rope-like strand. This plunges into the corresponding hemisphere of the cerebellum, and constitutes its **middle peduncle**, which is known as the **brachium pontis**.

The cerebrum, which forms the great mass of the brain, occupies the anterior and middle cranial fossæ, and extends backwards into the occipital region above the tentorium and the cerebellum. The greater part of the cerebrum is formed by the cerebral hemispheres, which are separated from each other in the median plane by the longitudinal fissure. At the bottom of this fissure is the **corpus callosum**, a broad commissural band which connects the two hemispheres with each other. Each hemisphere is hollow, the cavity in its interior being termed the **lateral ventricle** of the brain. Between and below the cerebral hemispheres, and almost completely concealed by them, is the **inter-brain** or **diencephalon**. The principal parts forming this portion of the brain are two large masses of gray matter, termed the **thalami**. Between these is the **third ventricle** of the brain—a deep narrow cavity occupying the median plane. The third ventricle communicates with the lateral ventricles by two small apertures, called the **foramina interventricularia.**

The cerebrum is connected with the parts in the posterior cranial fossa (pons, cerebellum, and medulla oblongata) by a narrow stalk called the **mesencephalon** or **mid-brain.** The mid-brain is built up of—(1) the **pedunculi cerebri**, passing from the pons to the cerebrum; (2) the **corpora quadrigemina**, forming its dorsal part; and (3) the **brachia conjunctiva** (O.T. **superior cerebellar peduncles**), proceeding from the cerebellum to the cerebrum. It is tunnelled by a narrow passage, the **aquæductus cerebri**, which extends between the fourth and third ventricles.

In a view of the intact brain the greater part of the mesencephalon and diencephalon is hidden by the cerebral hemispheres; but a precise idea will be obtained of the inter-relationships of the various parts of the brain, if we study the relationship of these structures to the series of cavities in the interior of the brain as they are displayed in a median sagittal section (Fig. 451).

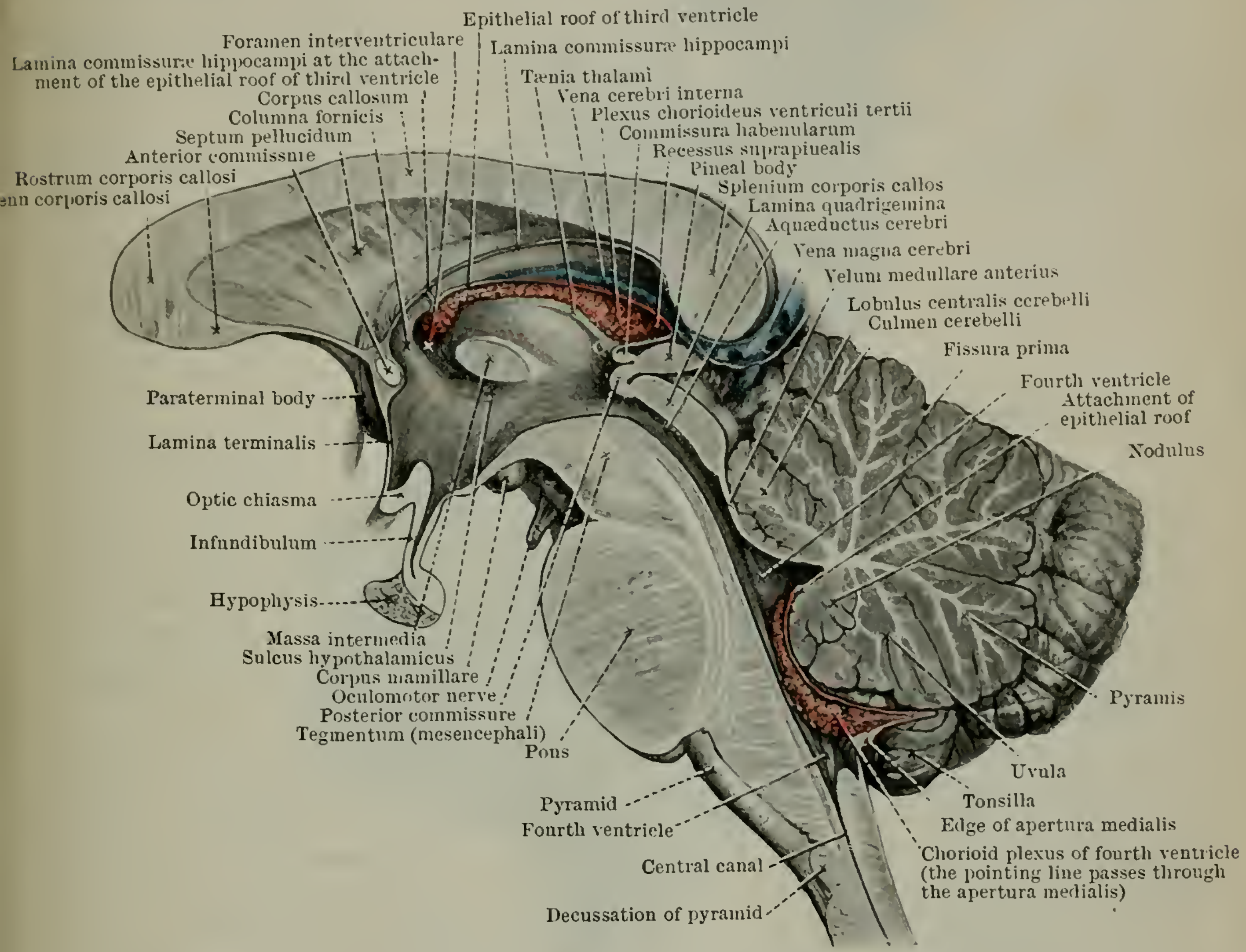

FIG. 451.—THE PARTS OF THE BRAIN CUT THROUGH IN A MEDIAN SAGITTAL SECTION. The side walls of the ventricular cavities are also shown.

The central canal which tunnels the spinal medulla is seen to extend into the medulla oblongata for a short distance; then it expands into the irregular cavity of the fourth ventricle, the floor (anterior wall) of which is formed partly by the medulla oblongata and partly by its continuation upwards, the **pars dorsalis pontis.** Behind the fourth ventricle lies the cerebellum, but it forms only a small part of the roof (**tegmen**). The roof consists mainly of the **velum medullare anterius** above and the thin epithelial lamina (**lamina chorioidea epithelialis**) below.

The fourth ventricle is continued upwards into the **aquæductus cerebri**, which tunnels the mesencephalon, of which the thick mass of the **tegmentum** is placed in front of it and the **lamina quadrigemina** behind.

The aqueduct opens in front into the third **ventricle**, the major portion of each side wall of which is formed by the **thalamus.** Near the antero-superior corner of each side wall of the third ventricle the small **foramen interventriculare** (O.T. **foramen of Monro**) leads into the cavity of the corresponding cerebral hemisphere, which is known as the **lateral ventricle.**

MEDULLA OBLONGATA.

The **medulla oblongata** is the continuation upwards of the medulla spinalis. It is a little more than 25 mm. (one inch) in length, and it may be regarded as beginning immediately above the uppermost root of the first cervical nerve, or, roughly, about the level of the foramen magnum. From this it proceeds upwards in a very nearly vertical direction, and ends at the lower border of the pons. At first its girth is similar to that of the spinal medulla, but it rapidly expands as it approaches the pons, and consequently it presents a more or less conical form. Its anterior surface lies behind the grooved surface of the basilar portion of the occipital bone, whilst its posterior surface is sunk into the vallecula of the cerebellum. The medulla oblongata is a bilateral structure, and this is indicated on the surface by the presence of **anterior and posterior median fissures,** on the ventral and dorsal surfaces respectively.

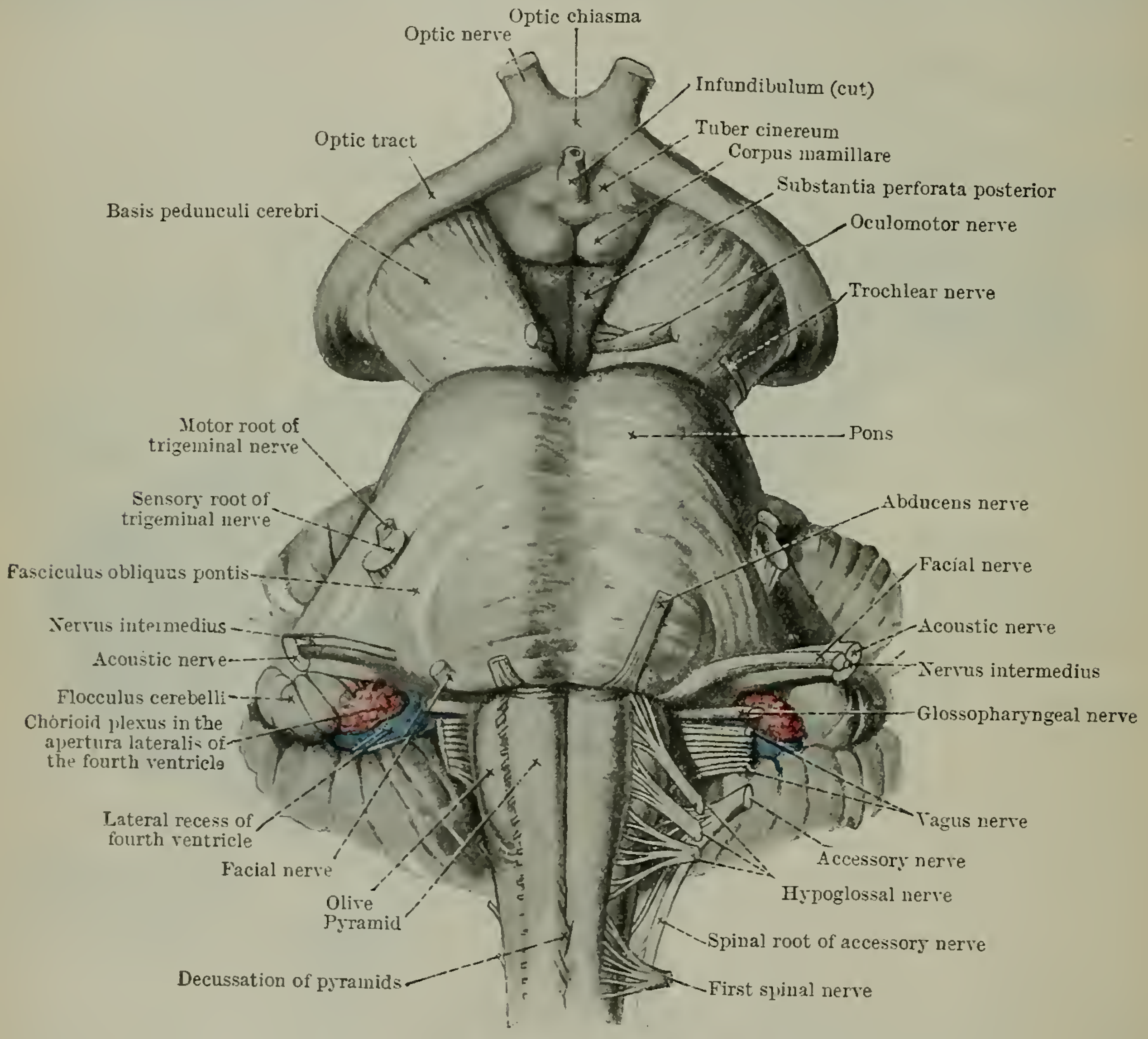

FIG. 452.—FRONT VIEW OF THE MEDULLA OBLONGATA, PONS, AND MESENCEPHALON.

The **fissura mediana** anterior, as it passes from the spinal medulla on to the medulla oblongata, is interrupted at the level of the foramen magnum by several strands of fibres which cross the median plane from one side to the other. This intercrossing is termed the *decussation of the pyramids.* Above this level the fissure is carried upwards to the lower border of the pons, but is often rendered very shallow by numerous external arcuate fibres which emerge upon the surface between its lips and then curve laterally to reach the posterior part of the medulla oblongata. At the lower margin of the pons it expands slightly and ends in a blind pit, which receives the name of the **foramen cæcum** of Vicq d'Azyr.

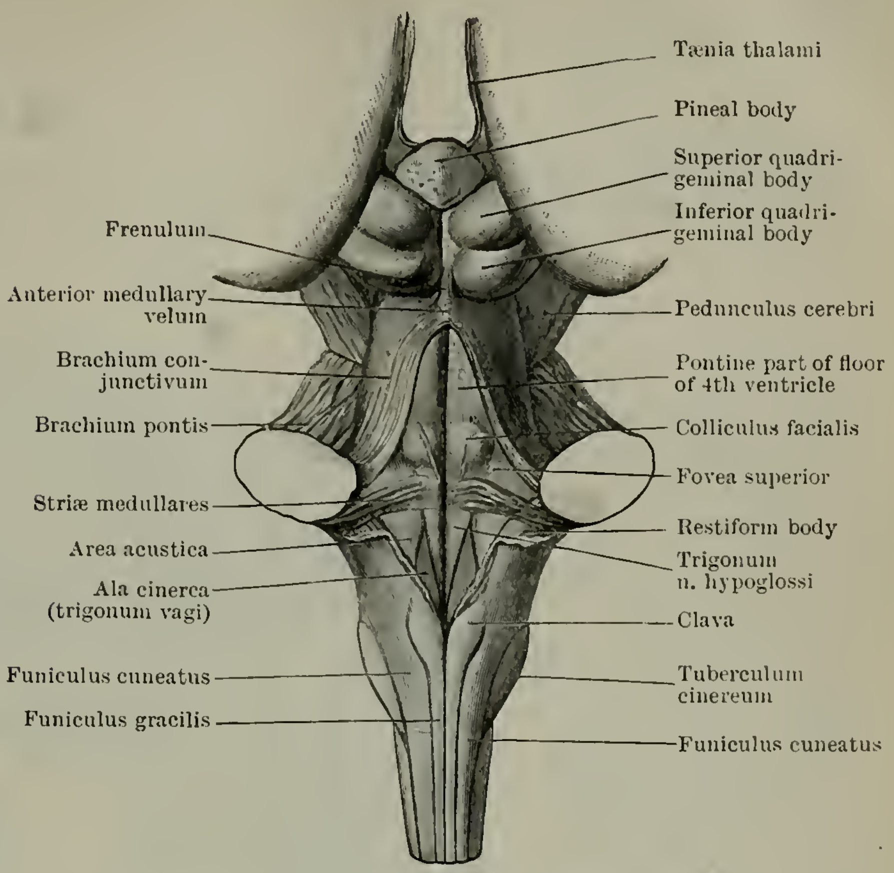

FIG. 453.—POSTERIOR VIEW OF THE MEDULLA, PONS, AND MESENCEPHALON OF A FULL-TIME HUMAN FŒTUS.

The **fissura mediana posterior** is present only on the lower half of the medulla oblongata. As it ascends it rapidly becomes shallower. Half-way up, where the central canal opens into the fourth ventricle, the lips of the posterior median fissure are thrust apart from each other and constitute the boundaries of a triangular field, which is seen when the epithelial roof of the lower part of the fourth ventricle is removed. This triangular field is the lower part of the **fossa rhomboidea**, or the floor of the fourth ventricle of the brain. The lower half of the medulla oblongata, containing as it does the continuation of the central canal of the spinal medulla, is frequently termed the **closed part of the medulla oblongata**; the upper half, above the opening of the canal, which contains the lower part of the fourth ventricle, is called the **open part** of the medulla oblongata.

The examination of the floor of the fourth ventricle will be deferred for the present, and the appearance presented by the surface of the medulla oblongata may now engage our attention. In the spinal medulla the corresponding surface area is divided into three districts or funiculi by the emerging motor roots and the entering sensory roots of the spinal nerves. Of these the sensory enter along the bottom of the sulcus lateralis posterior, whilst the motor fila are spread over a relatively broad surface area and have no groove in connexion with their emergence from the spinal medulla. In the case of the medulla oblongata corresponding rows of fila enter and emerge from the surface of each side. The fila of the hypoglossal nerve carry up the line of the anterior nerve-roots of the spinal medulla. In one respect, however, they differ: they emerge in linear order and along the bottom of a distinct furrow, termed the **sulcus lateralis anterior**, which proceeds upwards on the surface of the medulla oblongata. The fila which carry up the line of the posterior nerve-roots on the surface of the medulla oblongata are the root-bundles of the accessory, the glosso-pharyngeal, and the vagus nerves. These are attached along the bottom of a furrow which is the direct continuation upwards of the sulcus lateralis posterior of the spinal medulla, and therefore receives the name of the **sulcus lateralis posterior** of the medulla oblongata. The root-bundles of these nerves differ, however, in so far that they are not all composed of afferent fibres which spring from ganglionic cells placed without and enter the medulla. Certain of them are purely efferent (roots of accessory), whilst others contain a considerable number of efferent as well as afferent fibres, and are therefore to be regarded as mixed roots.

By the sulci laterales, and also by the two rows of fila attached along the bottom of these furrows, the surface of the medulla oblongata on each side is divided into three districts, viz., an anterior, a lateral, and a posterior, similar to the surface areas of the three funiculi on the side of the spinal medulla. Indeed, at first sight, they appear to be direct continuations upwards of these three portions of the spinal medulla; this, however, is not the case, because the fibres of the three funiculi of the spinal medulla undergo a rearrangement as they proceed upwards into the medulla oblongata.

Anterior Area of the Medulla Oblongata—Pyramis.—The district between the anterior median fissure, and the sulcus lateralis anterior, along the bottom of which the root fila of the hypoglossal nerve issue from the medulla oblongata, receives the name of the **pyramid**. An inspection of the surface is sufficient to show that the pyramid is composed of a compact strand of longitudinally directed nerve-fibres. It represents, in fact, the portion of the great cerebro-spinal fasciculus which is destined to carry fibres from the cerebral hemisphere to all the motor nuclei on the other side of the medulla oblongata and medulla spinalis. Somewhat constricted at the place where it emerges from the pons (Fig. 452) it swells immediately to form a prominent rounded column, which passes vertically downward, separated from the pyramid of the other side by the fissura mediana anterior. Towards the lower part of the medulla oblongata it gradually tapers.

Although the pyramid at first sight appears to be continuous with the anterior funiculus of the medulla spinalis, only a very small proportion of the fibres contained in the latter are derived from the pyramid. This at once becomes manifest when the lips of the anterior median fissure are thrust apart at the place of junction between the medulla oblongata and spinal medulla. The pyramid is then seen to divide at this level into two parts, viz., a small portion composed of a variable number of the most lateral fibres of the pyramid, termed the **fasciculus cerebrospinalis anterior** (O.T. **direct pyramidal tract**), and a much larger portion, situated next the median fissure, called the **fasciculus cerebrospinalis lateralis** (O.T. **crossed pyramidal tract**). The anterior cerebro-spinal fasciculus is continued down into the anterior funiculus of the medulla spinalis, and in this it takes up a medial position next the median fissure. The lateral cerebro-spinal fasciculus is broken up into three or more coarse bundles, which sink backwards and at the same time cross the median plane, to take up a position in the posterior part of the opposite lateral funiculus of the spinal medulla. The term **decussatio pyramidum (decussation of the pyramids)** is applied to the intercrossing of the corresponding bundles of the lateral cerebro-spinal fasciculi of opposite sides.

The anterior cerebro-spinal fasciculus is, therefore, the only part of the pyramid which has a place in the anterior funiculus of the spinal medulla. The much larger part of this funiculus, termed the fasciculus anterior proprius, as it is traced up into the medulla oblongata, is seen to be thrust aside by the decussating bundles of the lateral cerebro-spinal fasciculus. It thus comes to occupy a deep position in the substance of the medulla oblongata, behind and to the lateral side of the pyramid.

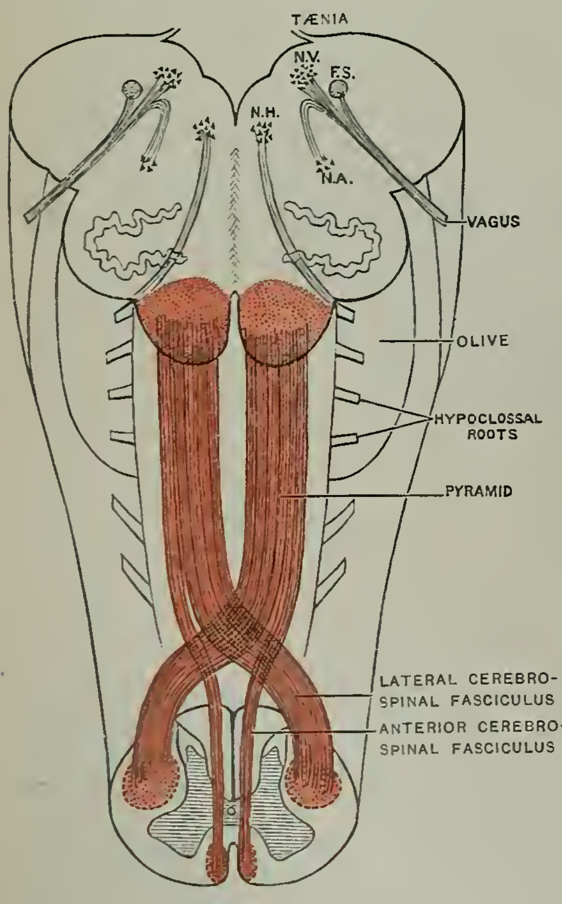
TÆNIA
N.V.
F.S.
N.H.
N.A.
VAGUS
OLIVE
HYPOGLOSSAL ROOTS
PYRAMID
LATERAL CEREBRO-SPINAL FASCICULUS
ANTERIOR CEREBRO-SPINAL FASCICULUS

Fig. 454.—Diagram of the Decussation of the Pyramids (modified from van Gehuchten).
NH, Nucleus hypoglossi; NV, Vago-glosso-pharyngeal nucleus; FS, Tractus solitarius; NA, Nucleus ambiguus.

Lateral Area of the Medulla Oblongata.—This is the district on the surface of the medulla oblongata which is included between the two rows of nerve-roots, viz., the hypoglossal roots in front, and the root-bundles of the accessory, the vagus, and the glossopharyngeal nerves behind. It presents a very different appearance in its upper and lower parts. In its lower portion it simply appears to be a continuation upwards of the lateral area of the spinal medulla; in its upper part a striking oval prominence bulges out on the surface of the medulla, and receives the name of **oliva** (O.T. **olivary eminence**).

The lower part of this district, however, is very far from being an exact counterpart of the lateral funiculus of the spinal medulla. The large lateral cerebrospinal tract is no longer present, seeing that it forms, in the medulla oblongata, the greater part of the pyramid of the opposite side. Another strand of fibres, viz., the fasciculus spinocerebellaris (posterior), prolonged upwards in the lateral funiculus of the medulla spinalis, gradually leaves this portion of the medulla oblongata. This tract lies on the surface, and is frequently visible to the naked eye as a white band (Fig. 455), which inclines obliquely backwards into the posterior district of the medulla oblongata to join its upper part, or, in other words, to join the restiform body. The remainder of the fibres of the lateral funiculus, comprising the fasciculus lateralis proprius and the fasciculus anterolateralis superficialis, is continued upwards in the lateral area of the medulla oblongata, and at the inferior border of the olive the majority of these fibres disappear from the surface by dipping into

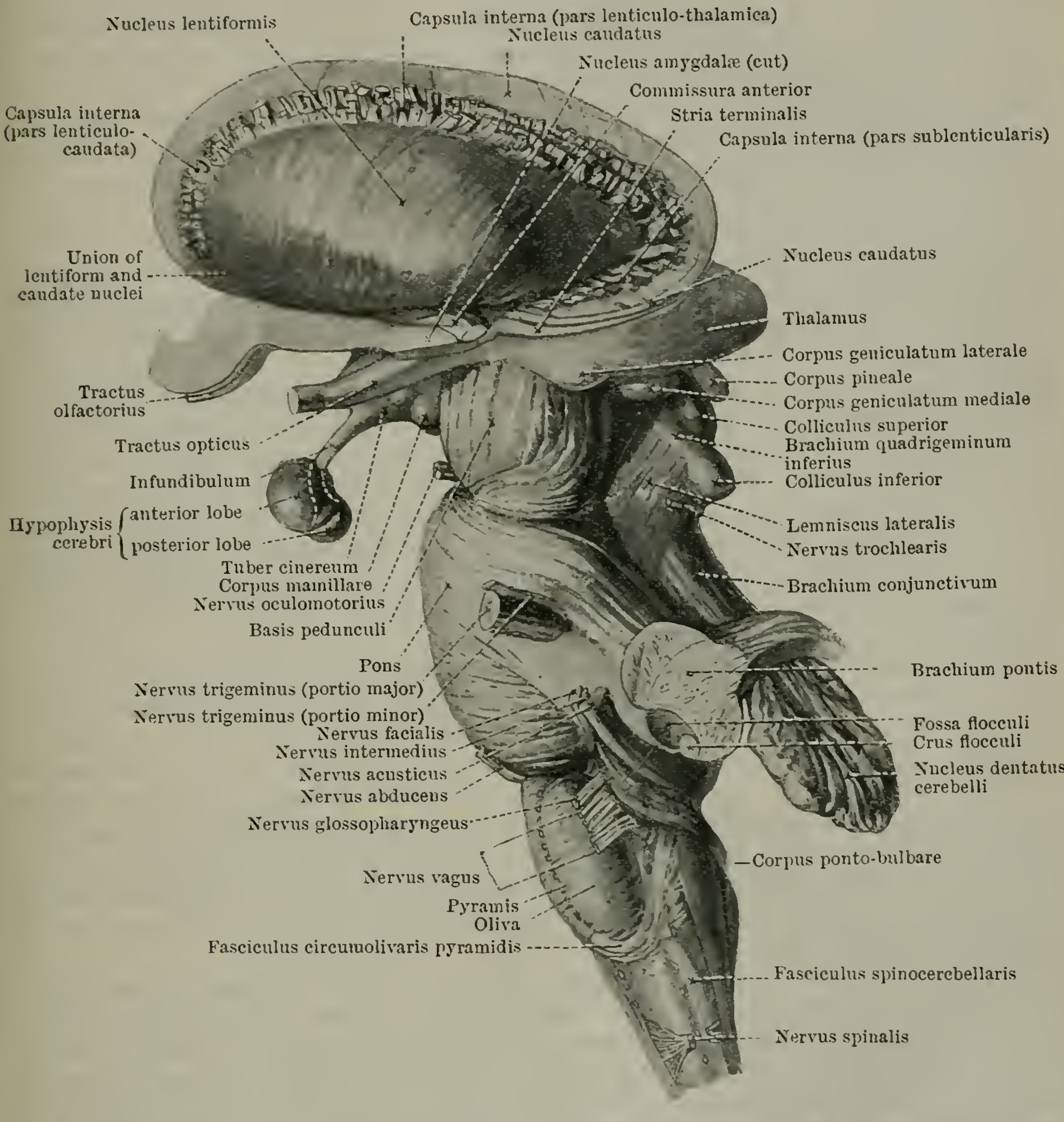

Fig. 455.—Left Lateral Aspect of a Brain from which the Cerebral Hemisphere (with the exception of the Corpus Striatum) and the Cerebellum (excepting its Nucleus Dentatus) have been removed.

the substance of the medulla oblongata under cover of that projection. A small proportion of the fibres, however, are retained on the surface and travel upwards towards the pons, in the interval which exists between the posterior border of the olive and the roots of the vagus and glossopharyngeal nerves.

The **olive** is a smooth oval projection which bulges out from the upper part of the lateral area of the medulla oblongata. Its long axis is vertical and is about half an inch long. It marks the position of the subjacent **nucleus olivaris inferior**, a crumpled thin-walled sac of gray matter, which is separated from the surface only by a very thin layer of superficial white matter.

Posterior Area of the Medulla Oblongata.—In its inferior half, this district is bounded behind by the posterior median fissure, and in its superior half by the lateral margin of the medullary part of the floor of the fourth ventricle of the brain. In front it is separated from the lateral area by the row of root-fila belonging to the accessory, glossopharyngeal, and vagus nerves. As in the lateral area, we recognise an inferior portion and a superior portion, which appear continuous but in reality are almost quite distinct the one from the other.

The inferior part of the posterior area corresponds more or less closely with the posterior funiculus of the spinal medulla. In the cervical region the posterior funiculus is divided by a septum of pia mater into a medial fasciculus gracilis and a lateral fasciculus cuneatus. These are prolonged upwards into the medulla oblongata, and in the lower part of the posterior area they stand out distinctly, and are separated one from the other by a continuation upwards from the spinal medulla of the sulcus intermedius posterior. In the medulla oblongata the medial of these strands is called the **funiculus gracilis**, whilst the lateral one is designated the **funiculus cuneatus**. When they reach the level of the inferior part of the floor of the fourth ventricle, each ends in a slightly expanded bulbous prominence. The swollen extremity of the funiculus gracilis is called the **clava**. This is thrust aside from its fellow of the opposite side by the opening up of the medulla oblongata to form the floor of the fourth ventricle, and the central canal opens on the surface in the angle between the two clavæ.

The elongated prominences formed on the surface of the medulla oblongata by these two strands and their enlarged extremities are due to the presence of two elongated nuclei or collections of gray matter which make their appearance subjacent to the strands, and represent the termini of these uppermost extensions of the spinal posterior root-fibres. These are termed respectively the **nucleus gracilis** and **nucleus cuneatus**. [*As it is the* slenderness *of the one nucleus and the* wedge-shape *of the other in transverse section which gave rise to the terms* gracilis *and* cuneatus *respectively, it is clearly wrong to introduce the word* **funiculi** *into the* B.N.A. *terminology. The funiculi were named from the nuclei and not the nuclei from the funiculi.*]

But a third longitudinal elevation is also apparent on the surface of the inferior part of the posterior area of the medulla oblongata. This is placed on the lateral side of the funiculus cuneatus—between it and the posterior row of nerve-roots—and it has no counterpart in the posterior funiculus of the medulla spinalis. It is called the **tuberculum cinereum.** It is produced by a mass of substantia gelatinosa coming close to the surface and forming a bulging in this situation. Extremely narrow below, it widens as it is traced upwards, and finally ends in an expanded extremity. A thin layer of white matter, composed of longitudinally arranged fibres, is spread over this district, and separates the substantia gelatinosa from the surface. These fibres constitute the **tractus spinalis** of the **trigeminal nerve**, which here assumes a superficial position as it descends in the medulla oblongata.

Corpus Restiforme.—The **restiform body** forms the upper part of the posterior area of the medulla oblongata. It lies between the floor of the fourth ventricle and the roots of the vagus and glossopharyngeal nerves. It is a large and prominent rope-like strand, which inclines upwards and laterally, and then finally takes a turn backwards and enters the cerebellum. It forms the great link of connexion between the cerebellum on the one hand and the medulla oblongata and spinal medulla on the other, and consequently it is also called the **inferior cerebellar peduncle**. A study of the surface of the medulla oblongata yields some important information regarding the constitution of the restiform body. Thus, the posterior spino-cerebellar tract (Fig. 455), from the lateral column of the spinal medulla, can be traced into it; and large numbers of fibres which take a curved course on the surface of the medulla oblongata may likewise be followed into it; these are the external arcuate fibres. Numerous other fibres enter the restiform body on its deep aspect, but these will be studied at a later stage.

Fibræ Arcuatæ Externæ.—The **external arcuate fibres** enter into the constitution of the restiform body, after pursuing a longer or shorter course on the surface of the medulla (Fig. 455).

They are more particularly seen in the neighbourhood of the olive, over the surface of which they may be observed coursing in the form of a number of fine curved bundles or as a continuous sheet of fibres. They vary greatly in number and in distinctness, and they are sometimes so numerous that they cover the olive almost entirely. An attentive examination will show that the majority of them come to the surface in the median fissure between the pyramids, and also, not infrequently, in the groove between the pyramid and olive, or through the substance of the pyramid itself. The anterior median fissure in its upper part is often almost completely blocked up by these emerging fibres. The external arcuate fibres, reaching the surface of the medulla in this manner, turn backwards, and the great majority enter the restiform body and form a considerable part of its outer portion.

Other arcuate fibres arise in the cuneate and gracile nuclei, and enter the restiform body of the same side. Van Gehuchten, however, denies this.

There is frequently present, especially upon the left side, a bundle of fibres that is usually mistaken for a group of arcuate fibres. It is the **fasciculus circumolivaris pyramidis** (Fig. 455). It consists of a bundle of varying size which emerges from the pyramid, bends backwards, curving round the inferior border of the olive, and then passes obliquely upward and backwards to end in a fusiform ridge of gray matter, the **corpus ponto-bulbare** (Essick), which crosses the restiform body very obliquely (Fig. 455, the ridge immediately posterior to the fila of the vagus nerve). These structures are of great morphological interest, and will be referred to again in the succeeding pages (see Fig. 469, p. 566).

PONS.

The **pons** (**Varolius**) is a marked white prominence on the basal aspect of the brain which is interposed between the medulla oblongata and the pedunculi cerebri, and lies in front of the cerebellum. It is convex from side to side, and from above downwards, and transverse streaks on its surface show that, superficially at least, it is composed of bundles of nerve-fibres, most of which course transversely. On each side these transverse fibres are collected together in the form of a large compact strand, which sinks in a backward and lateral direction into the white matter of the corresponding hemisphere of the cerebellum. This strand is termed the **brachium pontis**, and the term "pons," applied to the entire structure, expresses in an admirable way the arch-like manner in which this portion of the brain bridges across the interval between the two cerebellar hemispheres.

The *ventral surface* of the pons is in relation to the basilar part of the occipital bone and the dorsum sellæ of the sphenoid bone. It presents a median groove (**sulcus basilaris**), which gradually widens as it is traced upwards: it lodges the basilar artery. This median depression is produced by the prominence which is caused on each side by the passage of the cerebro-spinal fasciculus downwards through the pons. The **trigeminal nerve**, with its large entering sensory root and its small emerging motor root, is attached to the side of the anterior aspect of the pons, nearer its superior than its inferior border (Fig. 455). It is usual to restrict the term "pons" to that portion of the structure which lies between the two trigeminal nerves, and to apply the designation of brachium pontis to the part which extends beyond the nerve into the hemisphere of the cerebellum. The **abducens nerve**, the **facial nerve**, and the **acoustic nerve** are attached to the brain at the inferior border of the pons. The abducens nerve emerges at the inferior border of the pons opposite the lateral border of the pyramid; the facial and acoustic are also attached to the inferior edge of the pons, but far away from the median plane. The acoustic nerve is in contact with the cerebellum and the facial is on its medial side, with its sensory root (the nervus intermedius) between them (Figs. 452, 455). A large bundle of fibres upon the front of the pons departs from the transverse course pursued by most of the pontine fibres, and starting at the medial side of the trigeminal nerve, passes almost vertically downwards between the facial and acoustic nerves (Fig. 496, p. 591) and reaches the lateral aspect of the medulla oblongata, where it passes into the corpus ponto-bulbare (Fig. 455). This bundle is known as the **fasciculus obliquus [pontis]**. It is interesting to observe that while the facial nerve lies upon the medial side of this oblique bundle, its sensory root (the nervus intermedius) is placed on its lateral aspect, alongside the acoustic nerve (Fig. 497, p. 592).

Immediately below the insertion of the acoustic nerve at the inferior margin of the pons a little calyx-like appendage of the epithelial roof of the fourth ventricle (**recessus lateralis**) projects laterally, partly behind the glossopharyngeal nerve. Through an elliptical aperture in this epithelial process (**apertura lateralis ventriculi quarti**) a little cauliflower-like mass of chorioid plexus becomes extruded between the acoustic and the glossopharyngeal nerves (Fig. 497, p. 592).

The *posterior surface* of the pons looks backwards towards the cerebellum, and presents a triangular area covered with gray matter, which forms the superior part of the anterior wall or floor of the fourth ventricle. This area is directly continuous inferiorly with the medullary part of the floor of the fourth ventricle, and is bounded on each side by a band of white matter termed the **brachium conjunctivum** (Fig. 456).

Brachia Conjunctiva (O.T. **Superior Peduncles of the Cerebellum**).—The brachia conjunctiva are hidden from view by the superior part of the cerebellum, under cover of which they lie. They emerge from the hemispheres of the cerebellum, and, as they proceed upwards on the dorsal aspect of the pons, they converge towards each other until, at the inferior level of the corpora quadrigemina, the medial margins of the two brachia become almost contiguous (Fig. 456, p. 551). At first they form the lateral boundaries of the superior part of the fourth ventricle; but, as they ascend and approach closer to each other, they gradually come to overhang that cavity, and thus enter into the formation of its roof. They disappear from the surface of the brain by dipping under cover of the quadrigeminal bodies and entering the substance of the mesencephalon.

Velum Medullare Anterius.—Filling up the triangular interval between the two brachia conjunctiva, and stretching across from the medial and free margin of the one to the corresponding margin of the other, is a thin layer of white matter which completes the roof or dorsal wall of the upper part of the fourth ventricle, and receives the name of the **anterior medullary velum.** When traced downwards, the velum is seen to be carried, with the brachia conjunctiva, into the white matter of the cerebellum. Spread out on its posterior or superior surface is a small, thin, tongue-shaped prolongation of gray matter from the cortex of the cerebellum, which is termed the **lingula**, whilst issuing from its substance close to the inferior quadrigeminal bodies are the two **trochlear nerves.**

VENTRICULUS QUARTUS.

Fourth Ventricle.—The **fourth ventricle of the brain** is somewhat rhomboidal in form. Below, it tapers to a point and becomes continuous with the central canal of the lower half of the medulla oblongata; above, it narrows in a similar manner and is continued into the **aquæductus cerebri**, which tunnels the mesencephalon. The posterior wall is termed the **tegmen** or **roof** and is concealed by the cerebellum. The anterior wall is called the **floor** and is formed by the dorsal surface of the pons and the corresponding surface of the medulla oblongata. On each side a long, curved, and narrow prolongation of the ventricular cavity is carried laterally from its widest part and curves round the upper part of the corresponding restiform body. This is termed the **recessus lateralis.** The roof of the cavity is very thin and is intimately connected with the cerebellum. It is better, therefore, to defer its description until that part of the brain has been studied.

Fossa Rhomboidea (floor of the fourth ventricle).—In its inferior part the floor of the fourth ventricle is formed by the dorsal surface of the ventral part of the medulla oblongata, whilst in its superior part it is formed by the dorsal surface of the pons (Fig. 456). The area thus constituted is lozenge-shaped, its widest part being opposite the superior ends of the restiform bodies or inferior peduncles of the cerebellum. A thick layer of gray matter, continuous with that which surrounds the central canal, is spread out like a carpet over the ventricular floor, and covering this there is the usual ependymal layer which lines all the ventricles of the brain. The area is circumscribed by definite lateral boundaries. Thus, *below*, it is bounded on each side by (1) the clava, (2) the expanded upper end of the funiculus cuneatus, and (3) the restiform body; whilst *above*, the lateral limits are formed by the brachia conjunctiva.

The floor of the fourth ventricle is divided into two symmetrical portions by a median groove. Its lower narrow pointed portion between the two clavæ receives the name of the **pars inferior**, or, from its resemblance to the point of a pen, the **calamus scriptorius**. Crossing each half of the floor, at its widest part, are several more or less conspicuous bundles of fibres termed the **striæ medullares**. They begin upon the lateral and posterior aspects of the restiform body, where they spring from the cochlear nuclei, pass transversely medially, and disappear from view in the median furrow. The striæ medullares exhibit a large amount of variation in different specimens, both in their degree of prominence and also in the direction which they pursue. It is not uncommon to find that no trace of them is visible upon the surface.

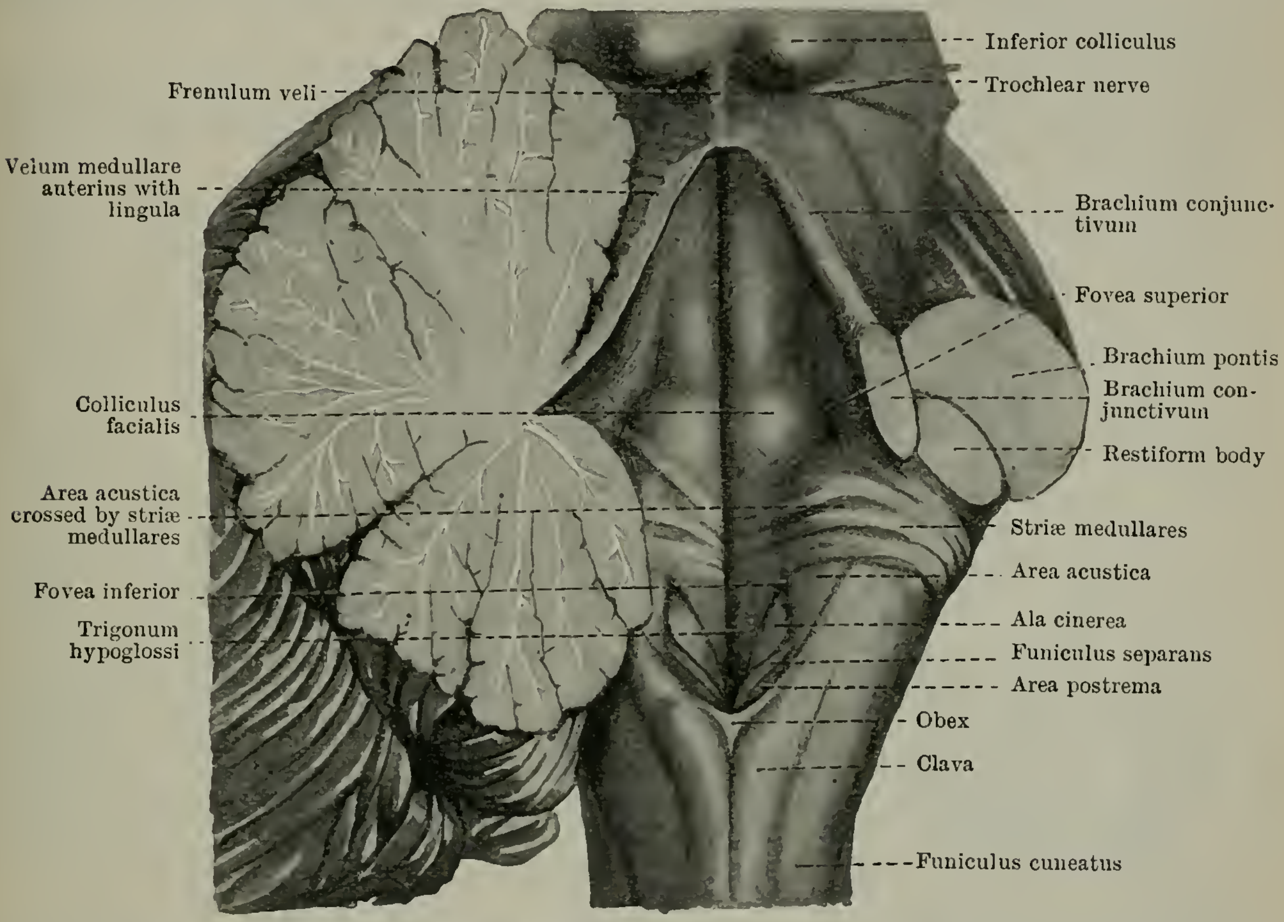

FIG. 456.—FLOOR OF THE FOURTH VENTRICLE. On the right side the right half of the cerebellum has been removed by cutting through its three peduncles and dividing it in the median plane. On the left side the left half of the cerebellum is drawn over to the left so as to expose the floor of the ventricle fully.

On the inferior (bulbar) district of the ventricular floor a small triangular depression, placed immediately below the striæ medullares, catches the eye. This is termed the **fovea inferior**. It is shaped somewhat like an arrow-head. The apex or point looks towards the striæ, whilst the lateral angles of the base are prolonged downwards in the form of diverging grooves (Fig. 456). Of these, the medial groove runs towards the opening of the central canal at the calamus scriptorius, whilst the lateral groove runs towards the lateral boundary of the floor. In this manner the portion of the floor which lies below the striæ medullares is mapped out into three triangular areas. The medial subdivision is slightly elevated and is termed the **trigonum nervi hypoglossi**, because subjacent to the medial part of this area is the nucleus of origin of the hypoglossal nerve. The intermediate area, between the two diverging grooves which proceed from the base of the fovea inferior, is the **ala cinerea**. It is sometimes called the **trigonum n. vagi** because the nucleus of the vagus and the glossopharyngeal nerves lies subjacent to it. Near the lateral angle is the **area acustica**. The base of this area is directed upwards and runs directly into an eminence over which the striæ medullares pass. Subjacent to this district of the floor of the ventricle lies the large terminal chief nucleus of the vestibular division of the acoustic nerve. A more accurate name for the area acustica would be **area vestibularis**.

A close inspection of the pars inferior fossæ rhomboideæ will show that the base of the trigonum vagi is separated from the medial margin of the clava by a narrow lanceolate strip of the ventricular floor, to which Retzius has given the name of **area postrema**. Beneath this area, which is very vascular, lies the nucleus postremus (J. T. Wilson), and marking it off on its superior and medial aspect from the base of the trigonum vagi there is a translucent cord-like ridge called the **funiculus separans**.

When the floor of the ventricle is examined under water with a magnifying glass, the trigonum hypoglossi is seen to consist of a narrow medial strip which corresponds to the hypoglossal nucleus, and a wider lateral part which has been shown to be the surface representation of another nucleus termed the **nucleus intercalatus**.

On the part of the floor of the ventricle which lies above the striæ medullares, and corresponds to the dorsal surface of the pons, there is also a slight depression, termed the **fovea superior**. Between it and the median groove is a marked prominence called the **eminentia medialis**. Inferiorly this elevation passes downwards and becomes continuous with the trigonum hypoglossi, whilst superiorly it is carried upwards towards the opening of the aquæductus cerebri. In both directions it gradually becomes less prominent, but still it forms a distinct elongated elevation, which stretches alongside the whole length of the median groove. As already stated, the **area acustica** extends upwards into the pontine part of the ventricular floor and forms an elevated region in the most lateral part of its widest portion, below and to the lateral side of the fovea superior. Proceeding upwards from the fovea superior to the opening of the aquæductus cerebri there is a shallow depression termed the **locus cœruleus**, seeing that it usually presents a faint slate-blue colour. When the ependyma is scraped away from the surface of this part of the floor, the colour is seen to be due to the **substantia ferruginea**,—a name applied to a linear group of strongly pigmented cells, which lies in the lateral part of the gray matter covering this portion of the ventricular floor. When transverse sections are made through the superior part of the pons, the substantia ferruginea appears on the cut surface as a small black spot or dot.

INTERNAL STRUCTURE OF MEDULLA OBLONGATA AND PONS.

The structure of the medulla oblongata and pons differs in a marked degree from that of the spinal medulla: indeed, in its superior part, it presents very little in common with the latter. Some of the largest fasciculi which come up from the spinal medulla (such as the funiculus posterior) end in the lower part of the medulla oblongata; others leave the medulla oblongata and pass into the cerebellum; and of the bundles of fibres which pass upwards or downwards, from or to the spinal medulla respectively, most of them come to occupy very different positions in the medulla oblongata and pons.

The gray matter, instead of being moulded into one compact column, as is the case in the spinal medulla, becomes broken up into a series of discrete nuclei. Thus, there are developed from the basal lamina of the rhombencephalon not one compact mass like the spinal anterior column, but three distinct broken columns of efferent nuclei (Fig. 452, p. 544):—(1) a **medial somatic column**, which in turn is broken up into two parts, a bulbar nucleus (*the hypoglossal*) which supplies the motor fibres to the tongue muscles, and a pontine nucleus (*the abducens*) which supplies the lateral rectus muscle of the eye; (2) a **lateral somatic column**, broken up into separate nuclei, viz., *accessorius, ambiguus, facial*, and *trigeminal*, supplying the sterno-mastoid and trapezius muscles and the striated muscles of the larynx, pharynx, and face and those concerned with mastication; and (3) a **splanchnic column** of nuclei, giving efferent fibres which pass out in the vagus, glossopharyngeal, and facial nerves, to be widely distributed to unstriped muscle, glands, and other tissues in the head, neck, thorax, and abdomen.

Further, the terminal nuclei of the sensory nerves which are developed in the alar lamina of the rhombencephalon do not unite to form a definite posterior column, as happens in the spinal medulla, but form discrete masses; and as these act as receptive organs for a much greater variety of sensory nerves than are represented in the spinal nerves there is a much greater number of nuclei than would be formed if the various components of the posterior column in the spinal medulla were dissociated. Thus, there are terminal nuclei in the medulla oblongata not only for the ordinary cutaneous nerves, but also for nerves coming from the mucous membranes of the alimentary and respiratory organs, as well as from other visceral structures; and there are also special nerves of taste (nervus intermedius and glossopharyngeal), of hearing (cochlear part of the acoustic), and of equilibration (vestibular part of the acoustic). But this does not exhaust the peculiar features of the terminal sensory nuclei of the rhombencephalon. In the description of the spinal medulla attention was called to the fact that certain of the fibres of the posterior nerve-root did not end in the gray matter of the spinal medulla, but passed upwards throughout the whole length (above their points of entry) of the funiculus posterior to reach the medulla oblongata. Special terminal nuclei are developed from the alar lamina to receive these fibres. They are the nucleus gracilis and nucleus cuneatus.

In addition, part of the terminal vestibular nucleus receives accessions of fibres from these (gracile and cuneate) nuclei as well as from other sensory terminal nuclei in the spinal medulla and develops into that great mass of tissue, the cerebellum, to which vast numbers of other fibres come and go, adding considerably to the complexity of the region of the pons and medulla oblongata. Moreover, there is developed from the alar lamina a whole series of other masses of gray matter—the **nucleus olivaris inferior, nuclei arcuati, nucleus pontobulbaris**, and **nuclei pontis**—as links in the complex chains that bind all parts of the central nervous system to the great co-ordinating mechanism of the cerebellum.

Thus it comes about that, instead of having, as in the spinal medulla, a definite column of gray matter ensheathed in a thick mass of white substance, the rhombencephalon is composed of many scattered masses of gray matter; and its white substance is represented partly by great longitudinal strands, but also by many great systems of fibres passing transversely through its substance, or upon its surface, *e.g.*, the superficial fibres of the pons and many of the arcuate fibres.

From what has already been said concerning the external form of the medulla oblongata and pons it will be apparent that the distortion of the neural tube which occurred as the result of the pontine flexure has also been largely responsible for the distinctive features of this region of the brain.

As the pontine flexure develops, a strain is thrown upon the thin roof-plate, which yields and becomes stretched so as to permit the thick lateral walls of the neural tube to fall laterally (Figs. 457 and 458). One result of this process is the great lateral expansion of the cavity of the hind-brain, which assumes the characteristic rhomboid form. If the thin and greatly attenuated epithelial roof is torn away from the rhombencephalon of an embryo of the third month the fourth ventricle will present the appearance (viewed from behind) shown in Fig. 457. The ventricle is seen to be prolonged laterally, on each side, to form a little recess upon the lateral aspect of the rhombencephalon. This is called the **recessus lateralis**.

This thin epithelial roof becomes invaginated towards the cavity of the fourth ventricle, on each side of the median plane, in the whole length of the epithelial roof, *i.e.* from the cerebellar attachment, above, almost as far as the closed part of the medulla oblongata below (Fig. 451). The upper end of this invaginated fold becomes prolonged laterally as far as the extremity of the recessus lateralis (Fig. 497). Pia mater and blood-vessels extend into these folds, which are then known as the **chorioid plexuses** of the fourth ventricle. At the extremities of these two plexuses, which are situated at the three corners of the epithelial roof of the ventricle, oval or elliptical perforations develop in the roof at about the fifth month of fœtal life. These are known as the **apertura medialis ventriculi quarti** (O.T. **foramen of Magendie**), which opens between the clavæ on the posterior surface and the **aperturæ laterales** upon the anterior faces of the lateral recesses (Fig. 478), behind the insertion of the glossopharyngeal nerve on each side. Through each of these lateral openings the great swollen cauliflower-like extremity of the chorioid plexus becomes extruded from the ventricle. The inferior extremities of the two plexuses lying side by side present an analogous relationship to the apertura medialis, but they are exceedingly attenuated and the epithelial lamella from which they spring becomes dragged backwards into contact with the cerebellum (Fig. 451), so that, when seen from below, the apertura medialis is a great funnel-shaped tube leading into the fourth ventricle and the chorioid plexuses look like two delicate vascular fringes on the cerebellum.

These three apertures are the only means provided for the escape of the fluid contained in the ventricles of the central nervous system. The fluid is poured into a space, enclosed by the arachnoid, which is called the subarachnoid space.

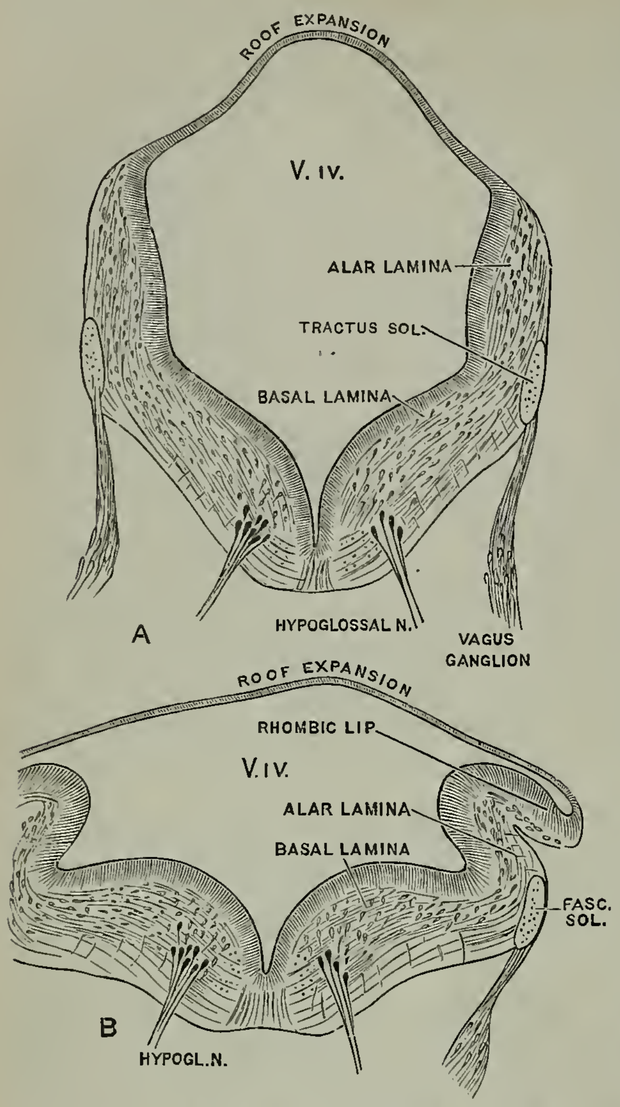

Fig. 457. — Transverse Sections across the Medulla Oblongata in two Human Embryos, representing Different Stages in the Expansion of the Roof and the falling laterally of the Side Walls. (From His, slightly modified.)

As a result of the pontine flexure the side walls of the neural tube in the neighbourhood of the bend fall away the one from the other and eventually come to be placed in the same transverse plane, one with the other and also with the floor-plate. At the time this process is in operation (see Fig. 457) the alar and basal laminæ are particularly well defined, and the limiting sulci are accentuated by the bending of the side wall; but this sharp distinction is soon lost as the result of the great expansion of the basal lamina (Fig. 459). This is due not only to growth of its intrinsic elements, but even more to its invasion by large numbers of neuroblasts which migrate from the alar into the basal lamina.

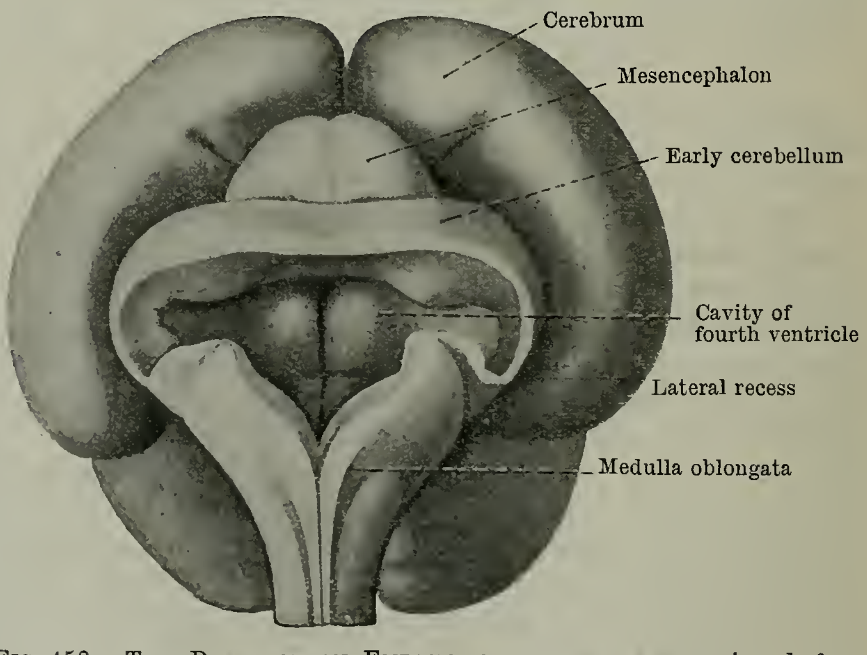

Fig. 458.—The Brain of an Embryo of eleven weeks, viewed from behind. The epithelial roof of the fourth ventricle has been removed. At this stage the cerebellum is in the form of a simple band or plate which arches over the posterior aspect of the anterior part of the cavity of the hind-brain. (From His.)

Later still, the development of the great sensory and motor tracts contributes largely to the dimensions of the basal lamina.

As the two basal laminæ (one on each side of the median plane) increase in thickness the epithelial cells in the intervening floor-plate become stretched and lengthened (Fig. 457), so that a definite septum or **raphe** is formed between the two halves of the rhombencephalon.

The fate of the extreme posterior edge of the alar lamina is very interesting. The nervus acusticus is inserted into this edge in the region of the recessus lateralis, and from it masses of neuroblasts develop to form receptive nuclei for the two parts of this nerve, these being the cochlear and vestibular. These are the **nucleus cochlearis** and **nucleus vestibularis** respectively. Sensory fasciculi, bringing impulses from muscles, skin and related structures in all parts of the body, make their way into the superior part of the vestibular nucleus, and it grows and forms a large thickening of the posterior edge above the recessus lateralis. Eventually, as it extends medially (Fig. 458), it reaches and invades the roof-plate and fuses with the corresponding rudiment of the other side. Thus a semilunar band, the primitive cerebellum, is formed, arching across the posterior aspect of the metencephalon. The part of the dorsal edge which lies below the vestibular nucleus becomes bent over (forwards) to form what is known as the **rhombic lip** (Fig. 457). It is destined to be transformed into a series of masses of gray matter, the chief function of which is to emit fibres to carry impulses into the cerebellum. But most of these fibres pass not so much to the part of the cerebellum derived from their own side as to that of the opposite side. Thus, from above downwards, the thickened margin of the fossa rhomboidea on each side develops into the following structures:—cerebellum, the rest of the vestibular nucleus, the cochlear nucleus, the nuclei pontis (and arcuate nuclei), the olivary nucleus, the nucleus gracilis and the nucleus cuneatus. At an early stage of development most of the neuroblasts that form the rudiments of the nuclei pontis, nuclei arcuati, and nucleus olivaris inferior begin a process of migration, the course of which is determined by the source and direction of the afferent tracts passing into each nucleus. Such migrations are of common occurrence throughout the brain, and attempts to explain them have given rise to much discussion. The factor that appears to lead certain nerve-cells away from the place where they originally developed has been called *neurobiotaxis* by Ariëns-Kappers. But the solution of the problems of these apparent migrations is quite a simple one. Take the case of a nerve-cell (*A*), at an early stage of development, which collects afferent impulses through its dendrites from the cell *B*, and emits an efferent impulse through its axon to the cell *C*: as the whole nervous system is very small at the stage under consideration, the three cells will necessarily be close the one to the other—a fact which may be represented by the positions of the letters thus:—

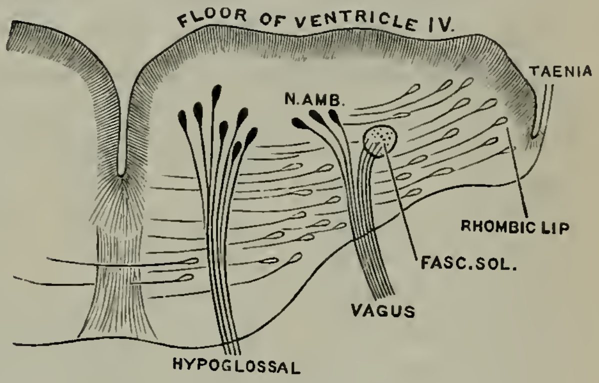

Fig. 459.—Transverse Section of the Human Embryo at a Later Stage than those shown in Fig. 457. (After His.)

B—A—C.

In the course of subsequent growth it must inevitably happen that the points *B* and *C* will become removed further and further apart. If we suppose that the cell *B* remains constant, the cell *A* will be faced with two alternatives if it is to continue to link together the elements *B* and *C*: either its dendrites or its axon must elongate. Now the axon is specially modified in structure for conducting impulses for long distances, and the dendrites are not so specialised. Therefore it invariably happens that it is the axon that becomes lengthened. In other words the cell-body *A*, considered in its relations to *C*, appears to migrate towards the direction *B* from which its chief supply of afferent impulses comes. This may be represented thus:—

B—A————————————*C.*

In the specific case we are considering the vestibular nucleus and the cerebellum receive their chief supply of afferent fibres from the incoming vestibular nerve: hence there is no reason for migration. Similarly the nucleus gracilis and nucleus cuneatus receive the fibres which come up through the funiculus posterior and remain where they are. But the nuclei pontis, the olivary nucleus, and the arcuate nuclei are "fed" with impulses passing downwards (and some perhaps upwards) in the basal lamina, close to the median plane, and they "migrate" towards the direction from which their afferent paths are approaching; the nuclei pontis towards the peduncles of the cerebrum bringing cerebro-pontine fibres from the cerebral cortex, and the olivary nucleus to the neighbourhood of certain descending tegmental tracts and ascending spinal sensory tracts that seem to supply the attractive force which leads them to forsake the rhombic lip of the alar lamina and migrate into the basal lamina.

The majority of the cells destined to form the nuclei pontis wander obliquely upwards and forwards between the facial and acoustic nerves to reach the basal lamina of the metencephalon. But strewn along this pathway from the edge of the fossa rhomboidea to the front of the pons are scattered nerve-cells which have, so to speak, fallen by the way, and remain to indicate in the adult brain the path taken by the majority of their sister cells. This remnant forms the **corpus ponto-bulbare**: the pontine fibres that spring from its cells and are making their way upwards to fall in line (Fig. 469, p. 566) with the other transverse fibres of the pons form the **fasciculus obliquus** [pontis], and the cerebro-pontine fibres that pass below the pons in order to reach this outlying part (corpus ponto-bulbare) of the nuclei pontis constitute the **fasciculus circumolivaris pyramidis** (Fig. 488, p. 582).

But not all of the elements of the nuclei pontis that migrate pass into the metencephalon; a certain proportion of them invariably pass into the myelencephalon. These collect upon the anterior surface of the pyramids to form small irregular patches of gray matter which have received the name **nuclei arcuati.** Their afferent fibres (probably cerebro-pontine) come from the pyramids; and their efferent fibres (which proceed to the cerebellum) form some of the **fibræ arcuatæ externæ**, which are visible upon the surface of the medulla oblongata (Fig. 463).

Olivary Nuclei.—The most conspicuous of the isolated clumps of gray matter in the medulla are the inferior olivary nucleus and the two accessory olivary nuclei. The **nucleus olivaris inferior** is the mass of gray substance which produces the swelling known as the olive, and constitutes a very striking object in transverse sections through this region. It presents the appearance of a thick wavy or undulating line of gray matter, folded on itself, so as to enclose a space filled with white matter. It is in reality a crumpled lamina arranged in a purse-like manner, with an open mouth or slit, which is called the **hilum** (hilus nuclei olivaris), directed towards the median plane. The hilum does not reach either extremity, so that in transverse sections through either end of the nucleus the gray lamina is seen in the form of a completely closed capsule. Into and out of the open mouth of the olivary capsule streams a dense crowd of fibres. These constitute what is called the **olivary peduncle.**

The **accessory olivary nuclei** are two band-like laminæ of gray matter, which are respectively placed on the dorsal and medial aspects of the main nucleus. In transverse section each of these nuclei presents a rod-like appearance (Fig. 461).

The **medial accessory olivary nucleus** extends lower down in the medulla oblongata than the main nucleus, and it is much larger in its lower than in its upper part. It begins immediately above the decussation of the pyramids, where it is seen lying on the lateral side of the cerebro-spinal fasciculus and the lemniscus medialis (Fig. 466). Higher up it lies across the mouth of the main nucleus and on the lateral side of the medial lemniscus. The **dorsal accessory olivary nucleus** is placed close to the dorsal aspect of the main nucleus. The two accessory nuclei fuse together before they finally disappear.

The nerve-cells of the inferior olivary nucleus are small and round, and emit a large series of short radiating, complexly branched dendrites, so that the cell-body seems to lie in the centre of a spherical mass formed by its own dendrites and an almost equally complex mass of intertwined end branches of the axons which bring impulses into these cells. There is no definite information as to the place of origin of these afferent fibres. Flechsig and Bechterew, using different methods of investigation, have demonstrated the presence of a large descending tract in the mesencephalon and rhombencephalon, which ends amidst the cells of the lateral pole of the olivary nucleus. This has been called the *fasciculus thalamo-olivaris*, but it is not quite certain that it arises in the thalamus, although its origin must be somewhere in the neighbourhood of it. Flechsig denies that any fibres reach the olivary nucleus from the spinal medulla, but the proximity of the spino-thalamic and bulbo-thalamic (lemniscus medialis) fibres and the demonstration of Ramon y Cajal that fibres enter the nucleus olivaris from adjoining fasciculi in these regions suggest that there may be a spinal afferent path.

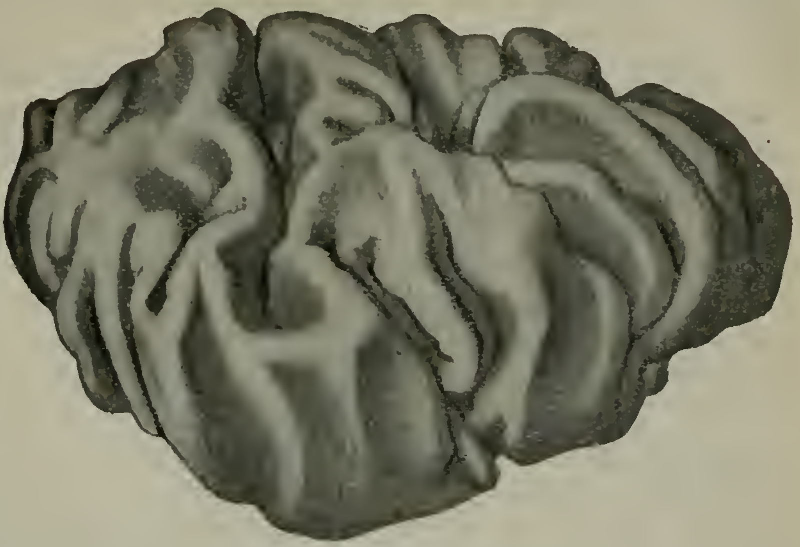

Fig. 460.—The Inferior Olivary Nucleus, as reconstructed and figured by Florence R. Sabin.

View of the dorso-lateral and lateral surfaces.

There seems to be a direct relationship between the size of the inferior olivary nucleus and the extent of the cortical area that presides over highly skilled movements.

The axons emitted by the cells of the olivary nucleus cross the median raphe and pass through the opposite side of the medulla oblongata as internal arcuate fibres, which enter the restiform body and pass into the cerebellum.[1]

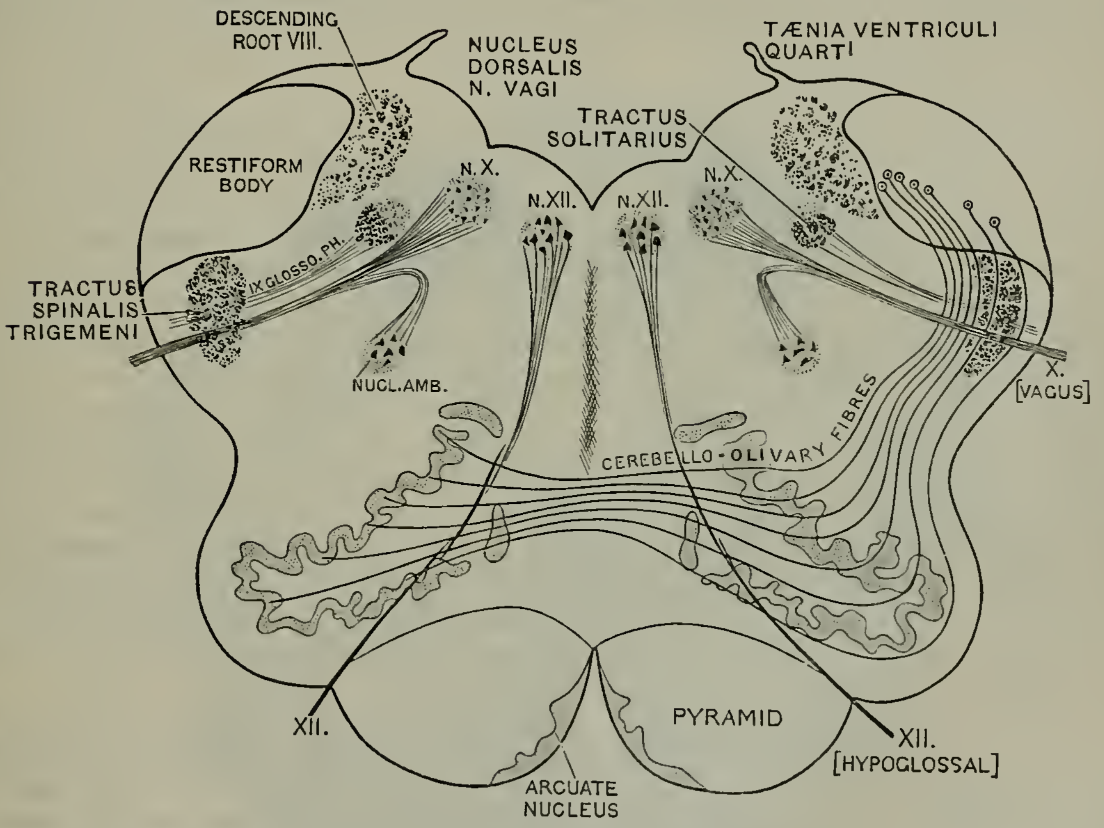

Fig. 461.—Diagram of the Fasciculus Olivocerebellaris (Cerebello-Olivary Fibres).

N.X., Vago-glossopharyngeal nucleus. N.XII., Hypoglossal nucleus.

These fibres are seen only in the superior part of the medulla oblongata. They form the deep part of the restiform body and constitute its chief bulk. Streaming out from the hilum of the inferior olivary nucleus, they cross the median plane, and in the opposite side of the medulla oblongata they either pass through the inferior olivary nucleus of that side or sweep round it. Ultimately, on the dorsal aspect of the olivary nucleus, they are gathered together in the form of a conspicuous group of arcuate fibres, which curve backwards to take up a position in the deep part of the restiform body. In passing back, they traverse the tractus spinalis of the trigeminal nerve and break it up into several separate bundles. The olivo-cerebellar fibres thus connect the inferior olivary nucleus of one side with the opposite side of the cerebellum. Each part of the inferior olivary nucleus is connected with a definite part of the cerebellum.

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[1] These fibres should be called the *fasciculus olivocerebellaris*, by which designation they will be referred to in this account, but in the recognised nomenclature (which most writers do not follow in this instance) the tract is called "*cerebello-olivaris*."

Decussation of the Pyramids and the Changes produced thereby.—As we examine, under the microscope, a series of successive transverse sections through the inferior end of the medulla oblongata and the upper end of the spinal medulla, the most striking change which meets the eye is the decussation of the lateral cerebro-spinal tracts. From their position alongside the anterior median fissure of the medulla oblongata most of the fibres of the pyramid cross the median plane and, after passing through the anterior column of gray matter, bend downwards in the lateral funiculus of the opposite side of the spinal medulla. Strands from the right lateral cerebro-spinal tract alternate with corresponding strands from the left side, and the interval between the bottom of the anterior median furrow and the gray matter surrounding the central canal becomes filled up with a great mass of inter-crossing bundles of fibres.

As a rule the medial three-fourths of the pyramid are composed of fibres which, lower down in the opposite lateral funiculus of the spinal medulla, form the fasciculus cerebrospinalis, whilst the lateral fourth of the pyramid proceeds downwards in the anterior funiculus of the spinal medulla of the same side, as the fasciculus cerebrospinalis anterior. A considerable amount of variation, however, occurs in the proportion of fibres which is allotted to the formation of these two tracts. Sometimes the lateral cerebro-spinal tract is much larger than usual, and then the anterior cerebro-spinal tract suffers a corresponding diminution in size. Cases, indeed, occur in which the entire pyramid enters into the decussation, and in these there is no anterior cerebro-spinal tract. Further, it is not uncommon to meet with variations of an opposite kind which lead to an increase of the anterior cerebro-spinal tract at the expense of the lateral cerebro-spinal tract. Sometimes the decussation is asymmetrical, and the corresponding cerebro-spinal tracts on opposite sides of the spinal medulla are then unequal in size. One factor that often comes into play and causes asymmetry is the prolongation downwards into the pyramid on one side (usually the left) of some of the cerebro-pontine fibres. In such cases these fibres soon leave the pyramid and form the **fasciculus circumolivaris.**

The variations indicated above receive an additional interest when viewed in the light of comparative anatomy. It would appear that only in man and the anthropoid apes is the decussation of the pyramids in the inferior part of the medulla oblongata incomplete. According to Sherrington, an anterior cerebro-spinal tract in the spinal medulla of the anthropoid apes stands in connexion with the arm-centre in the cerebral cortex. If this is the case in man it must have other connexions as well, seeing that it is carried down the spinal medulla for a considerable distance beyond the level of the spinal segments which give motor fibres to the upper limb. In the lower apes an anterior cerebro-spinal tract does not seem to exist: the whole pyramid crosses over to the opposite side of the spinal medulla in the shape of the lateral cerebro-spinal tract.

As we have noted, the decussating pyramidal bundles pass through the anterior column of gray matter, and cut it into two portions (Fig. 462). The basal part remains in position on the anterior and lateral aspect of the central canal, and forms part of the thick layer of gray matter which surrounds it. The detached head of the anterior column is set free; and from the large multipolar cells which lie in its midst some of the fibres of the anterior root of the first cervical nerve, and also some of the root fibres of the accessory nerve, take origin.

As we proceed into the medulla oblongata another effect of the decussation of the pyramids is seen in the submergence from the surface of the strand of fibres which, in the anterior funiculus of the spinal medulla, lies to the lateral side of the anterior cerebro-spinal tract, and which receives the name of the fasciculus anterior proprius. While the decussation is going on the fasciculus proprius is thrust aside, and in the medulla oblongata it takes up its position as a flattened band-like strand on the lateral side of the pyramid (Fig. 462). When the decussation is completed, this strand is seen to lie close to the median plane on the dorsal aspect of the pyramid, where it is separated from its fellow of the opposite side by the median raphe alone (Fig. 463). In the upper part of the medulla oblongata it approaches still nearer to the dorsal surface and appears to form the greater part of a strand, which is termed the **medial longitudinal bundle** (Figs. 465 and 466). The detached head of the anterior column of gray matter of the spinal medulla, as it is traced upwards, is observed to cling closely to its original relationship with the fasciculus anterior proprius. It is applied to the lateral side of this strand, and, gradually becoming smaller, finally disappears at the level of the inferior part of the inferior olivary nucleus.

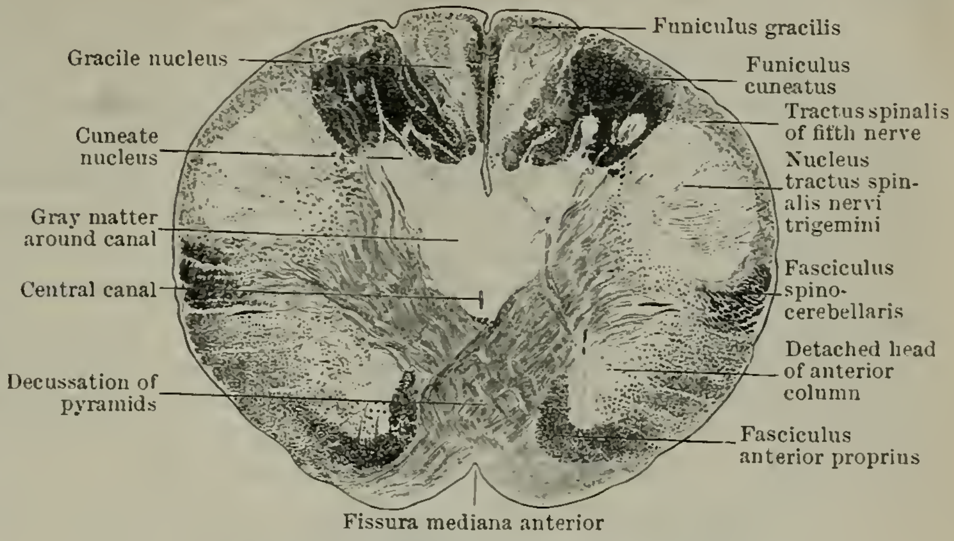
Funiculus gracilis
Gracile nucleus
Funiculus cuneatus
Tractus spinalis of fifth nerve
Cuneate nucleus
Nucleus tractus spinalis nervi trigemini
Gray matter around canal
Central canal
Fasciculus spino-cerebellaris
Detached head of anterior column
Decussation of pyramids
Fasciculus anterior proprius
Fissura mediana anterior

Fig. 462.—Transverse Section through the Inferior End of the Medulla Oblongata of a full-time Fœtus.

Treated by the Weigert-Pal method. The gray matter is bleached white, and the medullated tracts of fibres are black.

Cuneate and Gracile Fasciculi, with their Nuclei.—As the fasciculus gracilis and the fasciculus cuneatus of the posterior funiculus of the spinal medulla are traced up into the medulla oblongata they seem to increase in bulk, and in transverse sections they assume the form of massive wedge-shaped strands, quite distinct from each other. They increase in width and lose considerably in depth,

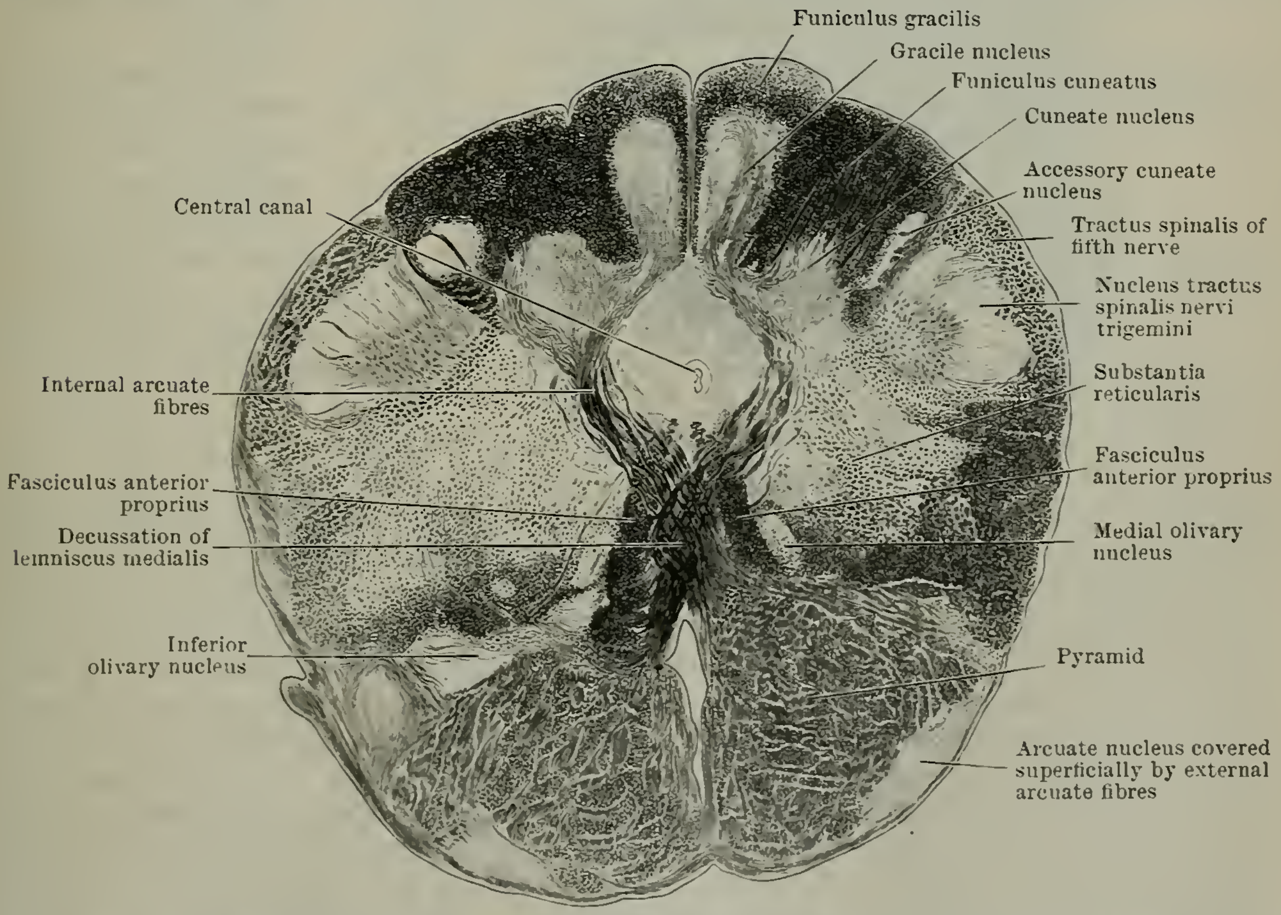
Funiculus gracilis
Gracile nucleus
Funiculus cuneatus
Cuneate nucleus
Accessory cuneate nucleus
Central canal
Tractus spinalis of fifth nerve
Nucleus tractus spinalis nervi trigemini
Internal arcuate fibres
Substantia reticularis
Fasciculus anterior proprius
Fasciculus anterior proprius
Decussation of lemniscus medialis
Medial olivary nucleus
Inferior olivary nucleus
Pyramid
Arcuate nucleus covered superficially by external arcuate fibres

Fig. 463.—Section through the Closed Part of the Adult Medulla Oblongata immediately above the Decussation of the Pyramids (Weigert-Pal specimen).

and consequently the transverse diameter of the area which they occupy becomes greater. As a result of this, and also owing to the removal of the lateral cerebro-spinal tract from the lateral funiculus of the spinal medulla immediately in front, the posterior column of gray matter is gradually rotated forwards and comes to lie transversely and in the same straight line with its fellow of the opposite side (Figs. 462 and 463). The substantia gelatinosa, at the same time, becomes increased in quantity and presents a horseshoe-shaped outline in transverse section. It clasps within its concavity the somewhat reduced head of the posterior column, and forms with it a conspicuous circular mass of gray matter which lies close to the surface, and produces upon it the bulging termed the tuberculum cinereum. The basal portion of the posterior column of gray matter remains upon the dorsal and lateral aspect of the central canal, and forms a portion of the central gray mass of the closed part of the medulla oblongata; but very soon the neck of the column, which at this level is greatly reduced owing to the absence of entering posterior nerve-roots, is invaded by bundles of fibres which traverse it in different directions and convert it into a formatio reticularis. By this means the rounded head of the posterior column becomes cut off from the central gray matter, and from this point upwards it remains as an isolated gray column intimately associated with the spinal root of the trigeminal nerve. It has, in fact, become the **nucleus tractus spinalis nervi trigemini.**

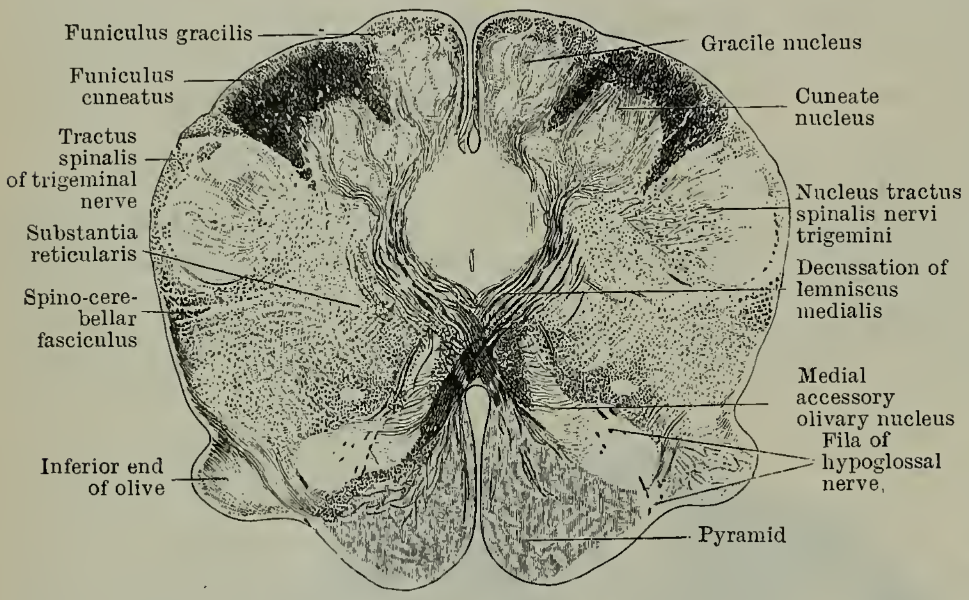
Funiculus gracilis
Funiculus cuneatus
Tractus spinalis of trigeminal nerve
Substantia reticularis
Spino-cerebellar fasciculus
Inferior end of olive
Gracile nucleus
Cuneate nucleus
Nucleus tractus spinalis nervi trigemini
Decussation of lemniscus medialis
Medial accessory olivary nucleus
Fila of hypoglossal nerve,
Pyramid

FIG. 464.—TRANSVERSE SECTION THROUGH THE CLOSED PART OF A FŒTAL MEDULLA OBLONGATA, IMMEDIATELY ABOVE THE DECUSSATION OF THE PYRAMIDS. Treated by Weigert-Pal method.

The **gracile** and **cuneate nuclei** are seen in their most typical form in sections at the level of the decussation of the pyramids (Figs. 463 and 464). The **gracile nucleus** appears in the form of a relatively slender mass of gray matter in the interior of the funiculus gracilis.

The **cuneate nucleus** is a direct offshoot from that part of the base of the posterior column of gray matter which is preserved as a portion of the central gray mass. In transverse section it is seen to invade the funiculus cuneatus upon its deep aspect, and it gradually grows backwards into its substance. It presents a very different appearance from the gracile nucleus, because throughout its whole length the gray nucleus and the fibres of the strand are separated from each other by a sharp line of demarcation. A little higher up, a second and much smaller mass of gray matter appears in the funiculus cuneatus, superficial to the main nucleus. This is termed the **accessory** or the **lateral cuneate nucleus** (Fig. 463).

As a series of sections is studied from below upwards, it will be noticed that the number of fibres in the gracile and cuneate funiculi rapidly decreases, until, at the level of the clava and cuneate tubercles, it is seen that these eminences are composed almost entirely of the gray nuclei, covered by a thin layer of the few remaining fibres of the two fasciculi involved. It would appear that no fibres belonging to the funiculus gracilis and funiculus cuneatus get beyond these nuclei. They all end in fine terminal ramifications around the cells of the nuclei. In the case of the funiculus cuneatus the bundles of fibres, as they pass from the surface into the subjacent gray nucleus, are very distinctly seen in transverse sections through the bulb.

When the medulla oblongata opens up into the fourth ventricle the gracile and cuneate nuclei are pushed laterally by the expanding ventricular floor, and the gracile nucleus soon comes to an end; but the cuneate nucleus extends upwards for a short distance farther, and terminates only when the restiform body begins to take definite shape on its lateral aspect.

Decussatio Lemniscorum.—Immediately above the level of the decussation of the pyramids another decussation of fibres takes place in the substance of the medulla oblongata in the median plane, and upon the dorsal aspect of the pyramids. This is the **decussation of the lemniscus medialis**, or the **sensory decussation**, so called in contradistinction to the term "motor decussation," which is sometimes applied to the decussation of the pyramids. The fibres which take part in this decussation are called **internal arcuate fibres**, and they are derived from the cells of the gracile and cuneate nuclei. From the deep aspects of these nuclei these fibres stream forwards and medially towards the median raphe, forming a series of concentric curves in the substance of the medulla oblongata. They cross the median plane and decussate with the corresponding fibres of the opposite side, upon the dorsal aspect of the pyramids. Having thus gained the opposite side of the medulla oblongata, they immediately turn upwards and form a conspicuous strand of longitudinal fibres, which ascends close to the median plane and is separated from its fellow of the opposite side by the median raphe alone. This strand is termed the **lemniscus medialis**.

As we proceed up the medulla oblongata internal arcuate fibres which first come into sight appear as coarse bundles which curve forwards in a narrow group round the central gray matter (Figs. 465 and 466). Soon, other finer bundles appear, which describe wider curves on the lateral side of the coarser group, until a very large part of each half of the medulla is seen to be traversed by these arcuate fasciculi (Fig. 466). The internal arcuate fibres decussate in the median plane with the internal arcuate fibres of the opposite side. They then change their direction and turn upwards, and the lemniscus, as already stated, takes form and gradually increases in volume as it ascends. This great and important tract is thus laid down between the pyramid and the **fasciculus longitudinalis medialis**; and the consequence of this is that the latter tract is pushed still farther backwards, and, when the lemniscus is fully established, it comes to lie immediately beneath the gray matter of the floor of the fourth ventricle (Fig. 466). But the lemniscus is not in direct contact with the fasciculus longitudinalis, for a bundle of fibres, the continuation of which has been seen in the anterior funiculus of the medulla spinalis, the **fasciculus tectospinalis**, separates them, as well as fibres coming from sensory nuclei of the cerebral nerves which are crossing the raphe to join the medial lemniscus (Fig. 466).

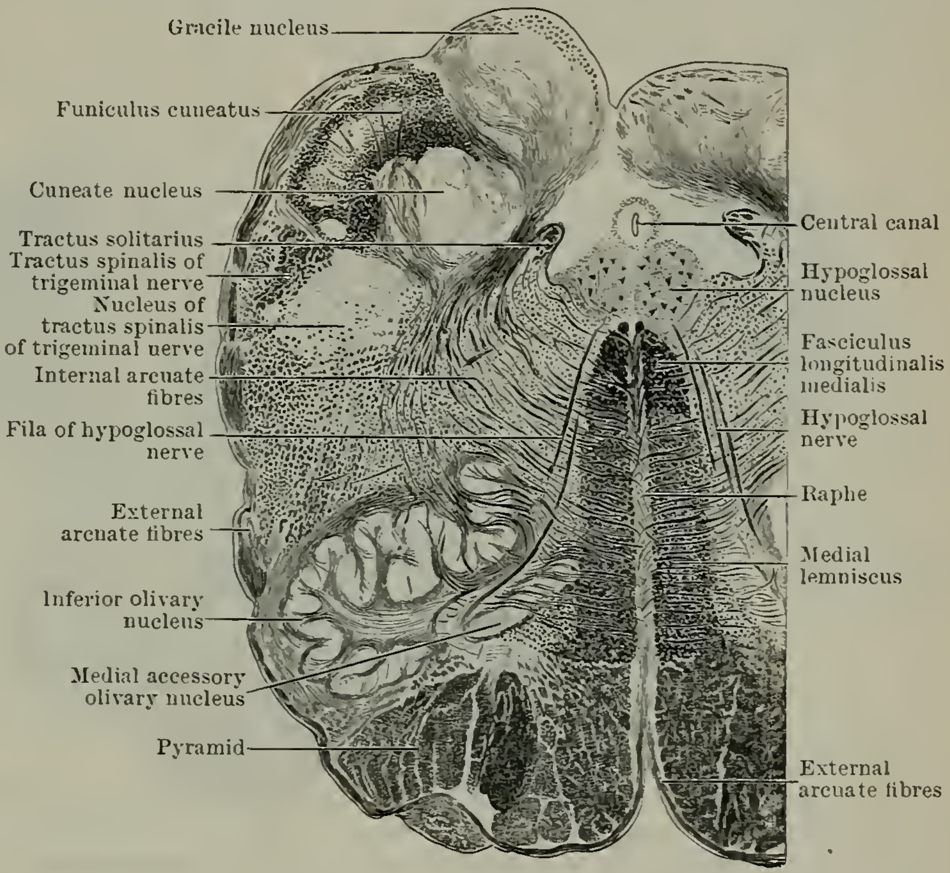

FIG. 465.—TRANSVERSE SECTION THROUGH THE MEDULLA OBLONGATA IN THE INFERIOR OLIVARY REGION.

It is important that we should realise at this stage the full significance of the decussation of the lemniscus and have a clear conception of the connexions of the fibres which take part in it. The funiculus posterior, which ends in the cuneate and gracile nuclei, is derived from the posterior roots of the spinal nerves. The lemniscus fibres therefore carry on the continuity of part of the posterior funiculus, the gracile and cuneate nuclei, which are thrown across its path in the lower part of the medulla oblongata, constituting merely a nodal interruption. At this point the lemniscus is transferred to the opposite side of the medulla oblongata. But it will be remembered that a large proportion of the fibres of the entering posterior nerve-roots of the spinal nerves end in connexion with the cells of the posterior column of gray matter of the spinal medulla. It must not be supposed that the path represented by these latter fibres comes to a termination thereby; from these posterior column cells other fibres arise which cross, in the anterior white commissure, to the opposite side of the spinal medulla and proceed up the spinal medulla to the lateral part of the medulla oblongata. These fibres constitute the **spino-thalamic tract** already referred to. *The practical bearing of this is that, owing to the crossing of the lemniscus medialis and lower down of the spino-thalamic tract, unilateral lesions of the medulla oblongata are apt to produce complete hemi-anæsthesia; whilst unilateral lesions of the spinal medulla produce only partial hemi-anæsthesia.*

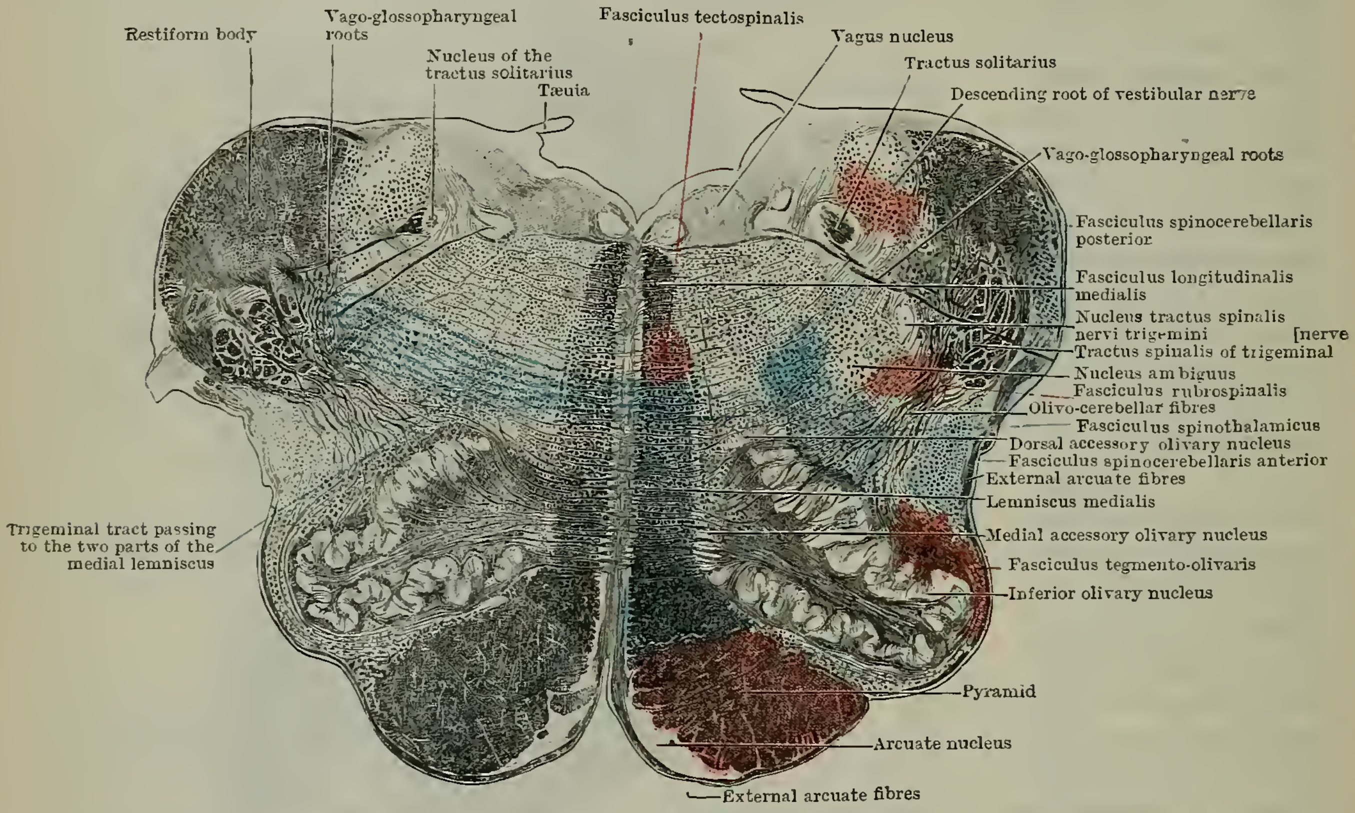
Restiform body
Vago-glossopharyngeal roots
Nucleus of the tractus solitarius
Tænia
Fasciculus tectospinalis
Vagus nucleus
Tractus solitarius
Descending root of vestibular nerve
Vago-glossopharyngeal roots
Fasciculus spinocerebellaris posterior
Fasciculus longitudinalis medialis
Nucleus tractus spinalis nervi trigemini
Tractus spinalis of trigeminal nerve
Nucleus ambiguus
Fasciculus rubrospinalis
Olivo-cerebellar fibres
Fasciculus spinothalamicus
Dorsal accessory olivary nucleus
Fasciculus spinocerebellaris anterior
External arcuate fibres
Lemniscus medialis
Trigeminal tract passing to the two parts of the medial lemniscus
Medial accessory olivary nucleus
Fasciculus tegmento-olivaris
Inferior olivary nucleus
Pyramid
Arcuate nucleus
External arcuate fibres

FIG. 466.—TRANSVERSE SECTION THROUGH THE MIDDLE OF THE OLIVARY REGION OF THE MEDULLA OBLONGATA.

The floor of the fourth ventricle is seen, and it will be noticed that the restiform body on each side has now taken definite shape. Some of the descending tracts in red; ascending tracts in blue.

The pyramid forms a massive tract in front of and quite distinct from the lemniscus medialis. The lemniscus medialis, the tecto-spinal bundle, and the medial longitudinal bundle are, in the first instance, not marked off from each other. They appear as a broad flattened band applied to the raphe. One edge of this band is directed backwards and reaches the gray matter on the floor of the fourth ventricle, while the other edge looks forwards and is in contact with the pyramid. In the upper part of the medulla oblongata the lemniscus and the medial longitudinal fasciculus begin to draw asunder from each other. The intermediate longitudinal fibres become reduced in number and the two strands grow denser—the one on the dorsal aspect of the pyramid, and the other immediately beneath the gray matter of the floor of the fourth ventricle (Fig. 466).

The **fasciculus longitudinalis medialis** is largely formed of fibres homologous with those which in the spinal medulla constitute the fasciculus anterior proprius. As they are followed upwards these fibres are thrust back by the two decussations: the lower decussation pushing them behind the pyramids, and the upper decussation displacing them still farther backwards to a position behind the lemniscus medialis.

Corpus Restiforme.—The gracile and cuneate nuclei gradually give place to the **restiform body** in the superior part of the posterior district of the medulla oblongata. Fibres from various quarters converge to form this great strand. It first takes shape as a thin superficial layer of longitudinal fibres, which are gathered together on the lateral aspect of the cuneate nucleus; but after that nucleus has come to an end, and as the superior part of the medulla oblongata is reached, the restiform body is seen to have grown into a massive strand, which presents a kidney-shaped or oval outline on transverse section (Fig. 466); and it ultimately enters the white central core of the cerebellum as its inferior peduncle. The fibres which build up the restiform body are the following: (1) the fasciculus spinocerebellaris [posterior], (2) arcuate fibres coming from the nucleus gracilis and nucleus cuneatus of both sides of the medulla oblongata; (3) external arcuate fibres coming from the arcuate nuclei; and (4) olivo-cerebellar fibres.

The **fasciculus spinocerebellaris [posterior]** extends upwards from the lateral funiculus of the medulla spinalis. In the lateral district of the medulla oblongata it occupies a similar position; but before the olive is reached it inclines backwards, crosses the posterior lateral furrow and passes obliquely upwards into the restiform body. As its fibres diverge backwards, they pass over and cover up the tractus spinalis of the trigeminal nerve and its nucleus, thus shutting them out from the surface. The fibres of the fasciculus spinocerebellaris, in the first instance, enter into the lateral or superficial part of the restiform body.

Bruce has shown that the fibres of the spino-cerebellar tract ultimately lie in the centre of the restiform body, forming as it were its central core, and that, in the cerebellum, they can be traced to the superior vermis.

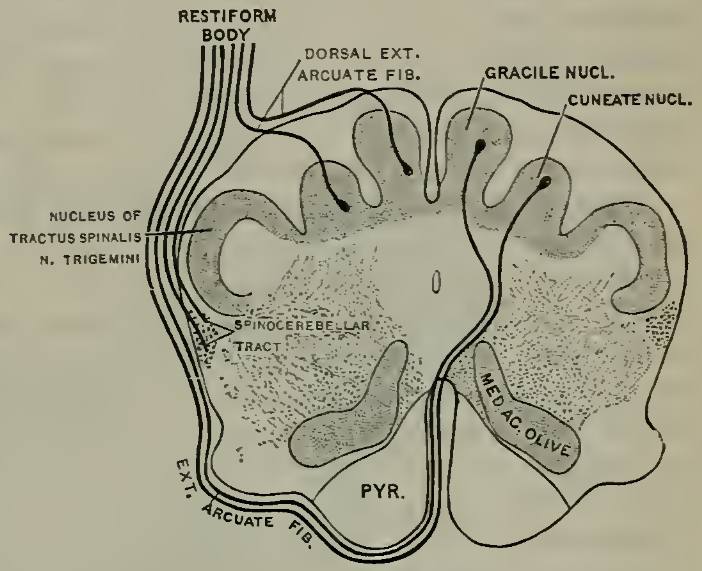

FIG. 467.—DIAGRAM, which shows in part the fibres which enter into the constitution of the restiform body.

The **posterior external arcuate fibres** take origin from the gracile and cuneate nuclei, and enter the superficial part of the restiform body of the same side.

The **anterior external arcuate fibres** proceed from the inferior portions of the gracile and cuneate nuclei of the opposite side. It can easily be determined that, after decussating in the median plane, all the internal arcuate fibres which arise from these nuclei do not enter the lemniscus medialis. A large proportion of them gain the surface by sweeping round the medial aspect of the pyramid in the anterior median fissure. Many of them gain the surface by piercing the pyramid or by passing out between it and the olive. These fibres constitute the anterior external arcuate group, and on the surface of the medulla oblongata they sweep backwards around it, forming a thin layer over the olive and ultimately reaching the restiform body. The anterior external arcuate fibres, as well as the spino-cerebellar tract-fibres, cover over the tractus spinalis of the trigeminal nerve, which thus comes to take up a deeper position in the substance of the medulla oblongata (Figs. 466 and 467).

The other elements in the restiform body, viz., those derived from the nucleus olivaris inferior and the nuclei arcuati, have already been described.

Thus, the restiform body conveys to the cerebellum (1) fibres conveying impulses from the posterior spinal roots of the same and also from the opposite side of the medulla spinalis, the former after being interrupted in the nucleus dorsalis and the nucleus gracilis and nucleus cuneatus of the same side, the latter in the nucleus gracilis and nucleus cuneatus of the other side; and (2) fibres from the olivary and arcuate nuclei, which convey impulses from the higher regions of the brain, directly or indirectly (probably the latter) from the motor area of the cerebral cortex.

Formatio Reticularis.—Behind the olive and the pyramid is the **formatio reticularis.** In the medulla oblongata it occupies a position which, to a large extent, corresponds with that of the lateral funiculus in the spinal medulla. In transverse section it appears as an extensive area, which is divided into a lateral and a medial field by the fila of the hypoglossal nerve as they traverse the substance of the medulla oblongata to reach the surface. In the lateral portion, which lies behind the olive, a considerable quantity of gray matter, continuous with that in the spinal medulla, is present in the reticular formation; it is therefore called the **formatio reticularis grisea.** In the medial part, which lies behind the pyramid, the gray matter is extremely scanty, and the reticular matter here is termed the **formatio reticularis alba.**

The nerve-fibres which traverse the formatio reticularis run both in a transverse and in a longitudinal direction. The **transverse fibres** are the internal arcuate fibres. The **longitudinal fibres** are derived from different sources in the two fields. In the formatio grisea they represent to a large extent the fibres of the lateral funiculus of the spinal medulla, after the removal of the posterior spino-cerebellar and the lateral cerebro-spinal tracts. They consist, therefore, of the fibres of the fasciculi rubrospinalis, thalamo-olivaris, spinothalamicus, and spinocerebellaris anterior (anterolateralis superficialis) of the spinal medulla. In the formatio alba the longitudinal fibres are the tract of the lemniscus medialis, the fasciculus tectospinalis, and the medial longitudinal bundle, all of which have already been described.

Central Canal and the Gray Matter which surrounds it.—The central canal, as it proceeds upwards through the closed part of the medulla, is gradually forced to assume a more dorsal position, owing to the accumulation of fibres on its ventral aspect. (Moreover, the posterior cleft-like part of the cavity of the fœtal neural tube, which becomes obliterated in the spinal medulla by the fusion of its walls, remains patent in the medulla oblongata. Hence the central canal in the closed part of the medulla oblongata extends backwards to the roof-plate.) First the decussation of the pyramids, and then the decussation of the medial lemniscus, both of which take place in front of the canal, tend to push it backwards; and the formation of the longitudinal strands in which these intercrossings result (viz., the pyramid and the medial lemniscus), together with the continuation upwards of the funiculus anterior proprius, leads to a great increase in the amount of tissue which separates it from the anterior surface of the medulla oblongata. In the closed part of the medulla oblongata the canal is surrounded by a thick layer of gray matter, which is continuous with the basal portions of the anterior and posterior columns of gray matter of the spinal medulla. This central gray matter is sharply defined on each side by the internal arcuate fibres, which curve forwards and medially around it. Finally, the central canal opens on the dorsal aspect of the medulla oblongata into the cavity of the fourth ventricle. The central mass of gray matter which surrounds the canal in the closed part of the medulla oblongata is now spread out in a thick layer on the floor of the fourth ventricle, and in such a manner that the portion which corresponds to the basal part of the anterior column of the spinal medulla is situated close to the median plane, whilst the part which represents the base of the posterior column occupies a more lateral position. This is important, because the nucleus of origin of the hypoglossal nerve is placed in the medial part of the floor, whilst the nuclei of termination of the afferent fibres of the vagus, glossopharyngeal, and acoustic nerves lie in the lateral part of the floor. The gray matter of the ventricular floor is covered with ependyma.

Three Areas of Flechsig.—In transverse sections, through the upper, open part of the medulla oblongata, the fila of the hypoglossal and vagus nerves are seen traversing the substance of the medulla oblongata. The nucleus of origin of the hypoglossal is placed in the gray matter of the floor of the fourth ventricle close to the median plane; the nucleus of the vagus is situated in the gray matter of the ventricular floor immediately to the lateral side of the hypoglossal nucleus. From these nuclei the root-bundles of the two nerves diverge from each other as they are traced to the surface and subdivide the substance of the medulla, as seen in transverse section, into the three areas of Flechsig, viz., an anterior, a lateral, and a posterior.

The **anterior area,** which is bounded medially by the median raphe and laterally by the hypoglossal roots, presents within its limits: (*a*) the pyramid; (*b*) the lemniscus medialis; (*c*) the fasciculus tectospinalis; (*d*) the medial longitudinal fasciculus; (*e*) the medial accessory olivary nucleus; (*f*) the arcuate nucleus.

The **lateral area** lies between the root fibres of the hypoglossal and those of the vagus. It contains: (*a*) the inferior olivary nucleus; (*b*) the dorsal accessory olivary nucleus; (*c*) the nucleus lateralis; (*d*) the nucleus ambiguus; (*e*) the splanchnic efferent nucleus of the vagus and glossopharyngeal nerves; (*f*) the formatio reticularis grisea.

The **posterior area** is situated behind the vagus roots, and within its limits are seen: (1) the restiform body; (2) the superior part of the cuneate nucleus; (3) to the medial side of this a crowd of transversely cut bundles of fibres, loosely arranged and forming the descending root of the vestibular part of the acoustic nerve; (4) close to these, but placed more deeply, a round, compact, and very conspicuous bundle of transversely cut fibres, viz., the tractus solitarius, or descending root of the vagus and glossopharyngeal nerves; (5) the large tractus spinalis of the trigeminal nerve close to the lateral side of its nucleus composed of substantia gelatinosa.

INTERNAL STRUCTURE OF THE PONS.

When transverse sections are made through the pons, it is seen to be composed of a basilar part and a dorsal or tegmental part. The latter may be regarded as the upward prolongation of the medulla oblongata, exclusive of the pyramids which are drawn forward into the basilar part.

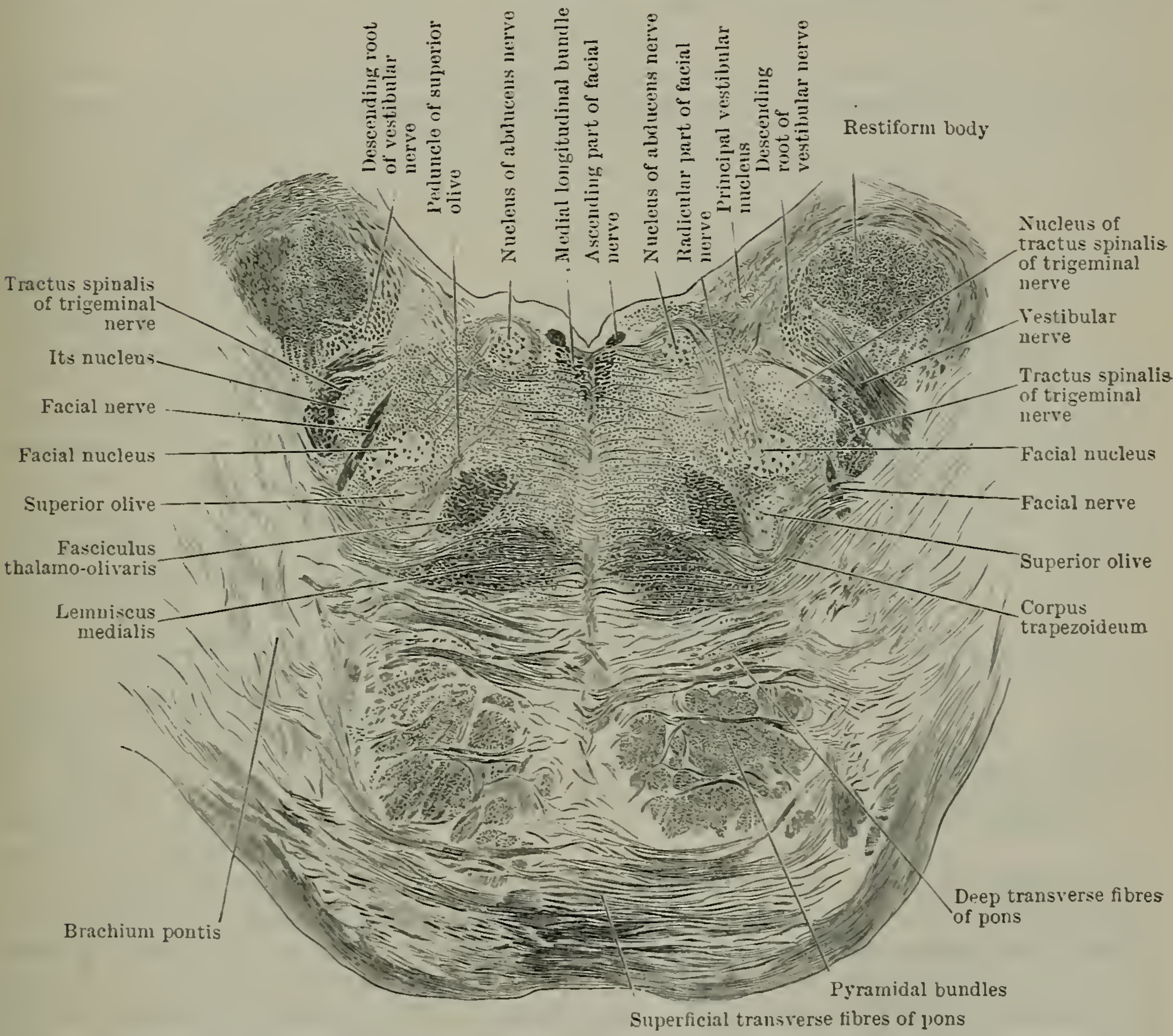
Descending root of vestibular nerve
Peduncle of superior olive
Nucleus of abducens nerve
Medial longitudinal bundle
Ascending part of facial nerve
Nucleus of abducens nerve
Radicular part of facial nerve
Principal vestibular nucleus
Descending root of vestibular nerve
Restiform body
Nucleus of tractus spinalis of trigeminal nerve
Vestibular nerve
Tractus spinalis of trigeminal nerve
Facial nucleus
Facial nerve
Superior olive
Corpus trapezoideum
Deep transverse fibres of pons
Pyramidal bundles
Superficial transverse fibres of pons
Tractus spinalis of trigeminal nerve
Its nucleus
Facial nerve
Facial nucleus
Superior olive
Fasciculus thalamo-olivaris
Lemniscus medialis
Brachium pontis

FIG. 468.—SECTION THROUGH THE LOWER PART OF THE PONS IMMEDIATELY ABOVE THE MEDULLA OBLONGATA.

Pars Basilaris Pontis.—This constitutes the chief bulk of the pons. It is composed of: (1) transverse fibres arranged in coarse bundles, called the **fibræ pontis**; (2) longitudinal fibres, gathered together in massive bundles; and (3) a large amount of gray matter, termed the **nuclei pontis**, which fills up the interstices between the intersecting bundles of fibres.

The **fasciculi longitudinales**, to a large extent, consist of the same fibres which, lower down, are gathered together in the two solid pyramidal tracts of the medulla oblongata. When the pyramids are traced upwards into the pons they are seen to present the form of two compact bundles. Superiorly, however, they are broken up into smaller bundles by the transverse fibres of the pons, and are spread out over a wider area. At the upper border of the pons they again come together and form two solid strands, each of which is continuous with the central part of the corresponding basis of the cerebral peduncle. Added to these there are twice as many other fibres entering the pons from the basis pedunculi to terminate in the nuclei pontis.

The **fibræ pontis** at the inferior border of the pons are placed on the superficial or ventral aspect of the pyramidal bundles. As we proceed upwards they increase in number, and many are seen breaking through the pyramids and even passing across upon their dorsal aspect. Laterally, these transverse fibres are collected together into one compact mass, which enters the white central core of the cerebellum and constitutes the **brachium pontis** (O.T. **middle cerebellar peduncle**). At the median plane the transverse fibres of the two sides of the basilar portion of the pons intercross and form a coarse decussation.

The **nuclei pontis** form a considerable part of the bulk of the basilar portion of the pons. The gray matter is packed into the intervals between the intersecting transverse and longitudinal bundles.

There is some analogy between the pyramidal portions of the medulla oblongata and the ventral part of the pons. In the medulla oblongata fine arcuate fibres, on their way to the surface, pass through the pyramids. Other external arcuate fibres sweep over the surface of the pyramids. These present a strong resemblance to the transverse fibres of the pons. They likewise reach the cerebellum, although by a different route, viz., the restiform body. The nuclei pontis are represented also in the pyramidal part of the medulla oblongata by the arcuate nuclei, which are covered over by the external arcuate fibres, and even tend to penetrate, to a slight extent, into the pyramidal tracts. These arcuate nuclei, as already pointed out, are continuous with the nuclei pontis.

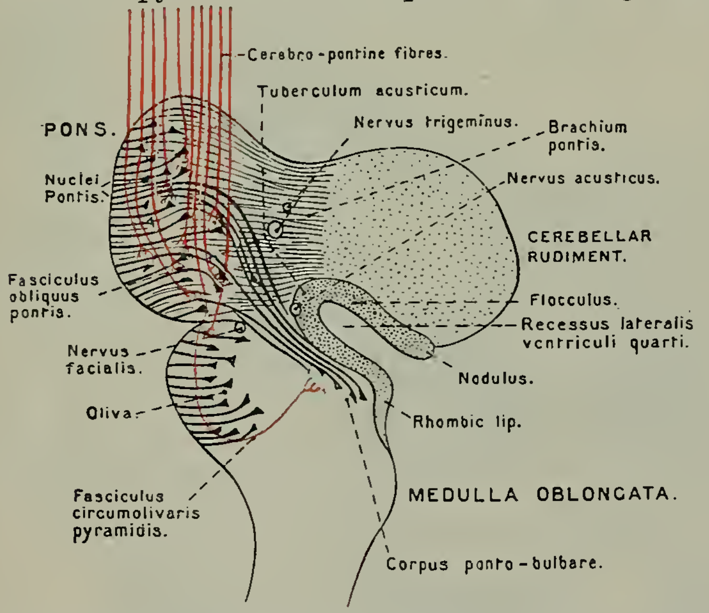

Fig. 469.—Diagram of the Left Lateral Aspect of the Fœtal Rhombencephalon representing some of the Cell Groups and Fibre Tracts.

Connexions of the Longitudinal and Transverse Fibres. — When a transverse section through the superior part of the pons is compared with one close to its inferior border, it becomes at once apparent that the numerous scattered bundles of longitudinal fibres which enter the ventral part of the pons from above, if brought together into one tract, would form a strand very much larger than the two pyramids which leave its lower aspect and enter the medulla oblongata. It is clear, therefore, that many of the longitudinal fibres which pass into the pons from above do not pass out from it below into the medulla oblongata. What becomes of these fibres that are thus absorbed in the pons? It is known that the pyramidal bundles suffer a small loss by the fibres which they send to the nuclei of origin of the efferent nerves which arise within the pons (viz., the motor root of the trigeminal, abducens, and facial nerve nuclei); but this loss is, comparatively speaking, trifling. It is clear, therefore, that other longitudinal bundles enter the pons from above apart from those which form the pyramidal tracts. These bundles occupy a lateral and dorsal position in the ventral part of the pons, and may be termed the **cerebro-pontine fibres**, seeing that they come from the cerebral cortex and end in fine ramifications around the cells of the nuclei pontis (Fig. 468).

The transverse fibres take origin as axons of the cells of the nuclei pontis. Crossing the median plane, they enter the brachium pontis of the opposite side, and thus reach the cerebellar cortex, where they end in ramifications round certain of the cortical cells.

Some authorities believe that there are also fibres passing in the opposite direction, *i.e.* from the cerebellum to the nuclei pontis; but there is some doubt concerning the existence of any such fibres. The brachium pontis thus may contain both efferent and afferent cerebellar fibres; but no fibres pass continuously through the pons from one brachium pontis into the other.

Certain of the transverse fibres of the pons turn backwards and enter the dorsal or tegmental part of the pons, but the precise connexions of these are doubtful.

Corpus Trapezoideum.—This name is applied to a group of transverse fibres which traverse the lower part of the pons (Fig. 468). They are quite distinct from those which have been just described as entering the brachium pontis, and they lie in the boundary between the dorsal and basilar parts of the pons, but encroaching considerably into the ground of the former. They arise from the cells of the terminal nucleus of the cochlear division of the acoustic nerve, and constitute a tract which establishes certain central connexions for that nerve. They will be more fully described when we treat of the cerebral connexions of the acoustic nerve.

Pars Dorsalis Pontis (Dorsal or Tegmental Part of the Pons).—On the dorsal surface of the tegmental part of the pons there is spread a thick layer of gray matter, covered with ependyma, which forms the floor of the upper or pontine part of the fourth ventricle. Beneath this the median raphe of the medulla oblongata is continued up into the pons, so as to divide its tegmental part into two symmetrical halves.

In the *inferior part of the pons*, immediately beyond the medulla oblongata, the restiform body is placed on the lateral side of the dorsal part (Fig. 468). In transverse sections through the pons it appears as a large, massive oval strand of fibres which inclines backwards into the cerebellum, and thus leaves the pons. Between the restiform body and the median raphe the tegmental part of the pons is composed of substantia reticularis, continuous with the same material in the medulla oblongata. Thus, arcuate or transverse fibres, curving in towards the raphe, and also longitudinal fibres, are seen breaking through a mass of gray matter which occupies the interstices of the intersecting fibres. To the naked eye the formatio reticularis presents a uniform gray appearance, but its constituent parts are revealed by low powers of the microscope in properly stained and prepared specimens. Embedded in this substantia reticularis are various clumps of compact gray matter and certain definite strands of fibres. These we shall describe as we pass from the restiform body medially towards the median raphe.

(1) **Spinal Root of the Trigeminal Nerve and its Nucleus.**—Close to the medial side of the restiform body, but separated from it by the vestibular root of the acoustic nerve as it proceeds backwards through the pons, is seen a large crescentic group of coarse transversely divided bundles of fibres. This is the tractus spinalis (O.T. spinal root) of the trigeminal nerve; and applied to its medial concave side is a small mass of gray matter, which is the direct continuation upwards of the substantia gelatinosa.

(2) The **nucleus of the facial nerve** comes next. It is sunk deeply in the dorsal part of the pons and lies close to the transverse fibres of the corpus trapezoideum. It is a conspicuous, obliquely placed, ovoid clump of gray matter. From its lateral and dorsal aspect the root-fibres of the facial nerve stream backwards and medially towards the gray matter on the floor of the fourth ventricle. Passing forwards between this nucleus and the trigeminal sensory nucleus a solid nerve-bundle may be observed. This is the facial nerve, traversing the pons towards its place of emergence from the brain.

(3) Immediately medial to the facial nucleus, but placed more deeply in the tegmental part of the pons, is the **superior olivary nucleus**. It lies in a bay formed for it by the transverse fibres of the corpus trapezoideum. These fibres curve round its ventral aspect, and many of them may be observed penetrating into its substance. In man, it is a very small mass of gray matter, and presents little resemblance to the inferior olivary nucleus, except in the size and shape of its constituent cells. In sections through the part of the pons where it attains its greatest size, it appears in the form of two, or it may be three, small isolated

masses of gray matter. It is intimately connected with the acoustic fibres, and establishes manifold connexions between them and the nuclei of other nerves.

Upon the medial and dorsal aspect of the superior olive there is a dense group of longitudinal fibres. These constitute the **fasciculus thalamo-olivaris** or **central tegmental tract**, to which we have already referred in discussing the inferior olivary nucleus (Fig. 468). It is uncertain whether this tract arises in the thalamus.

(4) The **medial longitudinal bundle** and the **lemniscus medialis** come next. As they proceed upwards through the tegmental part of the pons, these longitudinal tracts occupy the same relative position as in the medulla oblongata. They are placed close to the median raphe; but they have drawn further apart from each other, and their fibres are more distinctly concentrated into separate strands, with an interval of some little width between them, which is occupied by the **tecto-spinal tract**. The **medial longitudinal bundle** lies immediately under cover of the gray matter of the floor of the fourth ventricle. The **lemniscus medialis** is placed close to the trapezial fibres, many of which traverse it as they pass towards the median plane.

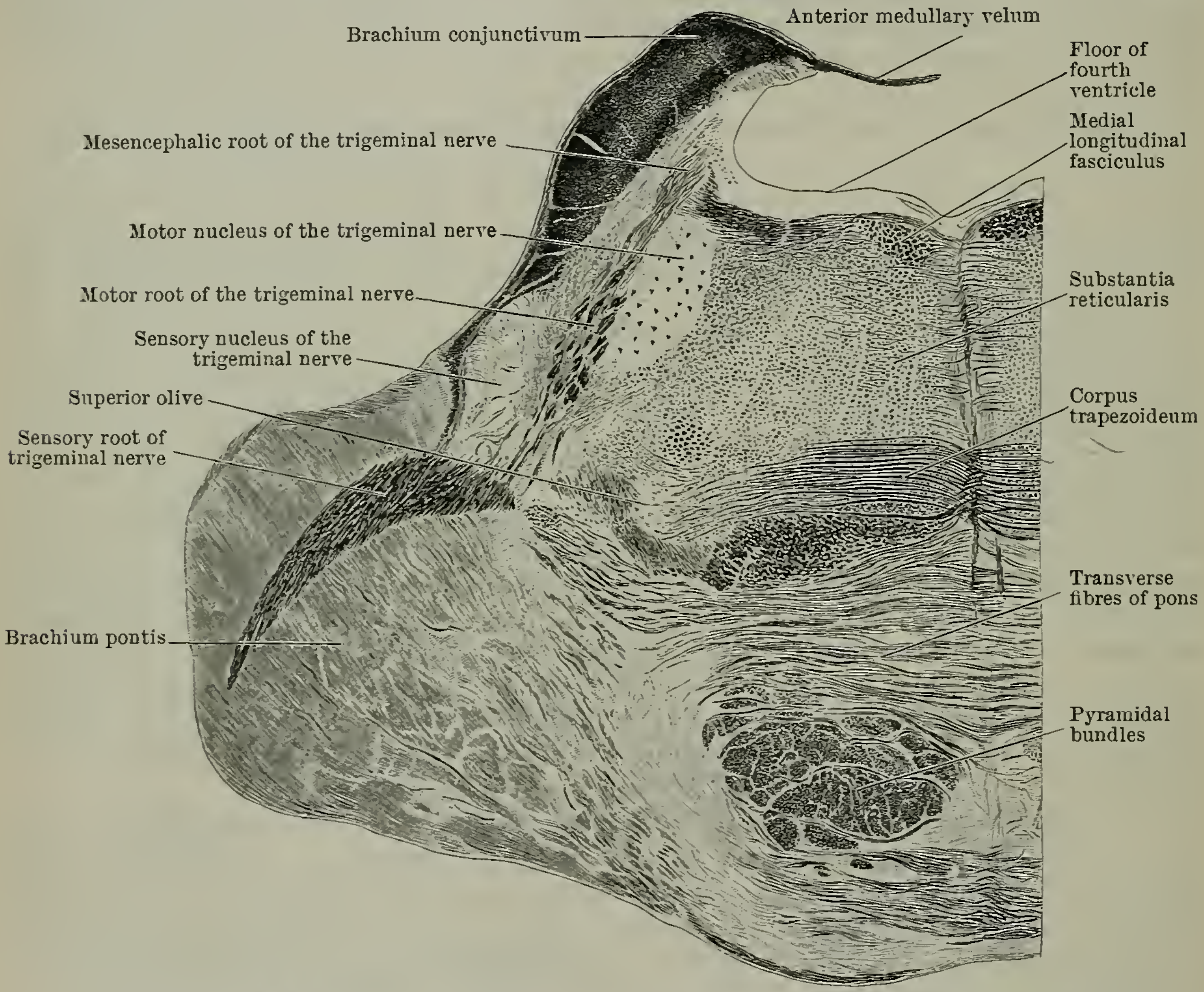
Brachium conjunctivum
Anterior medullary velum
Floor of fourth ventricle
Mesencephalic root of the trigeminal nerve
Medial longitudinal fasciculus
Motor nucleus of the trigeminal nerve
Motor root of the trigeminal nerve
Substantia reticularis
Sensory nucleus of the trigeminal nerve
Superior olive
Corpus trapezoideum
Sensory root of trigeminal nerve
Transverse fibres of pons
Brachium pontis
Pyramidal bundles

FIG. 470.—TRANSVERSE SECTION THROUGH THE PONS AT THE LEVEL OF THE NUCLEI OF THE TRIGEMINAL NERVE.

(5) The **nucleus of the abducens nerve** also forms a conspicuous object in sections through the lower part of the pons. It is a round mass of gray matter, which is situated close to the lateral side of the medial longitudinal bundle, and immediately under cover of the gray matter of the floor of the fourth ventricle. From its medial side numerous root-bundles of the abducens nerve pass out and proceed forwards between the lemniscus medialis and the superior olivary nucleus. They occupy in the pons, therefore, a position similar to that occupied by the hypoglossal root-fibres in the medulla oblongata.

Up to the present only the inferior part of the dorsal portion of the pons has been described, *i.e.* the portion immediately adjoining the medulla oblongata. As we proceed upwards and gain a point *above the level of the trapezial fibres*, many of the structures which have attracted attention lower down gradually disappear from the formatio reticularis. The lemniscus medialis becomes markedly increased in size by the addition of the fibres of the spino-thalamic tract. Further, the floor of the fourth ventricle becomes narrower, and other objects appear in the tegmental substance.

The **brachium conjunctivum** (O.T. **superior cerebellar peduncle**) is a very conspicuous object in sections through the middle and upper parts of the pons. In transverse section it presents a semilunar outline, and as it emerges from the cerebellum it lies immediately on the lateral side of the fourth ventricle, towards which its concave aspect is turned (Fig. 470). Its dorsal border is joined with the corresponding brachium of the opposite side by the thin lamina of white matter, termed the *anterior medullary velum,* whilst its ventral border is sunk to a small extent in the dorsal part of the pons. As it is traced upwards it sinks deeper and deeper into the pons until it becomes completely submerged, with the exception of the dorsal border to which the anterior medullary velum is attached. It now lies on the lateral side of the tegmental or reticular substance of the pons, and this position it maintains until the mesencephalon is reached (Fig. 471).

About *half-way up the pons* the nuclei of the trigeminal nerve mark a very important stage in its tegmental portion. These nuclei are two in number on each side, viz., a large oval terminal nucleus for certain of the sensory fibres of the nerve and a nucleus of origin, equally conspicuous, for certain of the motor fibres (Fig. 470). The **sensory nucleus** lies close to the lateral surface of the pons, deeply sunk in its tegmental part, and in the interval between the submerged anterior border of the brachium conjunctivum and the ventral part of the pons. The **motor nucleus** is placed on the medial side of the sensory nucleus, but somewhat nearer the dorsal surface of the pons. At this level the tractus spinalis of the trigeminal nerve begins by the bending downwards of the fibres of the sensory portion. The sensory and motor roots of the fifth nerve traverse the ventral part of the pons on their way to and from the region of the nuclei.

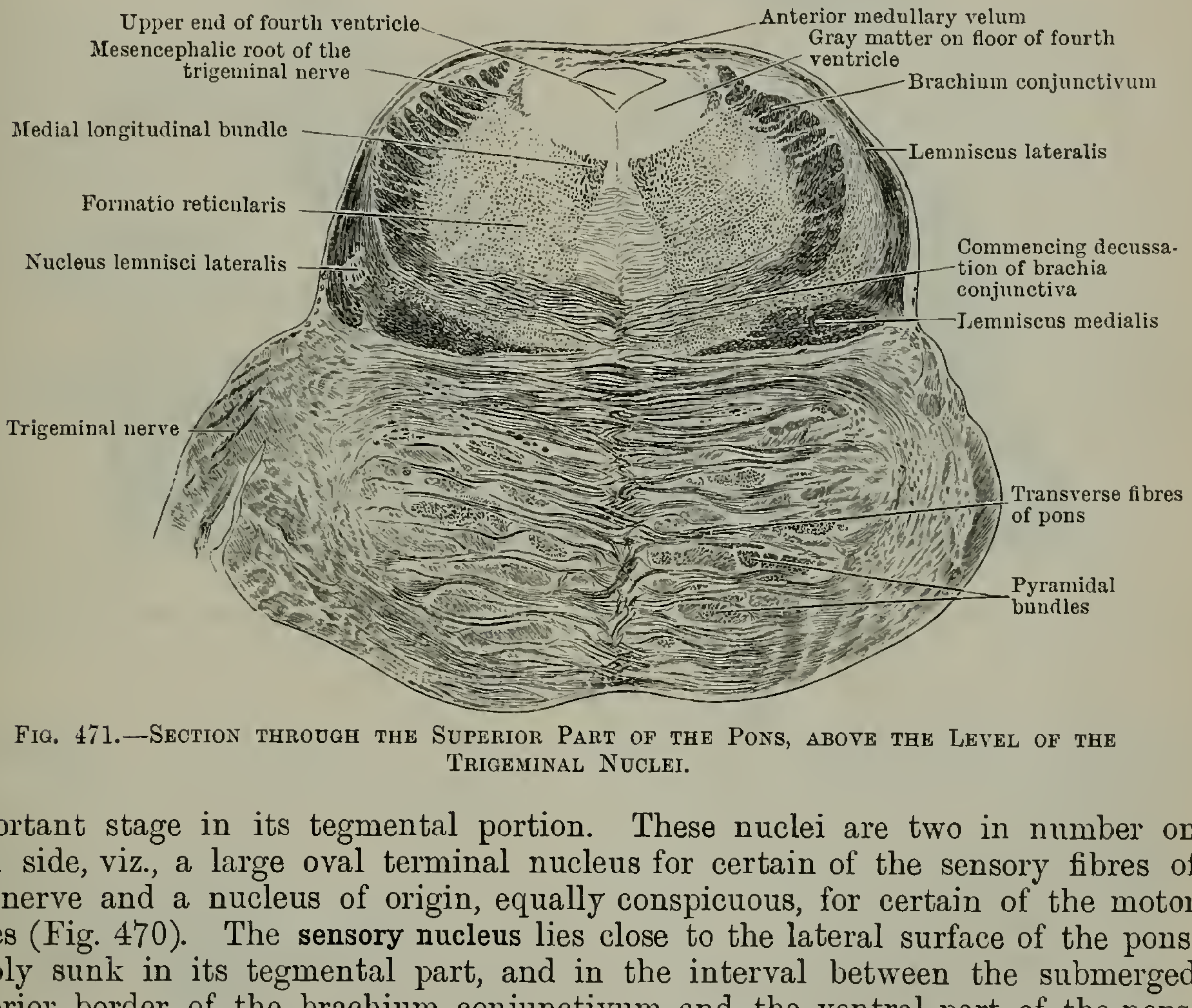
Upper end of fourth ventricle
Mesencephalic root of the trigeminal nerve
Medial longitudinal bundle
Formatio reticularis
Nucleus lemnisci lateralis
Trigeminal nerve
Anterior medullary velum
Gray matter on floor of fourth ventricle
Brachium conjunctivum
Lemniscus lateralis
Commencing decussation of brachia conjunctiva
Lemniscus medialis
Transverse fibres of pons
Pyramidal bundles

FIG. 471.—SECTION THROUGH THE SUPERIOR PART OF THE PONS, ABOVE THE LEVEL OF THE TRIGEMINAL NUCLEI.

Above the level of the nuclei of the trigeminal nerve a new tract of fibres comes into view. This is the **mesencephalic root** of the trigeminal nerve, as it descends towards the rest of the nerve. It is a small bundle of nerve-fibres, semilunar in cross section, which lies close to the medial side of the brachium conjunctivum and on the lateral and deep aspect of the gray matter on the floor of the fourth ventricle (Figs. 470 and 471).

On a slightly deeper plane than the mesencephalic root of the fifth nerve, between it and the medial longitudinal bundle, and in close relation to the gray matter of the floor of the ventricle, is the collection of pigmented cells which constitutes the **substantia ferruginea.**

The **medial longitudinal bundle**, as it is traced upwards through the tegmental part of the pons, maintains the same position throughout, and as it ascends it becomes more clearly mapped out as a definite and distinct tract. It lies close to the median raphe, and immediately subjacent to the gray matter of the floor of the fourth ventricle.

The **lemniscus medialis**, as it ascends through the tegmental part of the pons, undergoes striking changes in shape. In the lower portion of the pons its fibres, which in the medulla oblongata are spread out along the side of the median raphe, are collected together in the form of a loose bundle, which occupies a wide field, somewhat triangular in shape, on either side of the median raphe and immediately behind the basilar portion of the pons. As it proceeds up, the fibres spread out laterally until a compact ribbon-like layer is formed in the interval between the tegmental and basilar portions of the pons (Figs. 471 and 472).

Above the level of the trigeminal nuclei another flattened layer of fibres comes into view to the lateral side of the lemniscus medialis. To this the name of **lemniscus lateralis** is given. These fibres spread laterally and backwards, and finally take up a position on the lateral surface of the brachium conjunctivum. In the angle between the medial and lateral lemnisci a little knot of compact gray matter, termed the **nucleus lemnisci lateralis**, comes into view (Fig. 471). This appears to be in more or less direct continuity with the superior olivary nucleus. Many of the fibres of the lemniscus lateralis take origin in this nucleus. Bruce called attention to the continuity between the superior olive and the nucleus of the lateral lemniscus in man, and Cunningham confirmed the observation in so far as the orang brain is concerned. In many other mammals the nuclei are quite distinct.

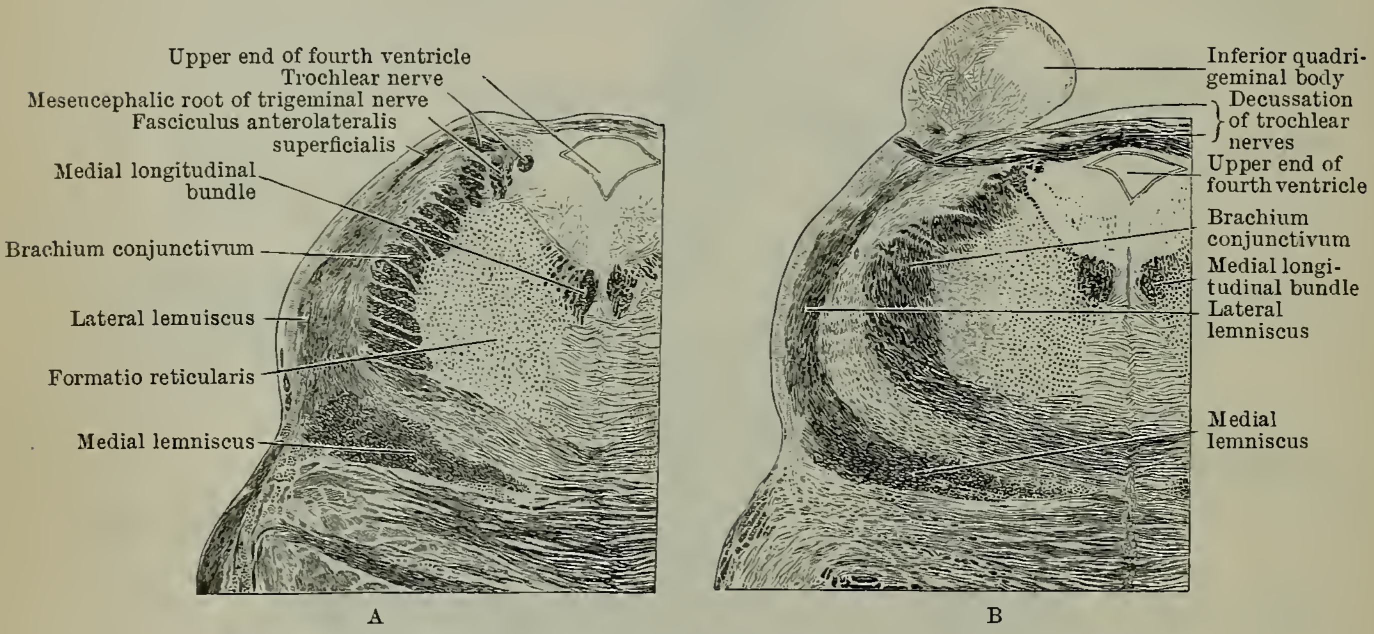
Upper end of fourth ventricle
Trochlear nerve
Mesencephalic root of trigeminal nerve
Fasciculus anterolateralis superficialis
Medial longitudinal bundle
Brachium conjunctivum
Lateral lemniscus
Formatio reticularis
Medial lemniscus
A
Inferior quadrigeminal body
Decussation of trochlear nerves
Upper end of fourth ventricle
Brachium conjunctivum
Medial longitudinal bundle
Lateral lemniscus
Medial lemniscus
B

Fig. 472.—Two Sections through the Dorsal Portion of the Pons at its Superior Part, close to the Mesencephalon.

A is at a slightly lower level than B.

THE CEREBELLUM.

In the foregoing account it has been seen that the cerebellum is formed from two distinct rudiments, each derived from the posterior edge of the alar lamina immediately above the pontine flexure and the insertion of the vestibular nerve. As development proceeds during the second month there is a rapid proliferation of cells in the mantle layer of the cerebellar rudiments, and they become considerably thickened. But at first this thickening manifests itself not so much as a swelling of the superficial aspect of the cerebellum but as a bulging inwards into the cavity of the fourth ventricle (Fig. 473).

The accentuation of the pontine flexure at this stage brings the two cerebellar rudiments into the transverse direction and in line one with the other and with the roof-plate, which is now being thickened by immigrant neuroblasts from the medial extremities of the two cerebellar rudiments. When one organ is thus formed by the union in the roof-plate of the originally separate rudiments, it presents the form of a dumb-bell shaped mass (Fig. 473). Upon the inferior aspect of this mass there is a slight ridge, to which the **tela chorioidea ventriculi quarti** is attached. Opposite the lateral cerebellar rudiments (but not in the median plane) the attachment of the tela becomes thickened to form the posterior medullary velum.

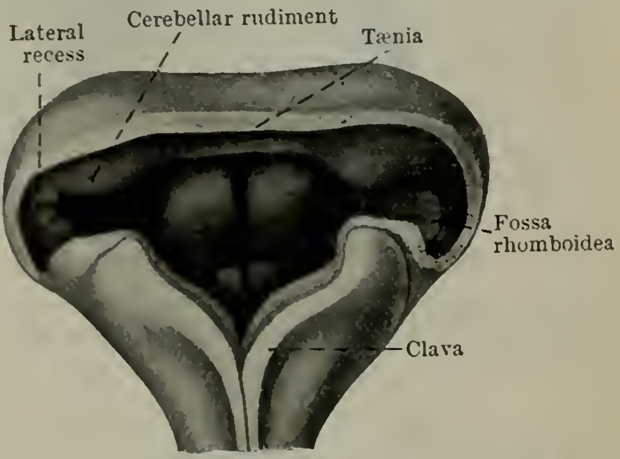

Fig. 473.—Dorsal Aspect of the Rhombencephalon in a Human Embryo.

Early in the third month the growth of the cerebellar rudiment begins to manifest itself by lateral bulgings of its surface.

The rhombic lip, the inferior part of which has been seen to play an important part in the development of the nuclei pontis and nucleus olivaris inferior, is also continued upwards beyond the pontine flexure on to the cerebellar rudiment, where it forms a marginal fringe. Thus, even in the second month, a groove can be detected upon the cerebellum separating off a band which is continuous with the tuberculum acusticum. The part nearest to the tuberculum represents the rudiment of the **flocculus** and the medial extremity the **nodulus** (Fig. 473). During the third month the cerebellum appears as a bar transversely placed across the upper part of the roof of the fourth ventricle, and as the lateral extremities of this bar expand (Fig. 474), it assumes a dumb-bell shape not unlike that presented a few weeks earlier (Fig. 473) on its ventricular aspect. As these lateral bosses (**hemispheres**) develop, a mass of transverse fibres in connexion with them also becomes apparent. It represents the fibræ transversæ of the pons. They arise from the cells (nuclei pontis) which have wandered into the basal lamina of the metencephalon from the rhombic lip of the myelencephalon (Fig. 469); and the fibres which enter each cerebellar hemisphere come mainly from the nuclei pontis of the other side. Towards the end of the fourth month, or even a month earlier in some cases, a little bud grows out from the cerebellum on each side immediately above the flocculus. It is the **paraflocculus** or **flocculus secundarius**. In man it never attains a large size, but in most mammals it develops into a large lobe, even as big as one-third the size of a cerebellar hemisphere (in the manatee), and in many animals a deep fossa is formed in the temporal bone to lodge this part of the cerebellum.

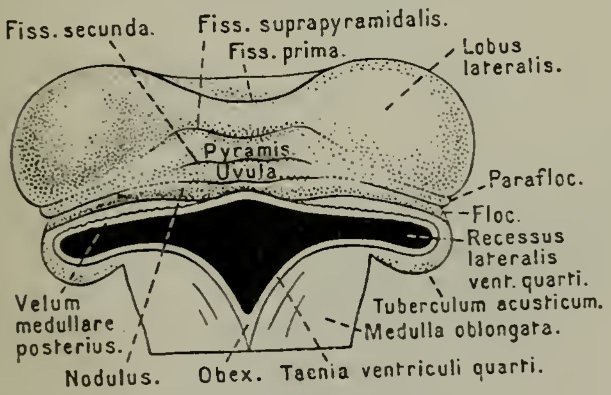

Fig. 474.—The Posterior Aspect of a Fœtal (Fourth Month) Cerebellum, Medulla Oblongata and Fossa Rhomboidea.

The label *Lobus lateralis* refers to the hemisphere.

The evidence of comparative anatomy seems to suggest that the reduction of the paraflocculus in man and the apes is associated with the adoption of the erect attitude (or in the apes the maintenance of equilibrium by the use of the arms). The enormous development of the paraflocculus in all marine mammals is due to the fact that it co-ordinates those muscular movements that maintain equilibrium by controlling the tendency to roll in the lateral direction, that is, around the long axis of the body. The mode of progression in the apes and man restricts this tendency and correspondingly minimises the need for a paraflocculus.

As the cerebellum grows the lateral hemispheres expand much more rapidly than the median part—the handle of the dumb-bell. But the superficial area of the latter becomes increased by means of transverse folds which begin to make their appearance at the close of the third month. Earlier in that month the median part of the cerebellum presents in sagittal section almost a semicircular outline (Fig. 477, A) with a slight notch near its inferior margin (**fissura postnodularis**) demarcating the **nodulus.** As development proceeds during the third month the nodular region becomes bent forwards upon the rest of the cerebellum (Fig. 477, B), thus starting the posterior diverticulum of the fourth ventricle, which ultimately assumes a tent-like outline (Fig. 451).

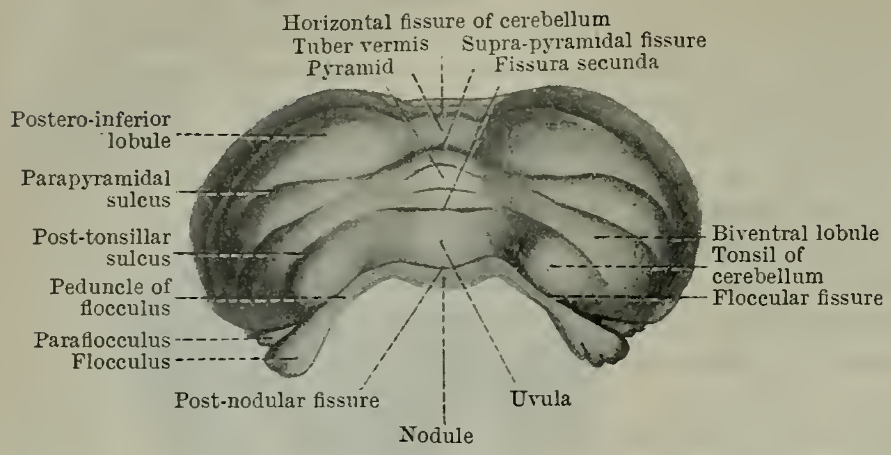

Fig. 475.—Inferior Surface of the Cerebellum of a Human Fœtus which has reached the End of the Fifth Month of Development.

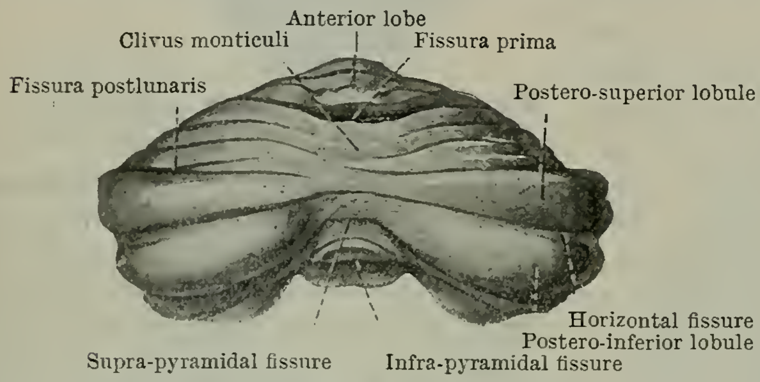

Fig. 476.—Cerebellum of a Human Fœtus which has reached the End of the Fifth Month of Development. Viewed from above and behind.

At the close of the third month the irregular growth of the surface of the median area of the cerebellum, which from its worm-like appearance in the adult (Fig. 480) is called the **vermis,** leads to the appearance of a transverse depression upon the superior surface. This is the **fissura prima** (Fig. 477, B, C, and D), which

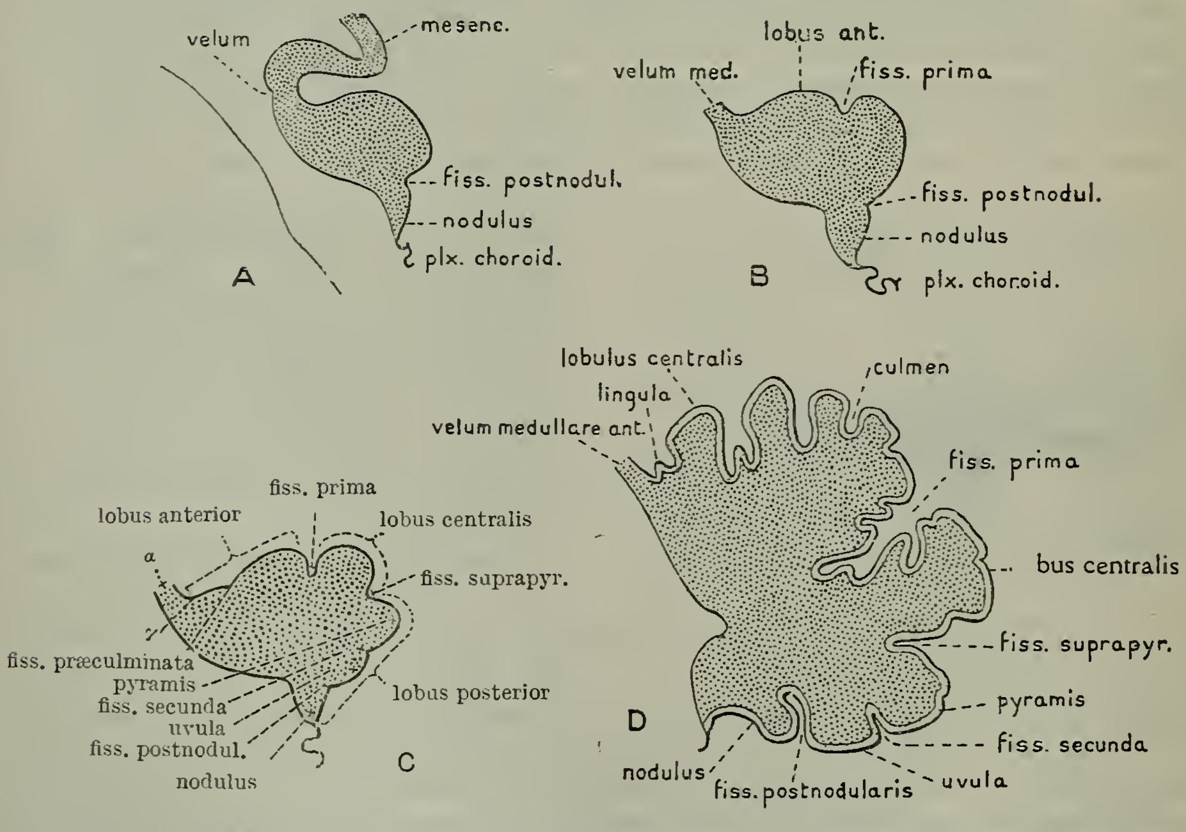

Fig. 477.—Median Sagittal Sections of Fœtal Cerebella in Four Stages of Development. A and B, third month; C, fourth month; D, fifth month.

becomes the deepest and most complex of all the multitude of fissures that ultimately cut into the cerebellum (Fig. 477). It cuts off a lozenge-shaped area of the front of the cerebellum that is called the **anterior lobe** (Fig. 478), which is believed to be concerned with the co-ordination of those movements that help to maintain equilibrium by preventing the body from falling forward. Soon afterwards two other fissures make their appearance further back, one that is phylogenetically old, the **fissura secunda**, appearing to delimit the uvula (Fig. 477, C and D) posteriorly, and another, which is very precocious in the human fœtus, the **fissura suprapyramidalis** (which might be called **tertia**), intermediate between the first and second fissures.

Other transverse fissures appear in rapid succession until the vermis becomes cut up into a series of folds to which the labels indicated in Fig. 477 D, used to be applied, but there is now no reason for retaining such terms as lobulus centralis, culmen, or declive. It is still useful to retain the terms **pyramid, uvula,** and **nodule.**

The posterior lobe is made up of the three lobules called pyramid, uvula, and nodule respectively (Fig. 477, D), and is supposed to be concerned with the co-ordination of the movements to prevent the body falling backward. Morphologically the pyramid should not be included in the posterior lobe, because the facts of comparative anatomy suggest that it is merely an outgrowth of the central lobe in front of it. But in the human brain it seems to be more intimately related to the uvula and to be precociously cut off (by the suprapyramidal fissure, Fig. 477) from the central lobe. The lateral connexions of the pyramid and the uvula with the parts of the hemispheres labelled (in Fig. 475) biventral lobule and tonsil respectively are quite fortuitous and devoid of any morphological or functional significance. The narrow bridge of vermis labelled central lobe in Fig. 477, D, when traced laterally, expands into an enormous mass forming the greater part of the cerebellar hemisphere. It can be divided into three natural subdivisions, an anterior crescentic strip called the **lobulus lunatus** (Fig. 478), a great feather-like mass forming the major part of the hemispheres that has been called **lobulus ansiformis** by Bolk, and the **tonsil**, a curious appendage packed on the under surface of the cerebellum (Fig. 481) between the pyramid and uvula on its medial side and the ansiform lobule ("biventral") on its lateral side. The tonsil corresponds to the part of the cerebellum of other mammals to which Bolk has given the name **paramedian lobule.** The enormous expansion of the ansiform lobule is the outstanding distinctive feature of the human cerebellum, and is believed to be due to the need for a very much more complex co-ordination of the muscles of the limbs, and more particularly of the arms and hands, not merely for purposes of equilibration but also for the performance of skilled movements.

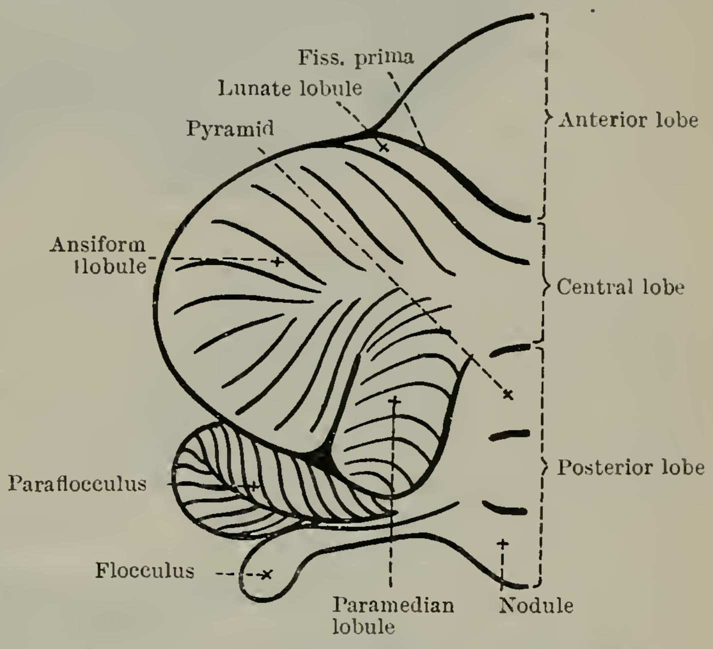

FIG. 478.—DIAGRAM OF LOBULATION OF LEFT HALF OF MAMMALIAN CEREBELLUM.

Only some of the fissures of the vermis become prolonged laterally beyond the limits of the vermis, but as the boss-like lateral lobes begin to expand, their surface becomes folded and a series of independent lateral fissures are formed. [*The anterior lobe, however, is prolonged laterally upon each side into tapering wings and all the fissures in them are merely prolongations of the fissures of the vermis.*]

After the limiting fissures of the flocculus and paraflocculus, the first independent fissure to make its appearance is one which develops behind and almost parallel to the lateral prolongations of the fissura prima. The intervening strip of cerebellum is the **lobulus lunatus** and its posterior boundary, the **fissura postlunaris.** These postlunar fissures begin far out on the lateral swelling in the fourth month and gradually approach the median plane, where they may meet and become confluent on the vermis.

At the end of the fourth or beginning of the fifth month an oval swelling makes its appearance alongside the uvula upon the inferior surface of each lateral lobe (Fig. 475). This is called the **tonsilla cerebelli** or **tonsil**, and the fissure which develops behind it and delimits it is called **post-tonsillar.** As a rule the two post-tonsillar fissures become confluent with the **fissura secunda** upon the vermis, and the whole furrow in the adult may be called **fissura secunda.** The fissure to which most importance is usually attached develops quite late in the human cerebellum, and not at all in that of the great majority of other animals. It is called the **fissura horizontalis cerebelli.** In the adult it begins upon the front, where the brachium pontis plunges into the cerebellum, and the furrow is formed in a more or less mechanical way by the bulging forwards (above and below the cerebellar peduncles) of the exuberant mass of the cerebellar hemispheres. The actual infolding is preceded by the appearance of several irregular depressions (Fig. 479) in the place where the horizontal fissure will develop. This fissure begins in front and passes continuously round the circumference of the organ, cutting deeply into its lateral and posterior margins. In front, its lips diverge to admit the three cerebellar peduncles as they pass into the interior of the cerebellum.

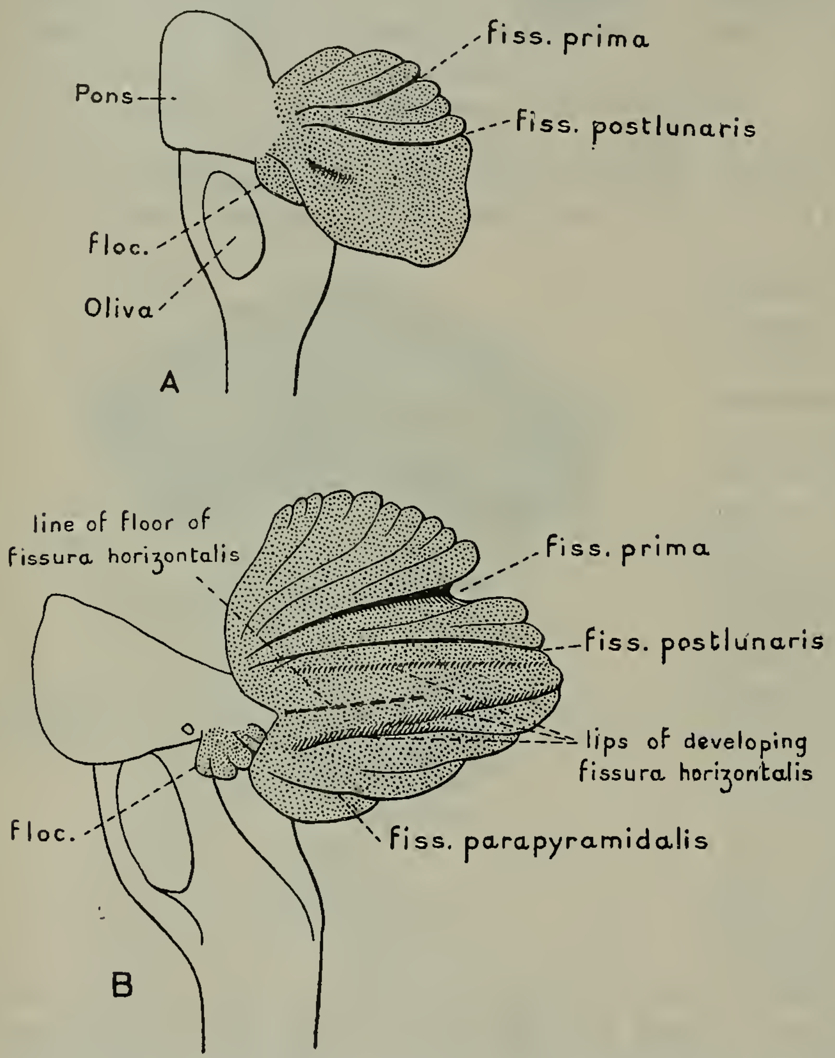

Fig. 479.—The Left Lateral Aspect of the Fœtal Rhombencephalon at the Fourth (A) and Fifth (B) Months.

The cerebellum is stippled.

In some cases it meets the corresponding fissure of the other side upon the vermis, but very often such a confluence does not occur.

It used to be the custom to subdivide the cerebellum somewhat arbitrarily into a median portion termed the **vermis,** and two much larger lateral portions called the **hemispheres.** The demarcation between these main subdivisions of the organ is not very evident from every point of view. In front, and also behind, there is a marked deficiency or notch. The **incisura cerebelli posterior** (O.T. **marsupial notch**) is smaller and narrower than the anterior notch. It is bounded at the sides by the hemispheres, whilst its bottom is formed by the axial lobe or vermis. It is occupied by a fold of dura mater called the falx cerebelli. The **incisura cerebelli anterior** (O.T. **semilunar notch**) is wide, and, when viewed from above, it is seen to be occupied by the inferior quadrigeminal bodies and by the brachia conjunctiva. As in the case of the posterior notch, its sides are formed by the hemispheres, and the bottom by the vermis.

On the superior surface of the cerebellum the vermis is not marked off from the hemispheres. It forms a high median elevation, from which the surface slopes gradually downwards on each side to the margin of the hemisphere. The vermis is highest in front, immediately behind the anterior notch, and from this it shows a somewhat sharp descent towards the posterior notch.

On the inferior surface of the cerebellum the distinction between the three main constituent parts of the organ is much better marked (Fig. 481). On this aspect the hemispheres are full, prominent, and convex, and occupy the cerebellar fossæ in the floor of the cranium. They are separated by a deep median hollow, which is continued forwards from the posterior notch. This hollow is termed the **vallecula cerebelli**, and in its anterior part the medulla oblongata is lodged. When the medulla oblongata is raised and the hemispheres are pulled apart, so as to expose the bottom of the vallecula, it will be seen that this is formed by the **vermis**, which is separated on each side from the corresponding hemisphere by a distinct furrow, termed the **sulcus valleculæ**.

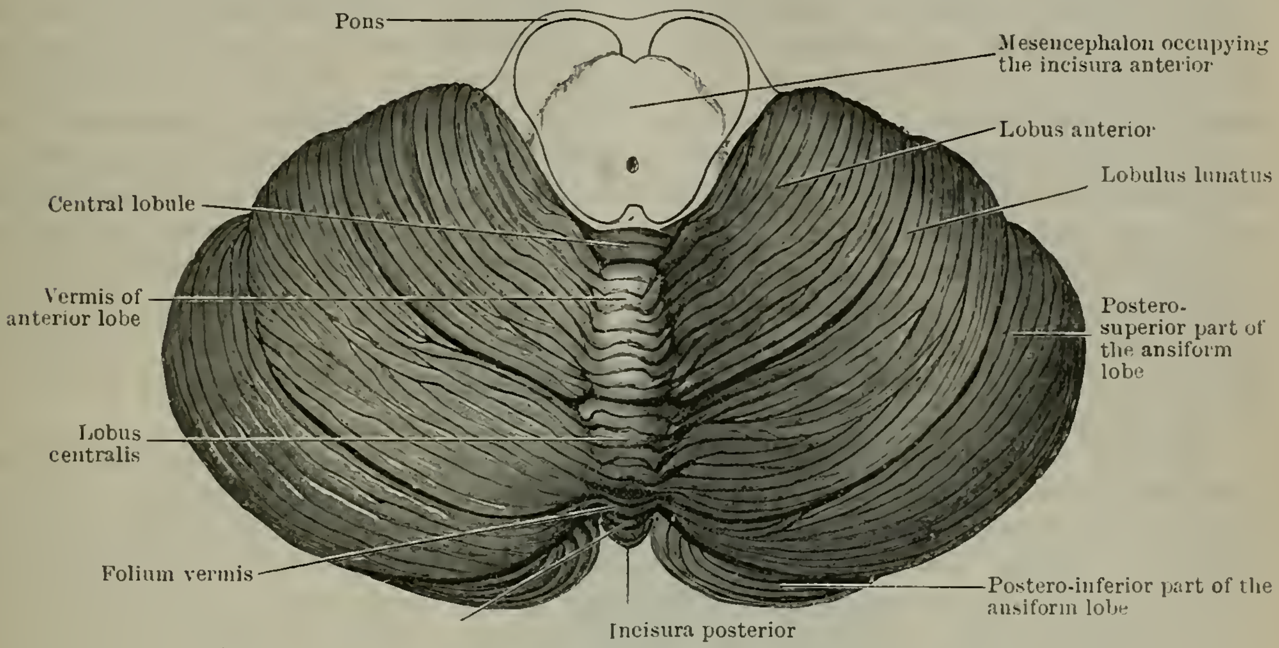
Pons
Mesencephalon occupying the incisura anterior
Lobus anterior
Lobulus lunatus
Central lobule
Vermis of anterior lobe
Postero-superior part of the ansiform lobe
Lobus centralis
Folium vermis
Postero-inferior part of the ansiform lobe
Incisura posterior

Fig. 480.—Superior Surface of the Cerebellum.

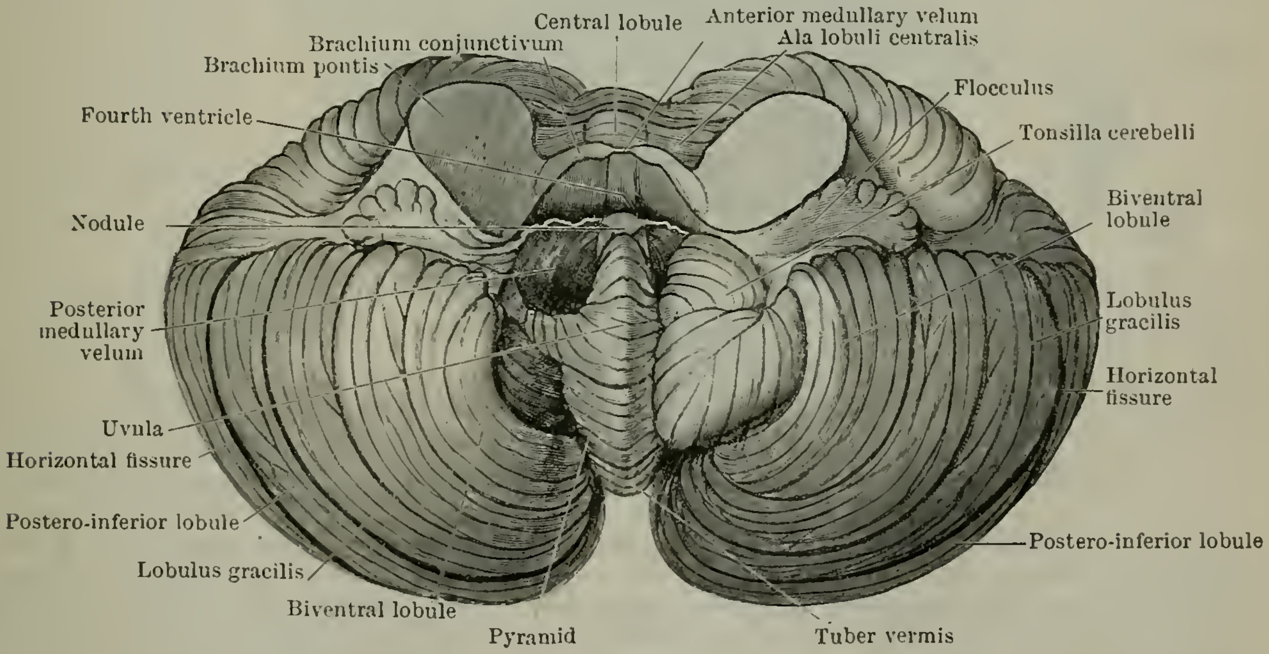

Fig. 481.—Inferior Surface of the Cerebellum.

The right tonsil has been removed so as to display more fully the posterior medullary velum and the furrowed band. The structures labelled "biventral lobule," "lobulus gracilis," and "postero-inferior lobule" are all parts of the lobulus ansiformis, the greatly expanded lateral part of the central lobe.

The nodule and the flocculus of each side are linked by a delicate connecting lamina which is formed by the **posterior medullary velum**.

The Structure and Connexions of the Cerebellum.

Arrangement of the Gray and White Matter of the Cerebellum.—The white matter of the cerebellum forms a solid compact mass in the interior, and over this is spread a continuous and uniform layer of gray matter. In each hemisphere the white central core is more bulky than in the vermis, in which the central white matter is reduced to a relatively thin bridge thrown across between the two hemispheres. When sagittal sections are made through the cerebellum, the gray matter on the surface stands out clearly from the white matter in the interior. Further, from all parts of the surface of the central core stout stems of white matter are seen projecting into the lobes of the cerebellum. From the sides of these white stems secondary branches proceed at various angles, and from these again tertiary branches are given off. Over the various lamellæ of white matter thus formed the gray cortex is spread, and the fissures on the surface show a corresponding arrangement, dividing up the organ into lobes, lobules, and folia. When the cerebellum is divided at right angles to the general direction of its fissures and folia, a highly arborescent appearance is thus presented by the cut surface. To this the term **arbor vitæ** is applied.

Nucleus Dentatus and other Gray Nuclei in the White Matter of the Cerebellum.—Embedded in the midst of the mass of white matter which forms the central core of each hemisphere there is an isolated nucleus of gray matter, which presents a strong resemblance to the inferior olivary nucleus of the medulla. It is called the **nucleus dentatus**, and it consists of a corrugated or plicated lamina of gray matter, which is folded on itself so as to enclose, in a flask-like manner, a portion of the central white matter (Figs. 482 and 483). This gray capsule is not completely closed. It presents an open mouth, termed the hilum, which is directed medially and upwards, and out of this stream the fibres of the brachium conjunctivum.

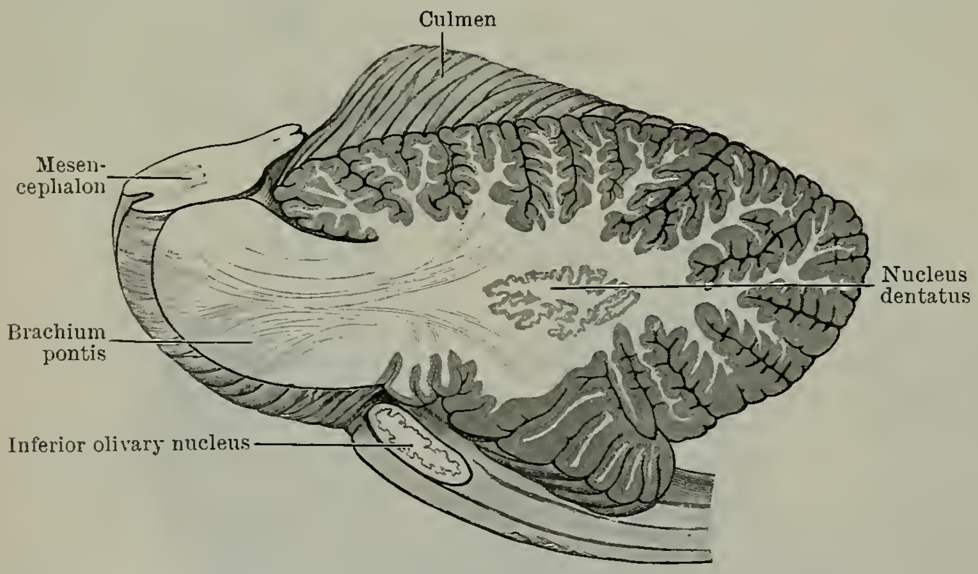

Fig. 482.—Sagittal Section through the Left Hemisphere of the Cerebellum.

Showing the "arbor vitæ" and the nucleus dentatus.

Three small additional masses of gray matter are also present on each side of the median plane in the central white matter of the cerebellum. These are termed the nucleus emboliformis, the nucleus globosus, and the nucleus fastigii. The **nucleus emboliformis** or **embolus** is a small lamina of gray matter which lies just medial to the hilum of the nucleus dentatus, being thus related to it somewhat in the same manner that the medial accessory olivary nucleus is related to the main inferior olivary nucleus. The **nucleus globosus** lies medial to the nucleus emboliformis and on a somewhat deeper horizontal plane. The **nucleus fastigii** or **roof nucleus** is placed in the white substance of the vermis close to the median plane and its fellow of the opposite side. It is, therefore, situated on the medial aspect of the nucleus globosus.

The nucleus dentatus and the emboliform nucleus present a structure very similar to that of the inferior olivary nucleus. In the nucleus globosus and the nucleus fastigii the cells are somewhat larger in size.

Cerebellar Peduncles.—These are three in number on each side, viz., the middle, the inferior, and the superior (Fig. 456, p. 551). The fibres of which they are composed all enter or emerge from the white medullary centre of the cerebellum.

The **middle peduncle** or **brachium pontis** is much the largest of the three, and has already been described on pp. 456 and 551. It is formed by the transverse fibres of the pons, and it enters the cerebellar hemisphere on the lateral aspect of the other two peduncles. The lips of the anterior part of the horizontal fissure are separated widely from each other to give it admission (Fig. 456). Within the cerebellar hemisphere its fibres are distributed in two great bundles. Of these, one, composed of the superior transverse fibres of the pons, radiates out in the inferior part of the hemisphere; whilst the other, consisting of the inferior transverse fibres of the pons, spreads out in the superior part of the hemisphere.

The **inferior peduncle** is simply the **restiform body** of the medulla oblongata. After leaving the medulla oblongata it ascends for a short distance on the dorsal surface of the pons and then turns sharply backwards, to enter the cerebellum between the other two peduncles.

The **superior peduncle** or **brachium conjunctivum**, as it issues from the cerebellum, lies close to the medial side of the middle peduncle (Fig. 456). Its further course upwards on the dorsum of the pons to the inferior quadrigeminal body has been previously described (pp. 549 and 550).

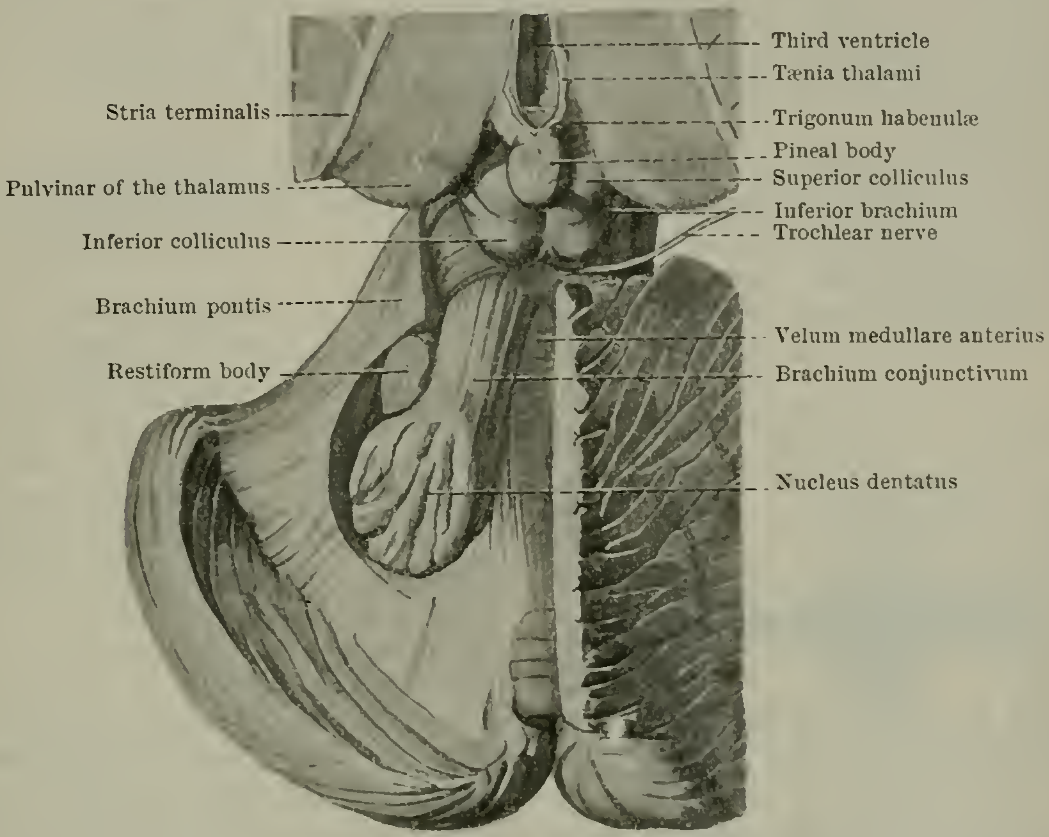

Fig. 483.—From a dissection by Dr. Edward B. Jamieson in the Anatomical Department of the University of Edinburgh. The nucleus dentatus is displayed from above and the brachium conjunctivum has been traced from it to the mesencephalon.

Connexions established by the Peduncular Fibres.—The fibres of the **brachium pontis** represent the second stage of the connexion between the cerebral hemisphere of one side and the opposite cerebellar hemisphere. The connexions which they establish in the pons are described on p. 566.

The **restiform body** is also composed of afferent fibres (see p. 548); only the more important connexions which these establish in the cerebellum can be touched on here. The principal afferent strand is the *fasciculus spinocerebellaris* [posterior]. The fibres of this strand end in the cortex of the *superior* vermis on both sides of the median plane, but chiefly on the opposite side. The olivo-cerebellar tract (*fasciculus olivocerebellaris*) are also afferent. It appears that they end in connexion with cells in the cortex of both the vermis and hemisphere, and also with cells in the nucleus dentatus. The numerous *external arcuate fibres* which enter the restiform body establish connexions with cells in the cortex of the hemisphere and of the vermis.

The **brachium conjunctivum** is an efferent tract: its fibres come from the cells of the nucleus dentatus, and pass to the red nucleus and thalamus of the opposite side.

According to Ramon y Cajal collateral branches springing from these fibres descend to the motor nuclei in the medulla oblongata and spinal medulla.

There is, however, a bundle of fibres passing *downwards* alongside the brachium conjunctivum from the tegmentum of the mesencephalon and possibly from the thalamus: these fibres cross in the mid-brain and pass inferiorly to the cerebellum, in contact with the lateral margin of (or intermingled with) the fibres of the brachium. They probably convey to the cerebellum fibres from the visual centres of the opposite side.

The **fasciculus anterolateralis superficialis** of the spinal medulla (O.T. Gowers' tract), for which the better name **fasciculus spinocerebellaris anterior** is now in common use, also enters the cerebellum alongside the emerging brachium conjunctivum. It has been noticed in connexion with the lateral funiculus of the spinal medulla (p. 537). The fibres which compose it are carried upwards through the formatio reticularis grisea of the medulla oblongata and the corresponding part of the tegmental portion of the pons. In this part of its course the fibres are scattered and do not form a compact strand. Reaching the superior end of the pons the tract turns backwards across the brachium conjunctivum, enters the anterior medullary velum, and proceeds downwards in it into the cerebellum.

Roof of the Fourth Ventricle.—In its superior part the roof of the fourth ventricle is formed by the anterior medullary velum as it stretches across between the two brachia conjunctiva, and also, to some extent, by these brachia themselves as they approach the mesencephalon.

In its inferior part the roof of the ventricle is exceedingly thin and is not all formed of nervous matter. The posterior medullary velum is a mere ridge which can hardly be said to enter into its formation: the epithelial lining of the cavity, supported by pia mater, is carried downwards towards the inferior boundaries of the floor of the ventricle. At the lowest part of the calamus scriptorius, and also along each lateral boundary of the floor, the epithelial roof becomes thickened at its attachment to the parts of the medulla oblongata. The small semilunar lamina which stretches across between the inferior parts of the two clavæ at the calamus scriptorius and overhangs the opening of the central canal is termed the **obex** (Fig. 456, p. 551). A downwardly directed protrusion of the epithelial roof is often found behind the obex.

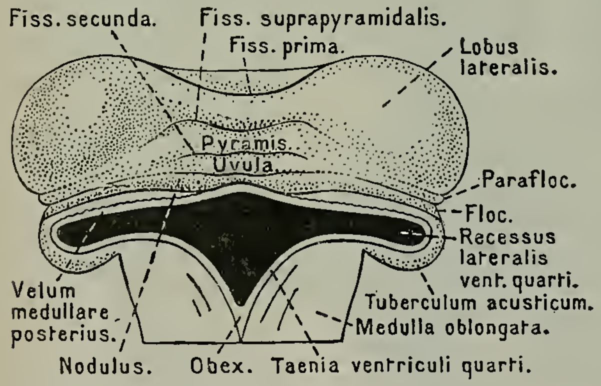

Fig. 484.—The Posterior Aspect of a Fœtal Cerebellum and Medulla Oblongata.

The Histogenesis and Minute Structure of the Cerebellum.

The developmental history of the cerebellum presents certain peculiar features which seem quite enigmatic unless considered from the point of view of the evolution of the connexions and functions of the organ. The cerebellum is derived from part of the alar lamina of the rhombencephalon, and at an early stage of its development the rudiment shows the regular lamination into ependyma, mantle layer, and marginal layer, which has already been described as distinctive of the corresponding place of development in the whole nervous system. The cells of this mantle layer are to be looked upon as an outlying (superior) part of the receptive nucleus of the vestibular nerve, the cells to which information concerning the position and movements of the body as a whole or of the head will be transmitted from the semicircular ducts of the internal ear. But, if such information is to be put to any use in influencing behaviour, it is obvious that the activity of these cerebellar cells must, firstly, be correlated with visual impressions, which also supply information concerning the position and movements of the body, and with all those nerves which are bringing into the encephalon or spinal medulla impressions of touch, pressure, or any other information concerning the state of the muscles, tendons, joints, or other structures which are concerned in movements; and, secondly, they must be brought to bear upon the various motor nuclei and other motor regulating parts of the brain (such as the red nucleus, tectum, mesencephali, basal ganglia, and cerebral cortex) to which the co-ordinating influence of the cerebellum is essential for the properly adjusted performance of complex actions.

The neuroblasts which receive all these extrinsic sensory impulses, visual, tactile, musculosensory, et cetera, collect at the threshold of what was originally the vestibular cerebellar rudiment; and they can be seen during the latter part of the second month migrating from the rhombic lip into the marginal layer of the cerebellum, until eventually its whole surface has been invaded by these alien neuroblasts, so that the originally non-nucleated marginal layer becomes a densely packed granular layer (**stratum marginale embryonale**). When this stage is reached the cerebellum consists of an inner ependymal layer, a mantle layer crowded with locally developed neuroblasts, a clear layer (the inner part of the original marginal layer), and the superficial layer of neuroblasts which have invaded the outer part of the marginal layer. As development proceeds in the mantle layer the axons of its neuroblasts are directed mainly towards the ventricular surface—the reverse of what happens in the spinal medulla; and as these fibre-masses increase in quantity the main part of the mantle layer becomes pushed farther and farther away from the ependyma by the accumulation of their own (and other) axons. Some of the neuroblasts, however, do not become pushed out into the line of the embryonic cerebellar cortex, but remain behind amidst the fibre-mass and receive the axons that come from the cortical cells. These neuroblasts left amidst the fibres gradually assume the form of the dentate, fastigial, globose, and emboliform nuclei already described; and their axons pass out (as the brachia conjunctiva) to the thalamus, mesencephalon, and pons. In the meantime many of the neuroblasts of the mantle layer have been converted into the large pear-shaped **Purkinje-cells**.

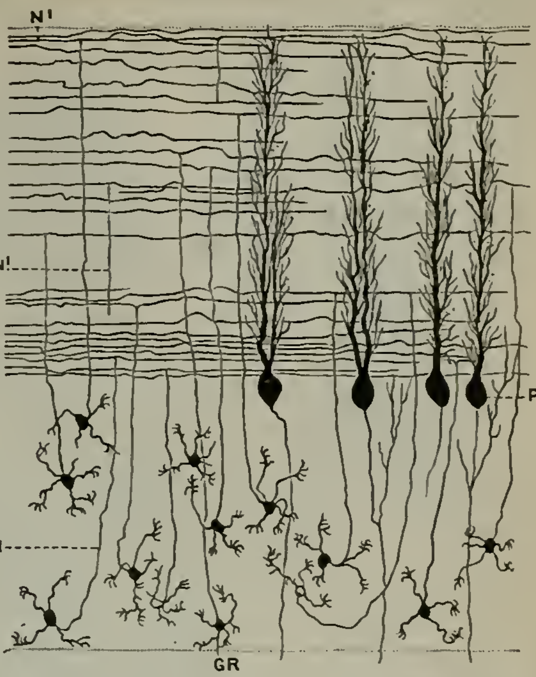

Fig. 485.—Section through the Molecular and Granular Layers in the Long Axis of a Cerebellar Folium. (After Kölliker.)

Treated by the Golgi method.

P. Cell of Purkinje.
GR. Granule cells.
N. Axon of a granule cell.
N¹. Axons of granule cells in molecular layer.

While these events have been occurring in the true mantle layer a peculiar process has been taking place in the superficial layer of immigrant cells. One by one they begin to leave their places upon the surface and dip into the mantle layer; many of them pass between the Purkinje-cells to a deeper plane, where they cease their wanderings and form a densely packed layer of granule cells (Fig. 485), the axons of which indicate the course of these migrations.

Minute Structure of a Cerebellar Folium.

A cerebellar folium is composed of a central core of white matter, covered with a layer of gray matter. The gray cortex is arranged in two very evident layers, viz., a superficial **molecular layer** and a subjacent rust-coloured **granular layer**. Between these strata a single layer of large cells, termed the **cells of Purkinje**, is disposed in the form of a very nearly continuous sheet. The cells of Purkinje constitute the most characteristic, and probably the most essential, constituents of the cerebellar cortex.

The **cells of Purkinje** are most numerous on the summit of the folium. At the bottom of the sulci which intervene between the folia they become fewer in number, and, therefore, looser in their arrangement. Each consists of a large flask-shaped or piriform cell body, the narrow end of which projects into the molecular layer, whilst the thicker, deeper end rests on the granular layer. From the latter arises a **single axon**, which passes into the granular layer and presents the peculiarity of almost immediately assuming its medullary sheath. From this axon a few collateral branches soon arise, which, taking a recurrent course, enter the molecular layer, to end in connexion with certain of the adjoining cells of Purkinje. They would seem to have the function of binding together adjacent cells, and thus enabling them to carry on their operations in harmony with each other.

The **dendritic processes** spring from the narrow end of the cell in the form of either one or perhaps two stout stalks. These ascend into the molecular layer, branching and rebranching until an arborescent arrangement of extraordinary richness and extent results. The dendritic branches extend throughout the entire thickness of the molecular layer, and the branching takes place in one plane only, viz., in a plane which is transverse to the long axis of the folium. Consequently, it is only when transverse sections through a folium are made that the full dendritic effect is obtained (Fig. 486); in sections made parallel to the long axis of the folium the cells are seen in profile, and are observed to occupy quite a narrow area (Fig. 485). The branching of the dendrites of a cell of Purkinje may, therefore, be compared to that which takes place in the case of a fruit-tree which is trained against a wall.

In the **molecular layer** the cells are not very numerous, and of these the most characteristic are the **basket-cells** which lie in the deeper part of the layer. In addition to numerous dendrites the basket-cell gives off an axon which runs transversely, as regards the long axis of the folium, between the planes of adjacent dendritic arborisations of the cells of Purkinje. At first very fine, these axons gradually become coarse and thick, and at intervals they give off collaterals which run towards the bodies of the cells of Purkinje. Reaching these, they break up into an enormous number of fine terminal branches, which enclose the cells of Purkinje, as well as the short non-medullated portions of their axons, in a close basket-work of fine filaments.

The **granular layer** is, for the most part, composed of large numbers of small granule-like bodies closely packed together. Each of these possesses a somewhat large nucleus, with a very small amount of surrounding protoplasm. From the cell body three or four, or perhaps five, dendrites and one axon proceed. The **dendrites** are short and radiate out from different aspects of the cell body. They end in tufts of claw-like twigs, which either embrace or are otherwise in contact with neighbouring granule cells. The whole multitude of granule cells, therefore, are brought into intimate connexion with each other. The **axon** passes into the molecular layer, in which it ends, at a varying distance from the surface, by dividing into two branches. These diverge so sharply from each other that they form almost a right angle with the parent stem, and they run parallel to the long axis of the folium, threading their way among the branches of the various dendritic planes of the cells of Purkinje and entering into contact association with them. When it is borne in mind that the number of granule cells is very great, and that each sends an axon into the molecular layer, the important part which these fibres, with their longitudinal branches, take in building up the molecular layer will be understood. They are found pervading its entire thickness—from the surface down to the bodies of the cells of Purkinje.

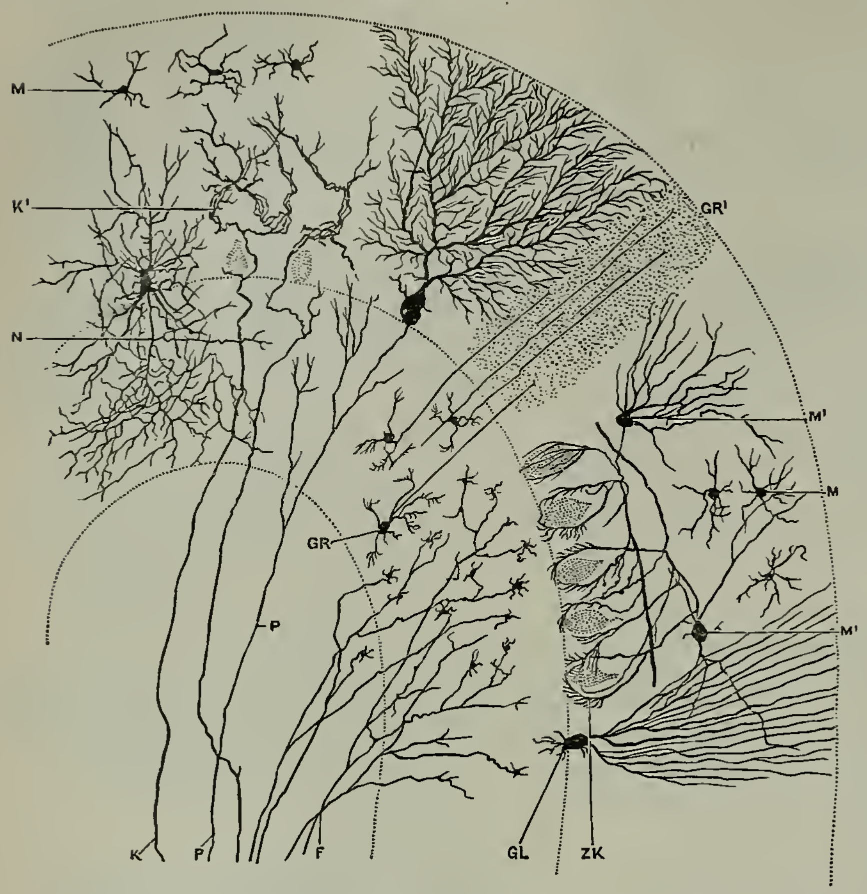

FIG. 486.—TRANSVERSE SECTION THROUGH A CEREBELLAR FOLIUM. (After Kölliker.)

Treated by Golgi's method.

P. Axon of cell of Purkinje.
F. Moss fibres.
K and K^1. Fibres from white core of folium ending in molecular layer in connexion with the dendrites of the cells of Purkinje.
M. Small cell of the molecular layer.
GR. Granule cell.
GR^1. Axons of granule cells in molecular layer cut transversely.
M^1. Basket-cells.
ZK. Basket-work around the cells of Purkinje.
GL. Neuroglial cell.
N. Axon of an association cell.

THE MESENCEPHALON.

The **mesencephalon** or **mid-brain** is the short, narrow part of the brain-stem which occupies the aperture of the tentorium cerebelli (incisura tentorii), and connects the cerebrum, which lies above, with the parts which occupy the posterior cranial fossa. It is about three-quarters of an inch in length, and it consists of a dorsal part, composed of the **corpora quadrigemina**, and a much larger ventral part, which is formed by the two **pedunculi cerebri**.

The pedunculi cerebri can be seen to some extent on the base of the brain, where they bound the posterior part of the interpeduncular fossa. Encircling the upper end of each cerebral peduncle, where it emerges from the cerebrum, is the optic tract (Fig. 497, p. 592).

The mesencephalon is tunnelled from below upwards by a narrow passage, called the **aquæductus cerebri**, which connects the fourth ventricle with the third ventricle (Fig. 451, p. 543). This channel lies much nearer the dorsal aspect than the ventral aspect of the mesencephalon.

Corpora Quadrigemina.—This name is applied to four rounded eminences or

colliculi on the dorsal aspect of the mesencephalon (Figs. 451 and 487). The **superior pair** are larger and broader than the **inferior pair**, but they are not so well defined nor are they so prominent. A longitudinal and a transverse groove separate the colliculi from each other. The longitudinal groove occupies the median plane and extends upwards to the posterior commissure of the brain. The superior end of this groove widens out into a shallow depression, in which the **pineal body**, a small conical structure which belongs to the diencephalon, rests. From the lower end of the same groove a short but well-defined and projecting band, the **frenulum veli**, passes to the anterior medullary velum, which lies immediately below the inferior colliculi. The transverse groove curves round below each of the superior pair of colliculi and separates them from the inferior pair. It is also continued in an upward and ventral direction on the lateral aspect of the mesencephalon.

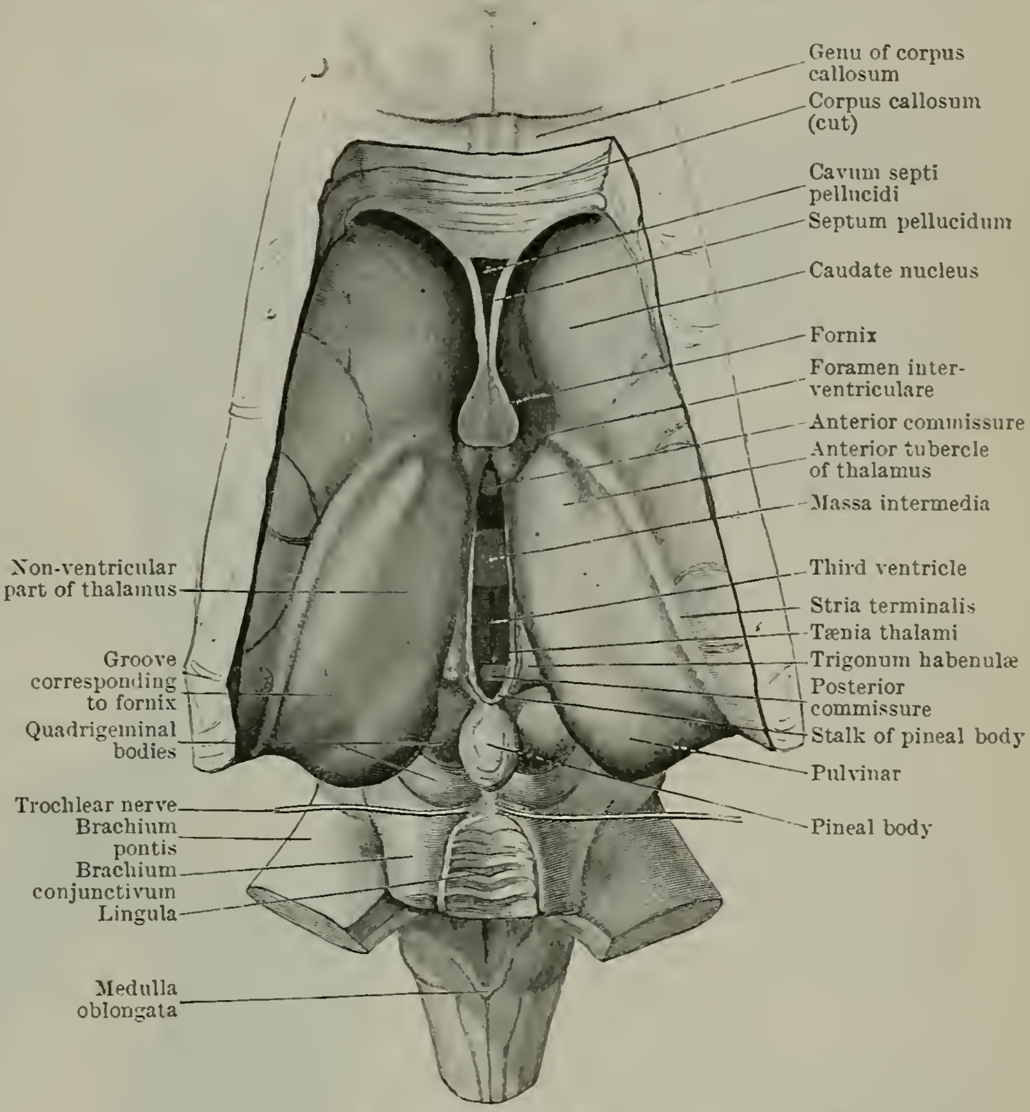

FIG. 487.—THE CORPORA QUADRIGEMINA AND THE NEIGHBOURING PARTS.

The quadrigeminal bodies are not marked off laterally from the sides of the mesencephalon, but each has in connexion with it, on this aspect, a prominent strand, which is prolonged superiorly and ventrally towards the thalamic region. These strands are called the **brachia of the corpora quadrigemina**, and they are separated from each other by a continuation, on the side of the mesencephalon, of the transverse groove which intervenes between the two pairs of colliculi.

The **corpus geniculatum mediale** is closely associated with the brachia, although it does not form part of the mesencephalon, but belongs to the prosencephalon. It is a small, sharply defined oval eminence, which lies on the lateral side of the superior part of the mesencephalon under shelter of the posterior end of the thalamus.

The **brachium quadrigeminum inferius**, proceeding upwards from the colliculus inferior, advances towards the corpus geniculatum mediale and disappears from view under cover of this prominence.

The **brachium quadrigeminum superius** is carried upwards and ventrally between the overhanging thalamus and the corpus geniculatum mediale. A superficial examination of the mesencephalon is sufficient to show that, while a large part of this strand enters the corpus geniculatum laterale, a considerable portion is a continuation of the lateral root of the optic tract.

Pedunculi Cerebri.—The **cerebral peduncles** (Figs. 488 and 497) appear upon the ventral or basal aspect of the mesencephalon as two large rope-like strands which emerge from the cerebral hemispheres and disappear below by plunging into the pars basilaris of the pons. At the place where each peduncle emerges from the corresponding side of the cerebrum it is encircled by the optic tract.

Each pedunculus cerebri is composed of two parts, viz., a dorsal tegmental part (**tegmentum**), which is prolonged upwards into the region below the thalamus (hypothalamus), and a ventral portion (**basis pedunculi**), which, when traced upwards into the cerebrum, is seen to take up a position on the lateral side of the thalamus and to be continuous with the internal capsule of the brain; and an intermediate part, the **substantia nigra.** When the base of the brain is examined, it is the basis pedunculi which is seen, and it is observed to be white in colour and streaked in the longitudinal direction. In the tegmentum the longitudinally-arranged fibres are, in large part, *corticipetal*, or, in other words, fibres which are ascending towards the cortex of the cerebrum; the basis pedunculi, on the other hand, is composed entirely of longitudinal strands of fibres which are *corticifugal*, or fibres which descend from the cerebral hemisphere.

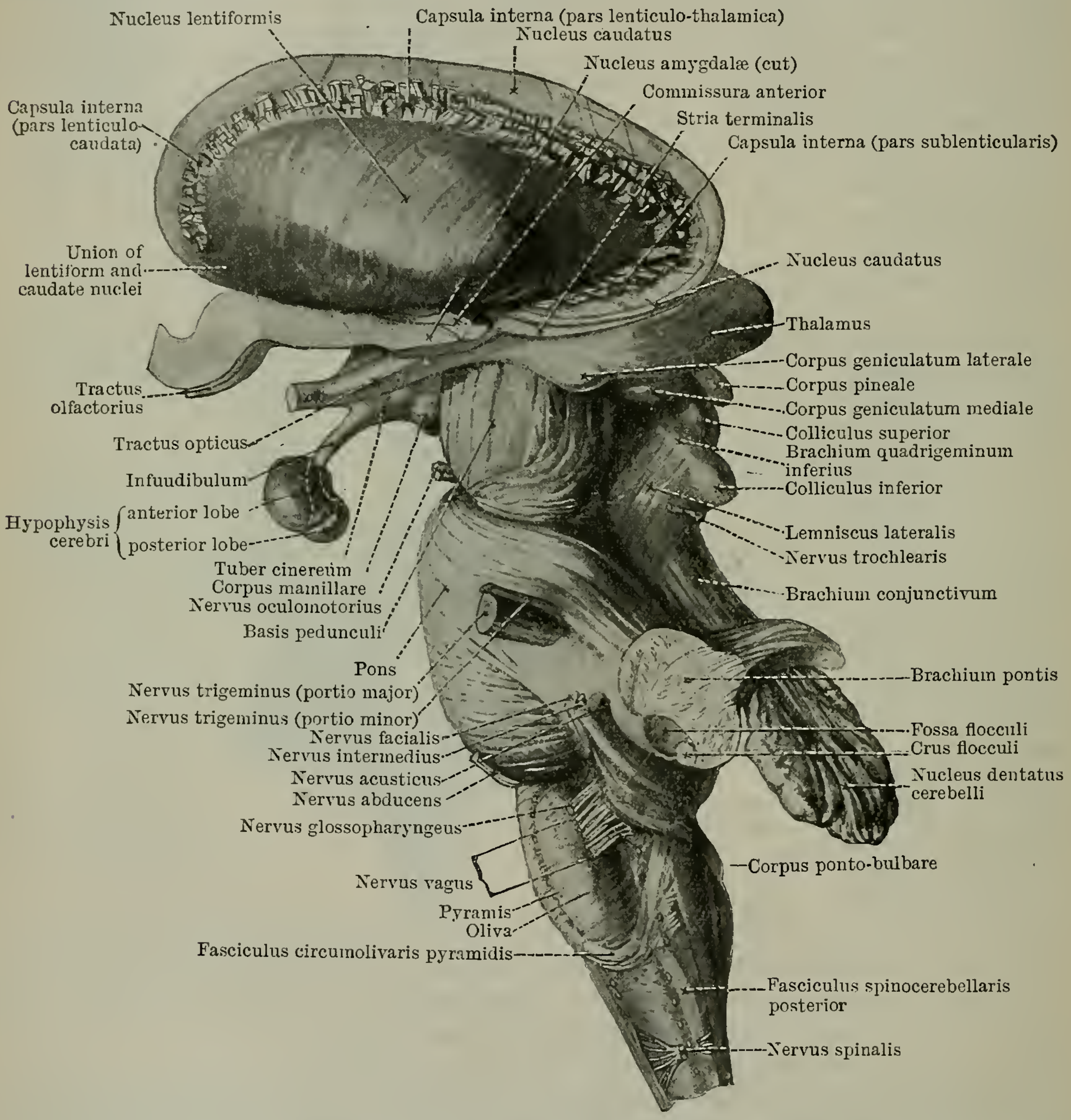

Fig. 488.—The Left Lateral Aspect of the Brain-stem after the Cerebral Hemisphere (except the Corpus Striatum) and the Cerebellum (except the Nucleus Dentatus) have been removed

On the surface of the mesencephalon the separation between the tegmental and basal portions of the pedunculus cerebri is clearly indicated by a medial and a lateral groove. The medial furrow is the more distinct of the two. It looks into the interpeduncular fossa, and from it emerge the fila of the oculomotor nerve. It is termed, therefore, the **sulcus n. oculomotorii.** The lateral groove, which is placed on the lateral aspect of the mesencephalon, is called the **sulcus lateralis** [**mesencephali**]. Its lower end becomes continuous with the furrow between the brachium pontis and brachium conjunctivum of the cerebellum.

A close inspection of the lateral surface of the tegmental part of the pedunculi cerebri, below the level of the brachia, will reveal some faintly-marked bundles of fibres curving obliquely upwards and backwards to reach the inferior colliculus (Fig. 488, p. 582). These are fibres of the **lateral lemniscus**, coming to the surface at the sulcus lateralis and sweeping over the subjacent brachium conjunctivum to gain the inferior colliculus, inferior brachium, and medial geniculate body.

INTERNAL STRUCTURE OF THE MESENCEPHALON.

When transverse sections are made through the mesencephalon the aquæductus cerebri is seen to be surrounded by a thick layer of gray matter, which receives the name of the **stratum griseum centrale** or the **central gray matter of the aqueduct**. On the dorsal aspect of this gray matter the corpora quadrigemina form a layer which separates it from the surface, and to which the term **lamina quadrigemina** is applied. On the anterior and lateral aspects of the central gray matter are the tegmental portions of the cerebral peduncles; whilst, intervening between each of the tegmenta and the corresponding basis pedunculi, there is a conspicuous mass of dark pigmented matter, termed the **substantia nigra**.

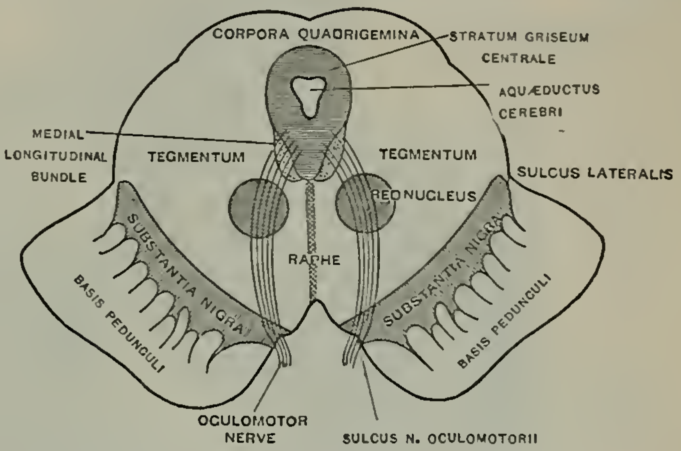

Fig. 489.—Diagrammatic View of the Cut Surface of a Transverse Section through the Superior Part of the Mesencephalon.

Aquæductus Cerebri and Stratum Griseum Centrale.—The aqueduct is the canal which leads from the fourth ventricle below, upwards through the mesencephalon, to the third ventricle above. It is not quite three-quarters of an inch in length, and it lies much nearer the dorsal than the ventral surface of the mesencephalon. When examined in transverse section, it presents a triangular outline as it passes into the fourth ventricle and a T-shaped outline close to the third ventricle. In the intermediate part of its course it assumes different outlines, and not always the same form at the same level in different specimens.

The aqueduct is lined with ciliated epithelium, and outside this is the thick layer of central gray matter, which is directly continuous below with the gray matter spread out on the floor of the fourth ventricle, and above with gray matter on the floor and sides of the third ventricle. Scattered more or less irregularly throughout the central gray matter are numerous nerve-cells of varying forms and sizes, whilst in addition to these there are three definite collections or clusters of cells, which constitute the nuclei of origin of the trochlear nerve, the oculomotor nerve, and the mesencephalic root of the trigeminal nerve. The position and relations of these will be given at a later stage.

Substantia Nigra.—When seen in transverse section, the **substantia nigra** presents a semilunar outline. It consists of a mass of gray matter, in the midst of which are large numbers of deeply pigmented nerve-cells. It is only when this substance is examined in bulk that it appears dark; in thin sections it does not differ much in colour from ordinary gray matter, although, under the microscope, the brown-coloured cells stand out very conspicuously, even under low powers. The substantia nigra is disposed in the form of a thick layer, interposed between the tegmental and basal portions of the cerebral peduncle. It begins below at the superior border of the pons and extends upwards into the hypothalamus. The margins of this layer of dark-coloured substance come to the surface at the oculomotor and the lateral sulci of the mesencephalon, and its medial part is traversed by the emerging fila of the oculomotor nerve. It is not equally thick throughout. Towards the lateral sulcus it becomes thin, whilst it thickens considerably near the medial aspect of the pedunculus cerebri. The surface of the substantia nigra, which is turned towards the tegmentum, is concave and uniform; the opposite surface is convex and rendered irregular by the presence of numerous slender prolongations of the substance into the basis pedunculi.

The morphological and physiological significance of the substantia nigra is not fully understood, and the connexions established by its cells are imperfectly known. Bechterew, however, is of the opinion that fibres arising in the motor area of the cerebral cortex end in relationship with the cells of the substantia nigra, the axons of which proceed to the motor trigeminal nucleus for the purpose of co-ordinating the muscles of mastication.

Colliculi Inferiores (or **inferior quadrigeminal bodies**).—Each **inferior colliculus** is composed largely of a mass of gray matter which, in transverse section, presents an oval outline (Fig. 520, p. 584). This central nucleus is, to a large extent, encapsulated by white matter. Numerous cells of various sizes are scattered throughout it, and the whole mass is pervaded by an intricate interlacement of fine fibres, which are derived, to a large extent, from the lateral lemniscus.

In transverse sections through this region, the lateral lemniscus is seen to abut against the lateral margin of the central nucleus. Many of the fibres of this tract enter it at once and become dispersed amongst its cells; others sweep over its dorsal surface, so as to give it a superficial covering; whilst a third group is carried medially, in the form of a thin layer, on its ventral aspect, so as to mark it off from the subjacent central gray matter of the aqueduct (Fig. 499, p. 584). In this manner, therefore, the inferior colliculus becomes partially circumscribed by the fibres of the lateral lemniscus. Several of the lateral lemniscus fibres, which proceed over the superficial or dorsal aspect of the nucleus, reach the median plane and form a loose decussation with the corresponding fibres of the opposite side.

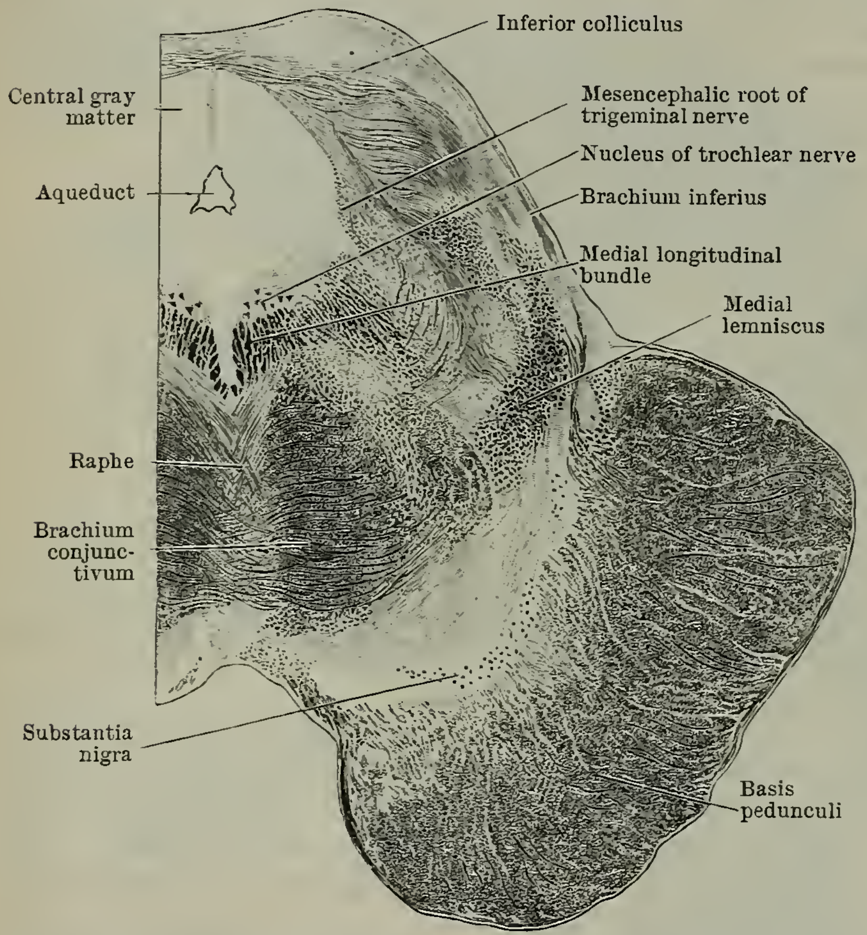

FIG. 490.—TRANSVERSE SECTION THROUGH THE MESENCEPHALON AT THE LEVEL OF THE INFERIOR COLLICULUS.

The intimate connexion which is thus exhibited between the fibres of the lateral lemniscus and the nucleus of the inferior colliculus is very significant. The lateral lemniscus, to a large extent, comes from the nuclei of termination of the cochlear nerve of the opposite side. We must associate, therefore, the inferior colliculus, and also the corpus geniculatum mediale, which likewise receives fibres from the lateral lemniscus, with the organ of hearing.

This view regarding the inferior colliculi is supported both by experimental and by morphological evidence. Speaking broadly, it may be stated that the inferior colliculi become prominent only in mammals, and then they are invariably correlated with a spirally wound and well-developed cochlea. That they have nothing to do with sight is shown by the fact that, when the eyeballs are extirpated in a young animal, the inferior colliculi remain unaffected, whilst the superior colliculi after a time atrophy (Gudden). When, on the other hand, the cochlear terminal nuclei are destroyed, fibres which have undergone atrophy may be followed to the inferior colliculi of both sides, but particularly to that of the opposite side (Baginski, Bumm, and Ferrier and Turner). A very considerable tract of ascending fibres takes origin within the inferior colliculus and passes upwards, in the inferior brachium, into the tegmentum subjacent to the medial geniculate body. Within the tegmentum they proceed up to the thalamus (Ferrier and Turner).

Colliculi Superiores (or **superior quadrigeminal bodies**).—The **superior colliculus** presents a more complicated structure (Fig. 491). Superficially, it is coated with a very thin layer of white matter, which is termed the **stratum zonale**. Underneath this there is a gray nucleus, called the **stratum griseum**, which, in transverse section, exhibits a crescentic outline and rests in a cap-like manner upon the subjacent part of the eminence. The succeeding two strata, which respectively receive the names of **stratum opticum** and the **stratum lemnisci**, present this feature in common, that they are composed of gray matter, traversed by numerous fibres. The source from which the fibres are derived is different, however, in each case.

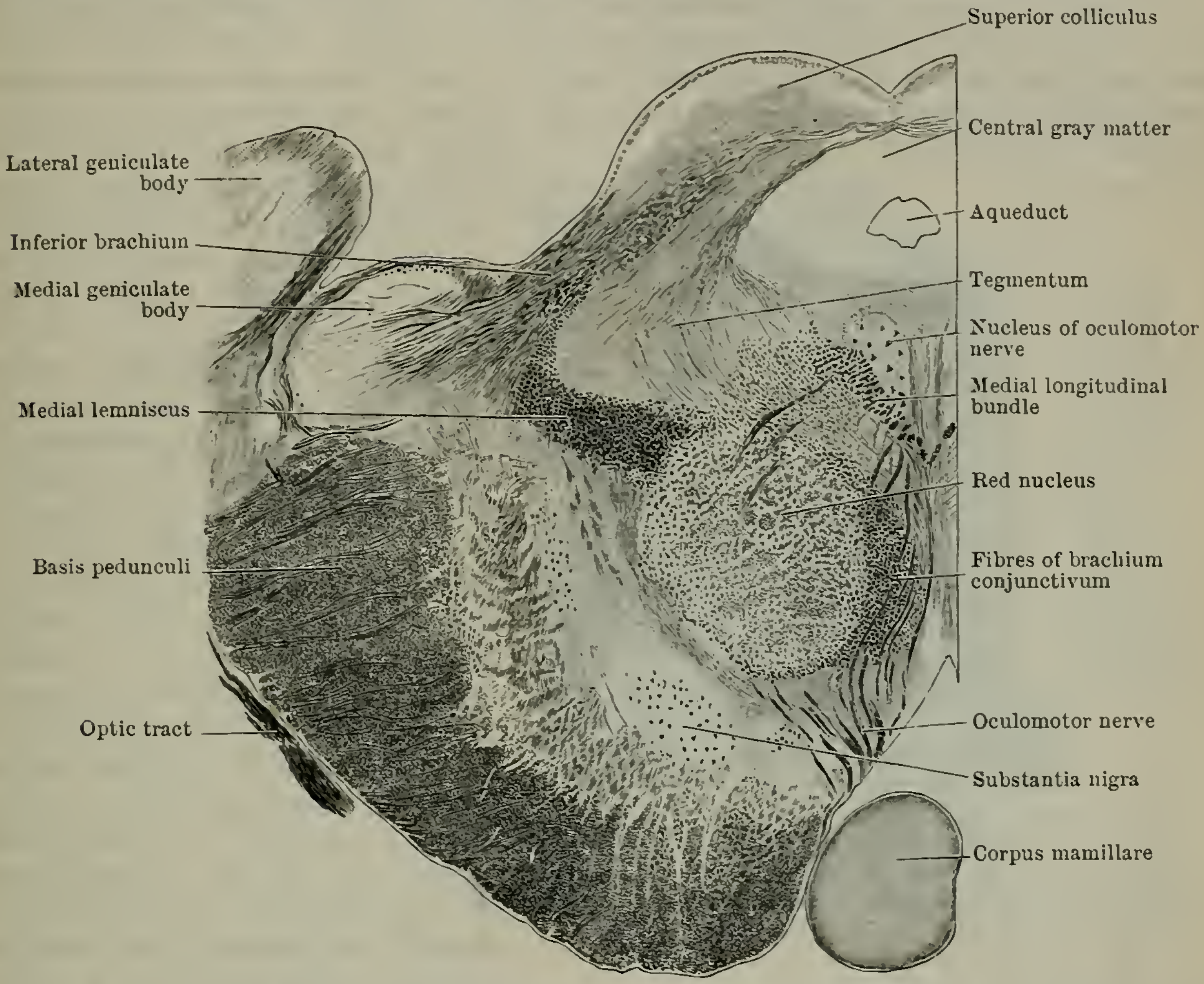

FIG. 491.—TRANSVERSE SECTION THROUGH THE MESENCEPHALON AT THE LEVEL OF THE SUPERIOR COLLICULUS.

Nerve-fibres reach the superior colliculus through—(1) the lemnisci and (2) the superior brachium.

The fibres of the lemnisci constitute the **stratum lemnisci**. The **superior brachium** contains fibres of two different kinds, viz., fibres from the optic tract and fibres from the cortex of the occipital lobe of the cerebrum. By the former it is connected with both retinæ, and by the latter with the visual centre in the occipital region of the cerebral cortex. The great majority of these fibres pass into the margin of the colliculus superior and form a layer—**stratum opticum**—underneath the stratum griseum, in which they ultimately terminate.

Tegmentum.—The tegmentum of the pedunculus cerebri may be regarded as the continuation upwards of the formatio reticularis of the medulla oblongata and the dorsal or tegmental portion of the pons into the mesencephalon. It consists, therefore, of fine bundles of longitudinal fibres intersected by arching fibres, which take a transverse and curved course. The interstices between these nerve-bundles is occupied by gray matter containing irregularly scattered nerve-cells. On its dorsal aspect the tegmentum is continuous, at the side of the central gray matter, with the bases of the corpora quadrigemina, whilst, ventrally, it is separated from the basis pedunculi by the substantia nigra. The tegmenta of opposite sides are, to some extent, marked off from each other in the median plane by a prolongation upwards of the median raphe of the pons and medulla oblongata, although, in the inferior part of the mesencephalon, this is much obscured by the decussation of the brachia conjunctiva. The two longitudinal strands, termed the **medial longitudinal bundle** and the **medial lemniscus**, are prolonged upwards throughout the entire length of the mesencephalon; and they present the same relations to the tegmentum as in the inferior parts of the brain. The medial longitudinal fasciculus is placed in relation to its dorsal aspect, whilst the lemniscus is carried up in its ventral part.

The tegmentum of the mesencephalon may be considered as presenting two parts: viz. (1) an inferior part, which is placed subjacent to the inferior colliculi and is largely occupied by the decussation of the brachia conjunctiva (Fig. 490); and (2) a superior part, subjacent to the superior colliculi, which is traversed by the emerging bundles of the oculomotor nerve. The superior part contains a large and striking nuclear mass, termed the **nucleus ruber** or the red tegmental nucleus (Fig. 491). In the inferior part of the central gray matter of the mesencephalon is the nucleus of the trochlear nerve; in the superior part, the nucleus of the oculomotor nerve is situated.

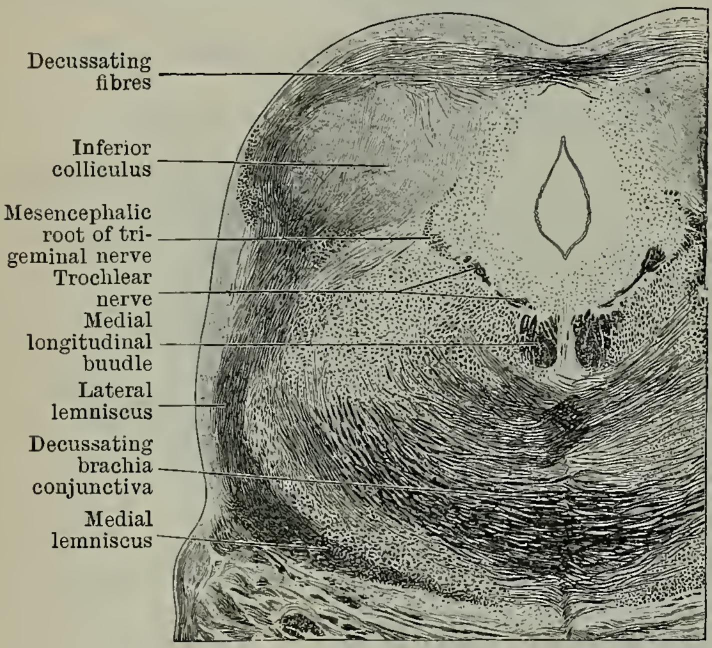
Decussating fibres
Inferior colliculus
Mesencephalic root of trigeminal nerve
Trochlear nerve
Medial longitudinal bundle
Lateral lemniscus
Decussating brachia conjunctiva
Medial lemniscus

FIG. 492.—SECTION THROUGH THE INFERIOR COLLICULUS AND THE TEGMENTUM OF THE MESENCEPHALON BELOW THE LEVEL OF THE NUCLEUS OF THE TROCHLEAR NERVE. (The decussation of the brachia conjunctiva and the course of the trochlear nerve in the central gray matter are seen.)

Brachia Conjunctiva.—As the **brachia conjunctiva** leave the pons and sink into the tegmentum of the mesencephalon, they undergo a complete decussation, subjacent to the inferior colliculi and the central gray matter (Figs. 490, 491, pp. 584, 585; and Fig. 492). In this manner each brachium is transferred from one side across the median plane, to the opposite side. The decussation is completed at the level of the superior borders of the inferior colliculi, and then each brachium proceeds upwards into the superior part of the tegmentum, where it encounters the red nucleus. Into this a large proportion of its fibres plunge, and come to an end in connexion with the nuclear cells. Many of the fibres, however, are carried around the nucleus so as to form for it a capsule, which is thicker on the medial than on the lateral side (Fig. 491). These are prolonged into the thalamus, and end ultimately in connexion with the ventral thalamic cells. The brachium conjunctivum is, therefore, a great efferent tract which issues from the nucleus dentatus of the cerebellum, crosses the median plane in the inferior part of the mesencephalon, and ends in the red nucleus and the ventral part of the thalamus.

Nucleus Ruber.—The **red nucleus** is a rounded nuclear mass, of a reddish tint in the fresh brain, which lies in the superior part of the tegmentum, and in the path of the brachium conjunctivum. In transverse section it presents a circular outline. It begins at the level of the inferior border of the superior colliculus and it extends upwards into the hypothalamus. At first it is small and is placed at a little distance from the median plane; but, as it proceeds upwards, it increases in bulk and approaches more nearly to the median raphe, and to its fellow of the opposite side. The curved emerging bundles of the oculomotor nerve pass through it on their way to the surface. The relation which the fibres of the opposite brachium conjunctivum present to it has been described. These fibres traverse its inferior part in such numbers that in Weigert-Pal specimens it presents a very dark colour; but higher up, as the fibres gradually end in the nuclear mass, they become less numerous in its midst, and the nucleus assumes a paler tint.

Numerous fibres which descend from the cerebral cortex, and others from the corpus striatum, enter the red nucleus. It also sends out fibres which proceed in two directions: (1) upwards into the thalamus; (2) downwards to the spinal medulla. The thalamic fibres may be regarded as carrying on the continuity of the path of the brachium conjunctivum after its nodal interruption in the red nucleus. The fibres to the spinal medulla, called the **rubro-spinal tract** and first described by Monakow, cross to the opposite side and then descend in the tegmentum to reach the lateral funiculus of the spinal medulla (Fig. 448, p. 536).

Fasciculus Longitudinalis Medialis.—The **medial longitudinal fasciculus** is a very conspicuous tract of longitudinal fibres which extends throughout the whole length of the medulla oblongata, pons, and mesencephalon, in the formatio reticularis or tegmental part of each. Below, at the level of the decussation of the pyramids, it becomes continuous with the fasciculus anterior proprius of the spinal medulla (p. 537), whilst, by its opposite or superior end, it establishes intricate connexions in the region immediately above the mesencephalon. Throughout its whole length it lies close to the median plane and its fellow of the opposite side. In the mesencephalon it is applied to the ventral aspect of the central gray matter, whilst in the pons and medulla oblongata it is situated immediately subjacent to the gray matter of the floor of the fourth ventricle. One of its most salient features is the intimate association which it presents with the three motor nuclei from which the nerves for the supply of the muscles of the eyeball take origin, viz., the oculomotor nucleus, the trochlear nucleus, and the abducent nucleus. The first two of these are closely applied to its medial and dorsal aspect, whilst the abducent nucleus is placed on its lateral side. Into each of these nuclei it sends many collaterals, and probably also some of its constituent fibres, and these end around the nuclear cells. It would appear, therefore, that one of the most important functions of this strand is to bind together these nuclei, and thus enable them to act in harmony one with the other. Fibres also enter the medial longitudinal fasciculus from the vestibular nucleus of the acoustic nerve system. The results obtained by degeneration would seem to indicate that, to a large extent, it is formed of fibres which run a short course within it.

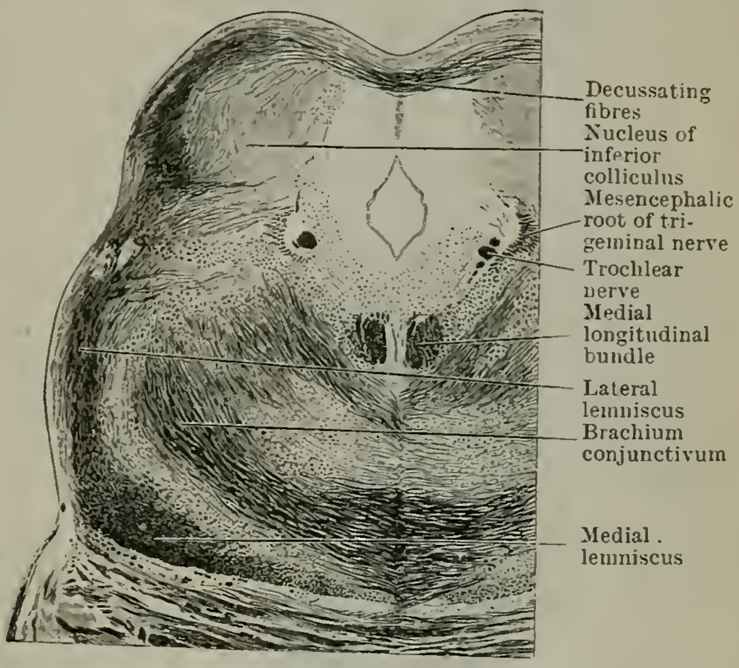
Decussating fibres
Nucleus of inferior colliculus
Mesencephalic root of trigeminal nerve
Trochlear nerve
Medial longitudinal bundle
Lateral lemniscus
Brachium conjunctivum
Medial lemniscus

FIG. 493.—SECTION THROUGH THE INFERIOR COLLICULUS AND THE TEGMENTUM OF THE MESENCEPHALON, AT A SLIGHTLY LOWER LEVEL THAN FIG. 492.

It is evident that it is a brain tract of high importance, from the fact that it is present in all vertebrates, and, further, that its fibres assume their medullary sheaths at an extremely early period. In fishes, amphibians, and reptiles, it is one of the largest bundles of the medulla oblongata. In man, its fibres medullate between the sixth and seventh months of fœtal life, and at the same time as the fibres of the fasciculus anterior proprius of the spinal medulla, with which it stands in connexion.

According to van Gehuchten and Edinger, it extends upwards beyond the level of the oculomotor nucleus, and in the thalamic region its fibres take origin from a special nucleus of its own in the gray matter of the third ventricle, immediately behind the level of the corpora mamillaria. Fibres also enter the medial longitudinal bundle from a nucleus common to it and the posterior commissure of the brain. This nucleus is placed in the anterior part of the central gray matter of the mid-brain. Held asserts that numerous fibres, arising from cells in the superior colliculus, curve in an arcuate manner in the tegmentum outside the central gray matter, to take part on the ventral aspect of this in what is called the **fountain decussation**. Reaching the opposite side, these fibres turn downwards and join the medial longitudinal bundle. The same authority considers that fibres from the ventral part of the posterior commissure can also be traced downwards into the medial longitudinal bundle. Edinger, on the other hand, places these fibres as a distinct tract on the ventral and lateral aspect of the medial longitudinal bundle, although in apposition with it.

Mendel believed that fibres from the oculomotor nucleus are carried down in the medial longitudinal bundle, and, from this, into the facial nerve for the supply of the orbicularis oculi and the corrugator supercilii, bringing these muscles, therefore, under the control of the same nucleus as the levator palpebræ superioris muscle. This view was adopted by many clinicians because this upper group of facial muscles is often spared in cases of facial paralysis; but Harman has adduced reasons in support of the view that there is a superior prolongation of the facial nucleus which innervates these muscles. It has been suggested further that fibres from the hypoglossal nucleus may, by the medial longitudinal bundle, reach the facial nerve, and through it the orbicularis oris. In this manner the same nucleus would hold sway over the tongue and the sphincter muscle of the lips. The close relation which exists between the ascending part of the intrapontine portion of the facial nerve and the medial longitudinal bundle would render the passage of

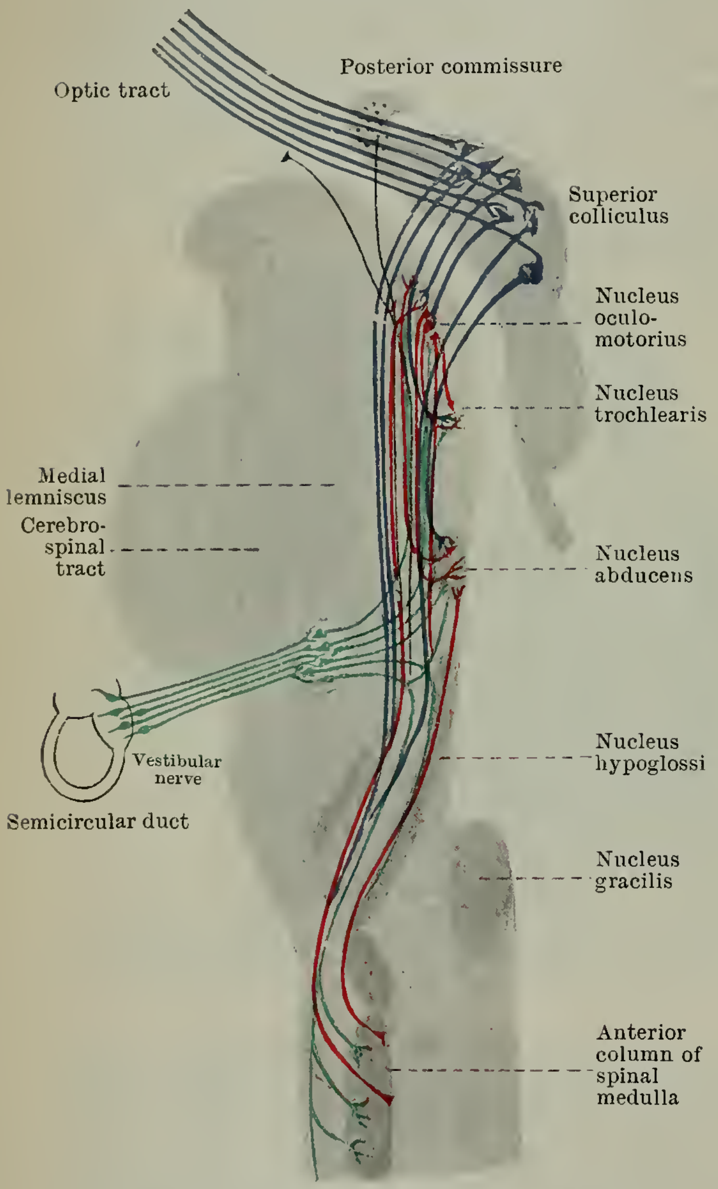

FIG. 494.—DIAGRAM REPRESENTING SOME OF THE CONSTITUENT ELEMENTS OF THE FASCICULUS LONGITUDINALIS MEDIALIS.

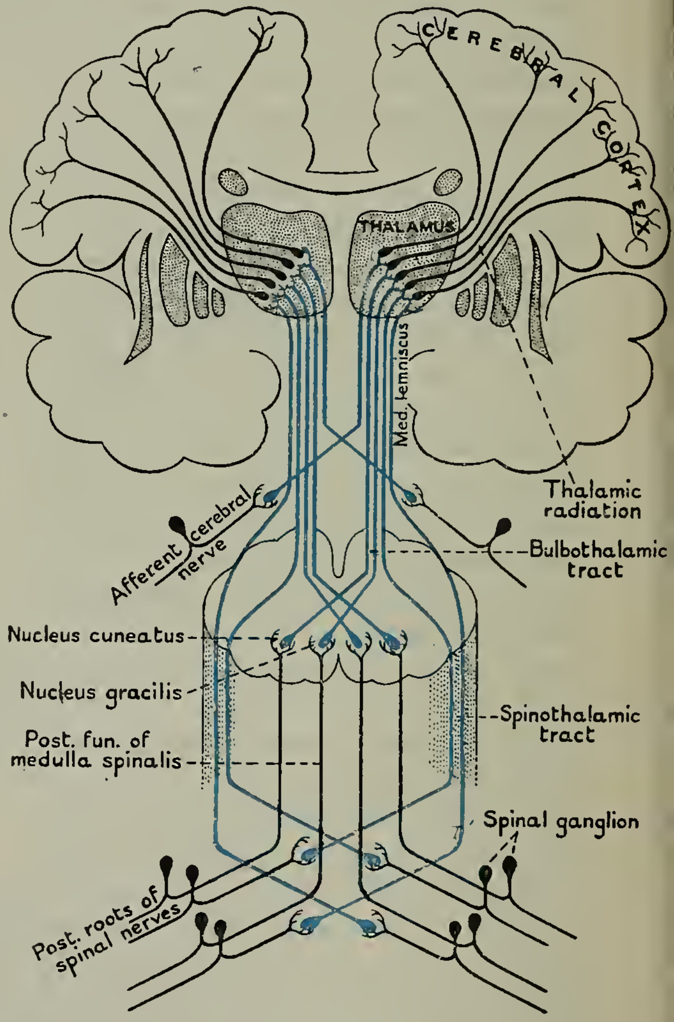

FIG. 495.—DIAGRAM OF THE CONNEXIONS OF THE MEDIAL LEMNISCUS AND ALSO OF CERTAIN OF THE THALAMO-CORTICAL FIBRES.

fibres from one to the other a circumstance which could easily be understood. But the balance of evidence now available inclines us to regard the facial nucleus as the origin of the fibres innervating all the facial muscles. Another interchange of fibres through the medial longitudinal bundle has been described by Duval and Laborde. According to these authorities, fibres from the abducens nucleus ascend in the medial longitudinal bundle into the mesencephalon, and establish connexions with that part of the oculomotor nucleus from which the nerve for the medial rectus of the opposite side derives its fibres. If this view is correct, it affords a ready and simple anatomical explanation of the harmonious action of the lateral and medial recti muscles in producing movements of the two eyeballs simultaneously to the right and to the left. From the investigations of E. H. Fraser it would appear that no fibres from the abducens nucleus go directly into the oculomotor nerve. The same observer has shown that many fibres from Deiters' nucleus, a part of the vestibular nucleus of the acoustic nerve to be described later in this account, enter the oculomotor and the trochlear nuclei through the path afforded by the medial longitudinal bundle.

Lemniscus Lateralis.—The **lateral lemniscus** is a definite tract of longitudinal fibres, which extends upwards through the lateral part of the tegmental substance of the superior portion of the pons and the mesencephalon. It is formed by the fibres of the corpus trapezoideum and striæ medullares in the inferior part of the pons, turning abruptly upwards and taking a course towards the quadrigeminal region. But the details of the arrangement and connexions of this important fasciculus must be left for fuller consideration when we are discussing the central connexions of the acoustic nerve.

Lemniscus Medialis.—The **medial lemniscus** has already been followed through the medulla oblongata and pons, and its position in each of these portions of the brain-stem has been defined (pp. 561 and 562). In the tegmentum of the inferior part of the mesencephalon it is carried up in the form of a more or less flattened band on the ventral aspect of the decussating brachia conjunctiva. To its lateral side, and forming an angle with it (as seen in transverse section), is the lateral lemniscus (Figs. 492 and 493), and at this level there is no clear demarcation between these two tracts. In the superior part of the mesencephalon the appearance of the red nucleus in the tegmentum causes the medial lemniscus to take up a more lateral and dorsal position, so that it now comes to lie subjacent to the corpus geniculatum mediale (Fig. 491, p. 585). At this level it exhibits a crescentic outline in transverse section, and the lateral lemniscus has to a large extent disappeared from its lateral side.

A part of the medial lemniscus, which is called the **fasciculus bulbothalamicus**, takes origin in the inferior part of the medulla oblongata from the gracile and cuneate nuclei of the opposite side (p. 561). Seeing that the posterior funiculus of the spinal medulla ends in these nuclei, the medial lemniscus may be considered to continue that funiculus upwards into the brain. Other fibres arise from the terminal nuclei of the various sensory cerebral nerves of the opposite side. The rest of the tract consists of the superior part of the **fasciculus spinothalamicus** from the spinal medulla. In the mesencephalon a considerable contribution of fibres is given by the medial lemniscus to the superior colliculus, and then the remainder of the tract proceeds into the lateral (ventro-lateral) nucleus of the thalamus. Here its fibres end amidst the thalamic cells.

Ganglion Interpedunculare and Fasciculus Retroflexus. — Immediately above the pons a small collection of nerve-cells is found in the median plane, wedged in between the two cerebral peduncles. It is all that is found in the human brain to represent a large nucleus projecting into the interpeduncular fossa in most other animals, especially those with a highly developed sense of smell. In this **interpeduncular ganglion** ends the **fasciculus retroflexus**, a tract of fibres which comes from the nucleus habenulæ of the epithalamus. We shall return to the consideration of this tract later.

Fountain Decussation. — If the region ventral to the medial longitudinal bundles is examined in the superior part of the mesencephalon a very close decussation of fibres in the median plane will be observed in the interval between the two red nuclei. This is the "**fountain decussation.**" According to Held, the fibres which take part in the dorsal portion of the fountain decussation (decussation of Meynert) come from the superior colliculi, and, after they have gained the opposite side, they turn downwards in the medial longitudinal fasciculus.

Many of the fibres that cross in this decussation enter a descending tract (*fasciculus tecto-bulbaris et spinalis*) which connects the corpora quadrigemina with the motor nuclei on the other side of the medulla oblongata and spinal medulla.

Basis Pedunculi.—The **basis pedunculi** presents a somewhat crescentic outline when seen in transverse section, and it stands quite apart from its fellow of the opposite side. It is composed of a compact mass of longitudinally directed fibres, all of which, as Déjerine has shown, arise in the cortex of the cerebrum and pursue an unbroken corticifugal course into and through the pedunculus cerebri. These fibres may be classified into two distinct sets, viz., cerebro-pontine and pyramidal or cerebro-spinal.

The **cerebro-pontine fibres** possess this leading character: in their course downwards they are all arrested in the ventral part of the pons, and end amidst the cells of the nuclei pontis. These tracts would appear to hold a very definite position within the crus. Thus, it has been satisfactorily established that the fibres coming from the temporal area of the cerebral cortex (*temporo-pontine strand*) form the lateral fifth of the basis pedunculi, whilst those coming from the frontal area (*fronto-pontine strand*) hold a similar position in the medial part of the basis pedunculi.

The **pyramidal fibres** constitute the great motor tract from the cerebral cortex. They occupy a position corresponding to the middle three-fifths of the basis. The pyramidal tract differs from the cerebro-pontine strands in being carried downwards through the ventral part of the pons and on the ventral aspect of the medulla oblongata into the spinal medulla, which it enters in the form of the fasciculi cerebrospinales lateralis and anterior. On its way through the pons and medulla oblongata it sends fibres across the median plane to the various motor nuclei on the opposite side of those sections of the brain-stem.

Development of the Mesencephalon.

Even in the early embryo the mesencephalon is the smallest section of the brain-tube, although the disproportion in size between it and the other primitive subdivisions of the brain is not nearly so marked as in the adult. Owing to the cephalic flexure, the mid-brain for a time occupies the summit of the head. Later it becomes completely covered over by the expanding cerebral hemispheres.

The corpora quadrigemina are derived from the alar laminæ of the side walls of the brain-tube, whilst the basal laminæ thicken and ultimately form the tegmenta. The original cavity of the mid-brain is retained as the aqueduct.

For a considerable time the cavity of the mesencephalon remains relatively large, and the lower part of its dorsal wall is carried downwards in the form of a diverticulum or recess, which overlaps the cerebellar plate. About this time, also, the dorsal wall shows a median fold or ridge. Both of these conditions are transitory. As the corpora quadrigemina take shape, the median ridge disappears and is replaced by the median longitudinal groove, which separates the quadrigeminal bodies. Only its inferior part is retained, and this is represented by the frenulum veli of the adult brain. The diverticulum of the cavity gradually becomes reduced, and finally disappears as the aqueduct assumes form.

The precise mode of origin of the red nucleus is not known.

Later in this account reasons will be given for the belief that the representatives of the neural crests in the region of the mesencephalon become absorbed and assimilated in the walls of the neural tube as it closes in.

THE DEEP CONNEXIONS OF THE CEREBRAL NERVES ATTACHED TO THE MEDULLA OBLONGATA, PONS, AND MESENCEPHALON.

There are twelve pairs of cerebral nerves, of which the inferior eight are attached to the medulla oblongata and pons. From above downwards these are named the trigeminal (fifth), the abducens (sixth), the facial (seventh), the acoustic (eighth), the glossopharyngeal (ninth), the vagus (tenth), the accessory (eleventh), and the hypoglossal (twelfth). Two others, the trochlear (fourth) and oculomotor (third) spring from the mesencephalon. The hypoglossal, the accessory, the greater part of the facial, the abducens, the motor root of the trigeminal, the trochlear and the oculomotor are efferent nerves; the acoustic, the nervus intermedius (sensory root of the facial) and the sensory root of the trigeminal are purely afferent nerves; whilst the vagus and the glossopharyngeal are composed of both efferent and afferent fibres. In all these cases (with a possible reservation in the case of part of the trigeminal) afferent fibres arise from ganglionic cells placed outside the brain and penetrate the brain-stem, to end in connexion with the cells of certain **nuclei of termination.** Efferent fibres, on the other hand, take origin within the brain as the axons of cells which are grouped together in certain places in the form of **nuclei of origin.**

Nuclei of Origin, or Motor Nuclei.—In the spinal medulla the nuclei of origin are represented by elongated columns of cells which run more or less continuously in the anterior column of gray matter of successive spinal segments, and from these the series of efferent anterior nerve-roots take origin. In the medulla oblongata, pons, and mesencephalon the nuclei of origin, or, in other words, the motor nuclei of the individual nerves, become, for the most part, discontinuous, and are represented by certain isolated clumps of compact gray matter, in which are placed the clusters of cells from which the fibres of the efferent nerves arise. The nucleus ambiguus, however, which consists of a column of cells from which root-fibres of the bulbar part of the accessory, of the vagus, and also of the glossopharyngeal are derived, is an exception to this rule. At the decussation of the pyramids, the anterior column of gray matter of the spinal medulla is broken up by the intercrossing bundles into a detached head and a basal part which remains in relation with the ventrolateral aspect of the central canal. Certain of the efferent nuclei of the medulla oblongata, pons, and mesencephalon lie in the line of the basal portion of the anterior column of gray matter of the spinal medulla, and, thus, close to the median plane. These are termed **medial somatic nuclei**, and are met with at different levels in the

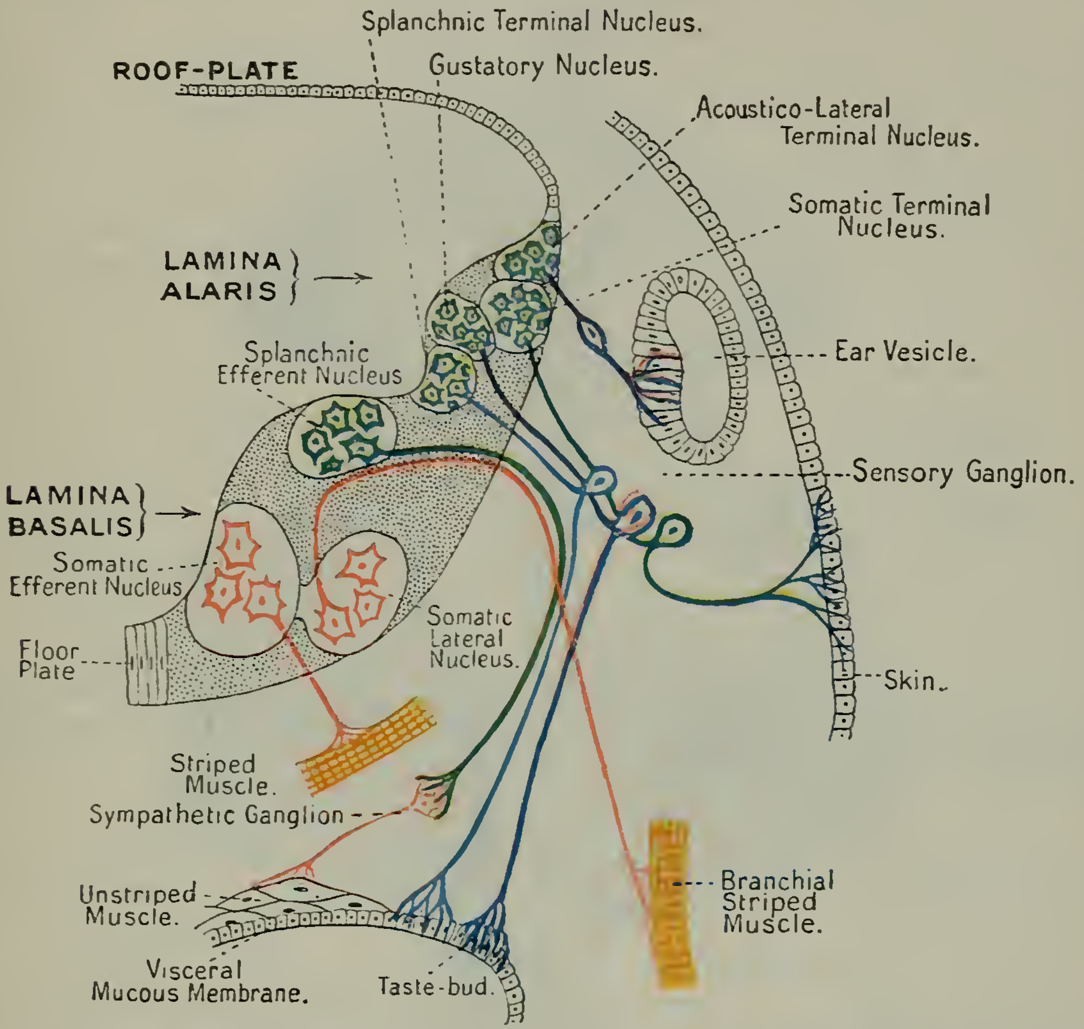

FIG. 496.—DIAGRAM REPRESENTING THE DIFFERENT KINDS OF COMPONENTS FOUND IN THE CEREBRAL NERVES AND OF THEIR NUCLEI OF ORIGIN OR TERMINATION.

brain-stem. This group comprises the hypoglossal nucleus, the abducens nucleus and, in the mesencephalon, the trochlear nucleus and part of the oculomotor nucleus. Other motor nuclei of origin are present in the form of isolated clumps or columns of gray matter, which lie at different levels in the medulla oblongata and pons in a more lateral and deeper situation. They are the nucleus ambiguus of the accessory, vagus and glossopharyngeal, the facial nucleus, and the nucleus of the motor root of the trigeminal nerve. From their position in the substantia reticularis of the medulla oblongata and pons they constitute a group to which the name of **lateral somatic nuclei** is applied.

In addition to these two columns of motor nuclei there is a third efferent column of **splanchnic nuclei** represented by the dorsal nucleus of the vagus and glossopharyngeal nerves, and similar nuclei emitting sympathetic fibres into the facial and oculomotor nerves. It is possible some splanchnic efferent fibres may pass into the trigeminal nerve.

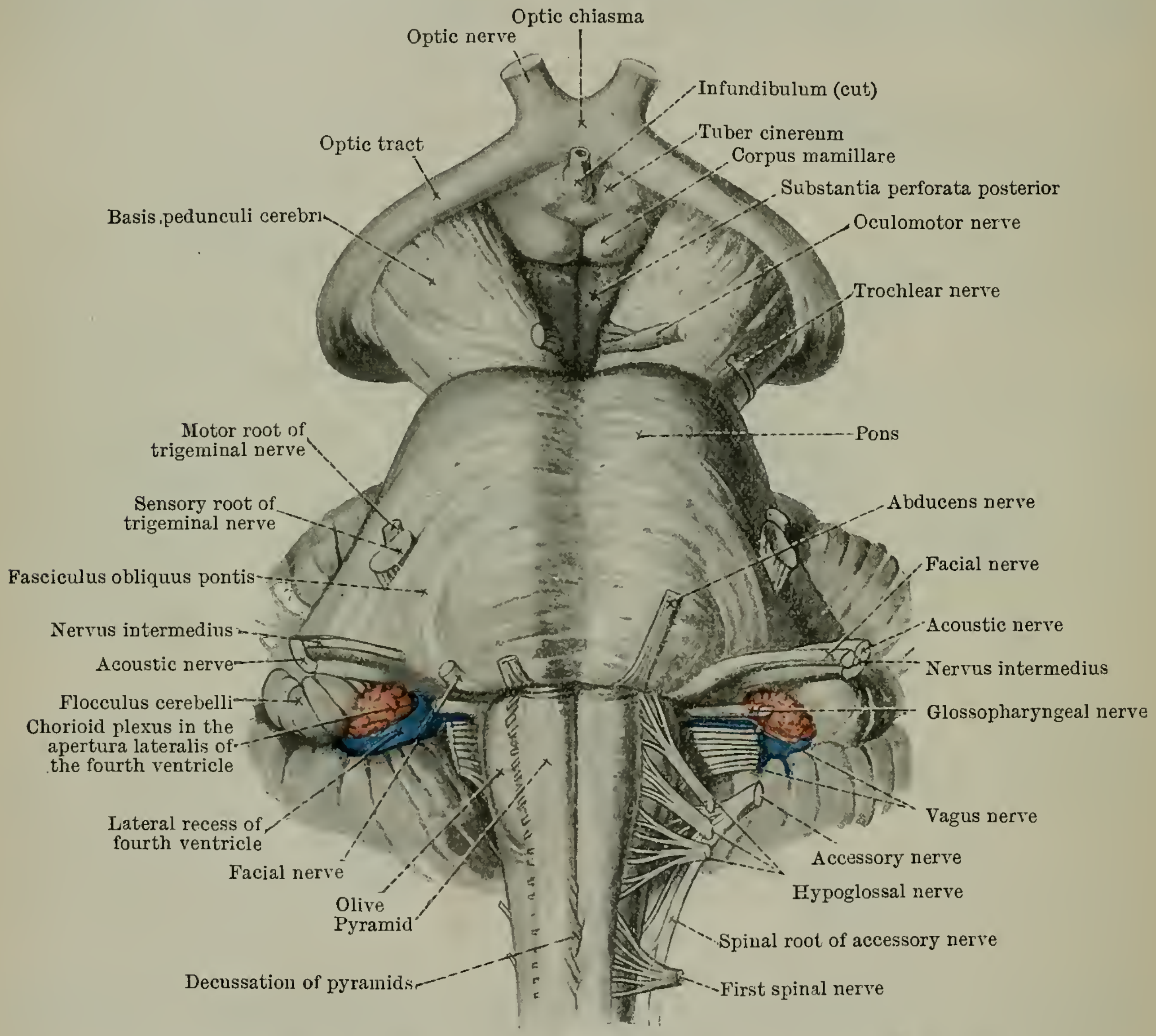

Fig. 497.—The Ventral Aspect of the Medulla Oblongata, Pons, and Mesencephalon, showing the nerve roots.

The different nuclei of origin of the efferent fibres which belong to the various cerebral nerves, both medial and lateral, are connected with the motor area of the cerebral cortex by fibres of the cerebro-spinal tract of the other side, which enter the nuclei and end in association with their cells.

Nuclei Terminales.—The general scheme of arrangement of the **terminal nuclei** has already been explained (Fig. 496); its details will be further elucidated as the various nerves are considered seriatim.

The axons of many of the cells of the nuclei of termination enter the substantia reticularis as arcuate fibres, and, crossing the median plane, are carried upwards in the substantia reticularis of the opposite side, to establish direct connexions with the thalamus and, indirectly through it, with the cerebral cortex (Fig. 495).

Others pass to the nuclei of motor nerves, to the cerebellum or other groups of nerve-cells, to form connexions necessary for the performance of reflex actions.

Nervus Hypoglossus.—The nucleus of origin of the **hypoglossal nerve**, the motor nerve of the tongue, lies in the substance of the medulla oblongata. It is composed of several groups of large multipolar cells, which closely resemble the cells in the anterior column of gray matter in the spinal medulla, and is pervaded by an intricate network of fine fibrils. In form it is elongated and rod-like, and in length it is about 18 mm. It extends from a point immediately above the decussation of the pyramids up to the level of the striæ medullares. The inferior portion of the nucleus is thus placed in the closed part of the medulla oblongata (Fig. 465, p. 561), whilst its superior part is situated in the open part (Fig. 466, p. 562). The former lies in that part of the central gray matter which is continuous with the basal part of the anterior column of gray matter of the spinal medulla. It is thus placed on the anterior and lateral aspect of the central canal, close to the median plane and the corresponding nucleus of the opposite side. The superior part of the nucleus occupies a position in the gray matter on the floor of the fourth ventricle, subjacent to the medial part of the surface area, which has been described under the name of the **trigonum hypoglossi**. Within the nucleus the axons of the cells arrange themselves in converging bundles of fine fibres, which come together and leave the ventral aspect of the nucleus as the fila radicularia of the nerve. The nerve bundles thus formed traverse the entire antero-posterior thickness of the medulla oblongata, between the substantia reticularis grisea and the substantia reticularis alba, and emerge on the surface, in linear order, at the bottom of the furrow between the olive and the pyramid. After they emerge these fibres collect to form three definite bundles like the anterior nerve-roots of three spinal nerves (Fig. 497). In the substance of the medulla oblongata the fila radicularia of the hypoglossal pass between the main inferior olivary nucleus and the medial accessory olivary nucleus, and many of them on their way to the surface pierce the ventral lamina of the main olivary nucleus.

No decussation between the nerves of opposite sides takes place in the medulla oblongata, but commissural fibres pass between the two nuclei (Kölliker). Further, numerous fibres from the opposite pyramidal tract enter the nucleus and end in connexion with its cells. The nucleus is thus brought into connexion with the motor area of the opposite side of the cerebral cortex.

Nervus Accessorius.—The **accessory nerve** also is a motor nerve, and it is generally described as consisting of a spinal and a cerebral or accessory part.

The **spinal part** of the nerve emerges by a series of roots which issue from the surface of the lateral column of the superior part of the spinal medulla as low down as the fifth cervical nerve. These take origin in a column of cells situated in the anterior column of gray matter of the spinal medulla, close to its lateral margin, and immediately behind the nerve-cells which give rise to the fibres of the anterior roots of the upper five cervical nerves. The cells of the accessory nucleus are large, multipolar, and in every respect similar to the motor cells of the spinal nerves. The axons from these cells leave the dorsal aspect of the nucleus in converging groups to form the fila radicularia or root-bundles of the nerve. These, in the first place, proceed straight backwards in the anterior column of gray matter. Reaching the bay between the two columns of gray matter, they turn sharply laterally into the white matter and traverse the lateral funiculus to gain their points of exit from the spinal medulla. At the decussation of the pyramids, fila, which join the accessory nerve, are seen to proceed from the detached head of the anterior column of gray matter.

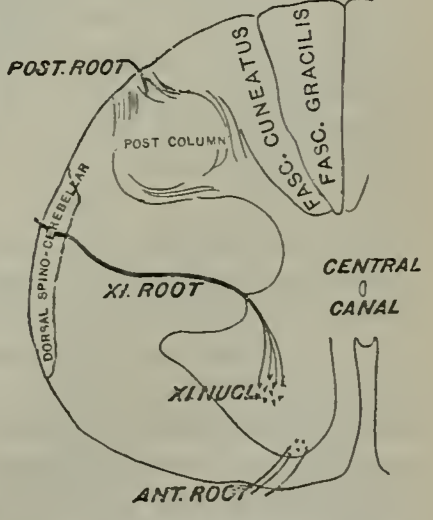

Fig. 498.—Diagram of the Spinal Origin of the Accessory Nerve. (After Bruce.)

The **cerebral part** of the accessory nerve has its nucleus of origin in the medulla oblongata; and its fila, as they proceed laterally from this, can be distinguished by the fact that they pursue a course on the ventral side of the tractus spinalis of the trigeminal nerve, whereas the vagus roots, with which they are apt to be confused, pass through or lie on the dorsal aspect of the trigeminal root (Kölliker). The nucleus of origin of the cerebral part of the accessory nerve is formed by the same column of cells which constitutes the **nucleus ambiguus**, and which, at a higher level, gives motor fibres to the vagus and glossopharyngeal nerves.

The part of the accessory nerve which takes origin in the spinal medulla supplies the sterno-mastoid and trapezius muscles. The cerebral portion joins the vagus, and through the external laryngeal and recurrent nerves it supplies the muscles of the larynx. The portion of the nucleus ambiguus from which it arises has thus been termed the laryngeal nucleus (Edinger) but it is not certain whether it is vagal or accessory.

Collaterals and fibres of the opposite lateral cerebro-spinal tract end in connexion with the cells of origin of the accessory nerve, and thus bring its nucleus into connexion with the motor area of the cerebral cortex. Fibres also from the posterior roots of the spinal nerves (afferent or sensory fibres) end in the nucleus.

Nervus Vagus, Nervus Glossopharyngeus.—The **vagus and glossopharyngeal nerves** present similar connexions with the brain, and they may therefore be studied together. The greater part of both nerves is composed of afferent fibres, which arise outside the brain-stem from ganglionic cells placed in relation to the nerve-trunks. Both nerves possess efferent fibres also, which spring from two special nuclei of origin situated within the medulla oblongata and termed respectively the **dorsal** or **splanchnic nucleus** and the **nucleus ambiguus**, which is the **somatic nucleus**. The afferent ganglionic fibres of the vagus and glossopharyngeal enter the brain by a series of roots which penetrate the medulla oblongata along the ventral side of the restiform body. Within the medulla oblongata they separate into two sets, viz., a series of bundles (composed chiefly of vagus fibres, *i.e.* afferent splanchnic), which end in the **dorsal nucleus of termination** of the vagus and glossopharyngeal nerves, and another series of bundles (composed chiefly of glossopharyngeal fibres, *i.e.* taste fibres), which join a conspicuous longitudinal tract of fibres called the **tractus solitarius**.

The **dorsal nucleus** (Figs. 461, p. 587, and 496, p. 591) of the vagus and glossopharyngeal nerves is mixed, and contains both motor cells which give origin to efferent fibres, and cells around which afferent fibres of the vagus, and possibly also of the glossopharyngeal nerve, break up into terminal arborisations. It very nearly equals in length the nucleus of the hypoglossal nerve, with which it is closely related. Above, it reaches as high as the striæ medullares, whilst, below, its inferior end falls slightly short of that of the hypoglossal nucleus. In specimens stained by the Weigert-Pal method the two nuclei offer a marked contrast. The hypoglossal nucleus presents a dark hue, owing to the enormous numbers of fine fibres which twine in and out amidst its cells; the vago-glossopharyngeal dorsal nucleus is pale, from the scarcity of such fibres within it. Its cells, like those of all splanchnic efferent nuclei, are much smaller than the somatic cells of the nucleus ambiguus. In the closed part of the medulla oblongata the dorsal vago-glossopharyngeal nucleus lies in the central gray matter immediately behind the hypoglossal nucleus, and upon the lateral aspect of the central canal; in the open part of the medulla oblongata it lies in the gray matter of the floor of the fourth ventricle, immediately to the lateral side of the hypoglossal nucleus and subjacent to the surface area termed the trigonum vagi or ala cinerea.

All the fibres which arise from this dorsal or splanchnic efferent nucleus are very fine, and in sections of the vagus nerve can readily be distinguished from the much coarser somatic fibres, which come from the nucleus ambiguus, and also from the medium-sized sensory fibres, which spring from the ganglia placed upon the nerves. The fine fibres from the dorsal nucleus are distributed (probably indirectly, *i.e.* after being interrupted in a peripheral ganglion), to the involuntary striped muscle of the œsophagus and heart, and the unstriped muscle of the œsophagus, stomach and respiratory system (van Gehuchten and Molhant, *La Névraxe*, June 15, 1912, p. 55).

The **nucleus ambiguus** (Figs. 461, 499, 496) gives origin to the somatic motor fibres of the glossopharyngeal and vagus nerves. All the fibres from this nucleus which pass into the glossopharyngeal nerve end in the stylo-pharyngeus muscle; the vagal branches are distributed to the striated muscles of the pharynx and larynx. The cells of the nucleus ambiguus are large, multipolar, and similar in every respect to the large cells in the anterior column of the spinal medulla. These cells are arranged in a slender column which is best developed in the open part of the medulla oblongata. Here the nucleus can easily be detected, in transverse sections, as a small area of compact gray matter which lies in the substantia reticularis grisea, midway between the dorsal accessory olive and the nucleus tractus spinalis nervi trigemini. It therefore lies more deeply in the substance of the medulla oblongata than the dorsal vago-glossopharyngeal nucleus. Kölliker states that it can be traced downwards as low as the level of the decussation of the medial lemniscus, and upwards as high as the place of entrance of the cochlear root of the acoustic nerve. From its dorsal aspect the axons of the cells proceed, and in the first instance they pass backwards towards the floor of the fourth ventricle; then, bending suddenly laterally and forwards, they join the afferent roots of the vagus and the glossopharyngeal nerves, and emerge from the brain in company with these.

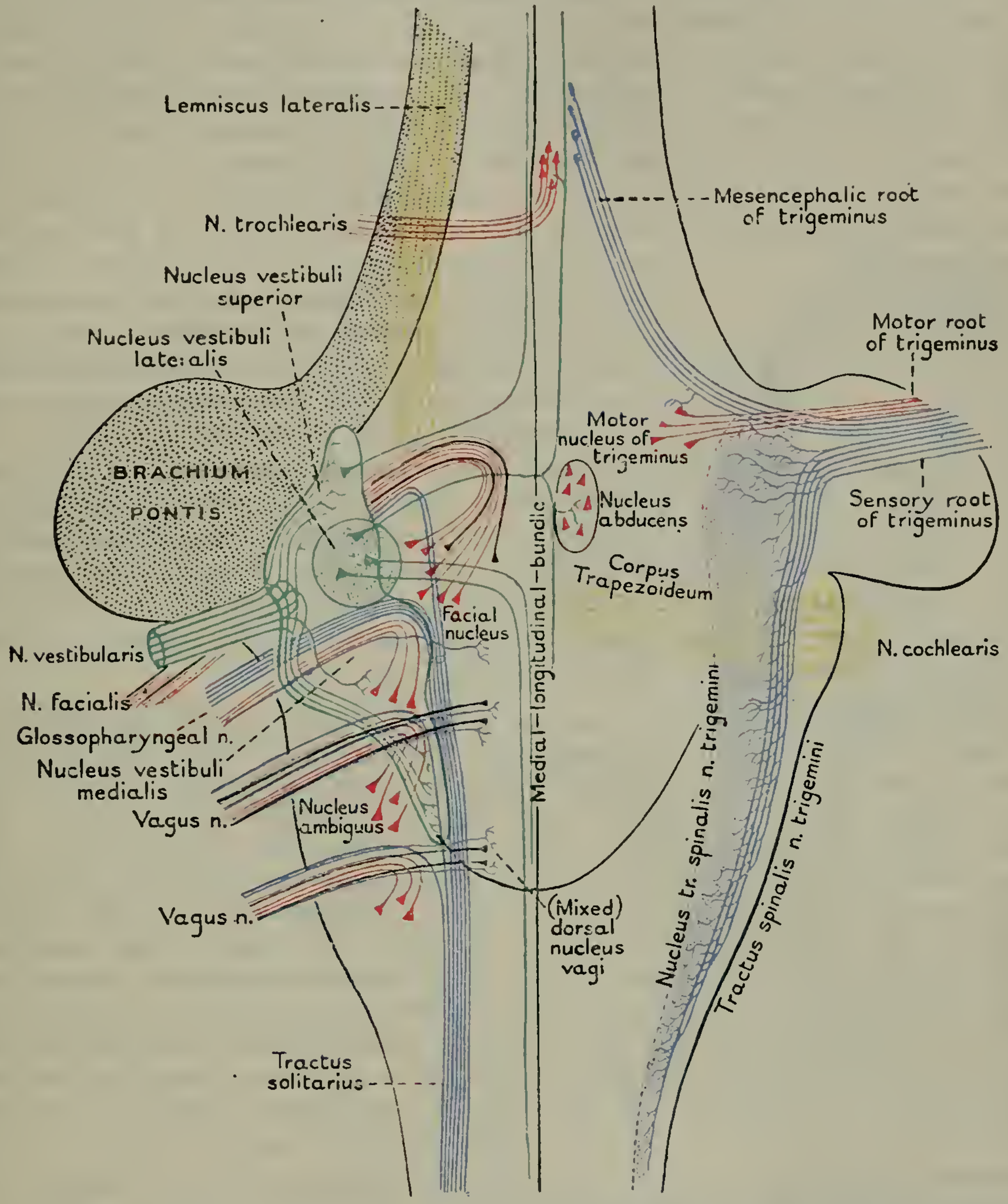
Lemniscus lateralis
N. trochlearis
Nucleus vestibuli superior
Nucleus vestibuli lateralis
BRACHIUM PONTIS
N. vestibularis
N. facialis
Glossopharyngeal n.
Nucleus vestibuli medialis
Vagus n.
Nucleus ambiguus
Vagus n.
Tractus solitarius
Mesencephalic root of trigeminus
Motor root of trigeminus
Motor nucleus of trigeminus
Nucleus abducens
Sensory root of trigeminus
Corpus Trapezoideum
Facial nucleus
Medial longitudinal bundle
N. cochlearis
Nucleus tr. spinalis n. trigemini
Tractus spinalis n. trigemini
(Mixed) dorsal nucleus vagi

FIG. 499.—DIAGRAM, showing the brain connexions of the vagus, glossopharyngeal, acoustic, facial, abducens, and trigeminal nerves.

Sensory or Terminal Nuclei of the Glossopharyngeal and Vagus. Splanchnic and Gustatory Components.—The cells in the portion of the dorsal nucleus which acts as a *nucleus of termination* are spindle-shaped in form and similar to those found in the posterior column of gray matter in the spinal medulla. In connexion with these cells, the greater number of the afferent fibres of the vagus nerve, and a small proportion of the afferent fibres of the glossopharyngeal nerve, end in fine terminal arborisations. A small part of the superior portion of the nucleus may be said to belong to the glossopharyngeal nerve and the remainder of the nucleus to the vagus nerve.

The **tractus solitarius** (Figs. 465, p. 561; 466, p. 562; and 499) is a round bundle of longitudinal fibres which forms a very conspicuous object in transverse sections through the medulla oblongata. It begins at the superior limit of the medulla oblongata, and can be traced downwards through its whole length. Its precise point of termination is not known, but some authorities believe that it is carried for some distance downwards into the superior part of the spinal medulla, and, according to Kölliker, to the level of the fourth cervical nerve. Most modern writers, however, limit it to the medulla oblongata. The relations of the tractus solitarius are not the same in all parts of its course. It lies immediately to the lateral side of the dorsal vago-glossopharyngeal nucleus; but, whereas in the superior part of the medulla oblongata it is situated somewhat on the ventral side of that nucleus, in the inferior, closed part of the medulla oblongata it is placed on its dorsal aspect. Throughout its entire length it is intimately associated with a column of gelatinous gray substance called the **nucleus tractus solitarii,** which constitutes the nucleus of termination in which its fibres end. When traced from above downwards, the tractus solitarius is observed to become gradually smaller owing to the loss of fibres which it thus sustains. The great bulk of the tractus solitarius is formed of fibres derived from the glossopharyngeal nerve; only a few of the afferent fibres of the vagus enter it, but fibres of the sensory root (**nervus intermedius**) of the facial also enter it. As the fibres of the three nerves join the fasciculus they immediately turn downwards, and at different levels come to an end in the associated nucleus tractus solitarii.

As the afferent root-bundles of the vagus and the glossopharyngeal nerves traverse the substance of the medulla oblongata in a backward and medial direction to reach the tractus solitarius and the dorsal nucleus of termination, they pass through the tractus spinalis of the trigeminal nerve and the nucleus of that tract. As the afferent root of the vagus passes through the trigeminal tractus spinalis and its nucleus, which is somatic sensory in nature, it gives off to this nucleus its own somatic sensory branches, the peripheral ends of which constitute the auricular branch, distributed to the skin on the back of the auricle. The other afferent fibres in the glossopharyngeal and vagus nerves include taste fibres, sensory fibres from the pharynx, larynx, and other parts of the respiratory and alimentary systems, and other splanchnic afferent fibres. Although there is no sharp demarcation between the terminal nuclei of these various components, it is probable that the taste fibres proceed to the nucleus tractus solitarii, the splanchnic afferent fibres to the dorsal nucleus, and the somatic afferent fibres to the nucleus of the spinal trigeminal tract.

Nervus Acusticus.—As this is a nerve of special sense it will be left for consideration after the rest of this series.

Nervus Facialis (Figs. 499 and 500).—The **facial nerve** is composed of two distinct parts, viz., a large efferent (mainly motor) portion, the **facial nerve proper,** and a small afferent sensory portion termed the **nervus intermedius.**

The facial nerve proper emerges from the brain at the inferior border of the pons, to the medial side of the acoustic nerve, whilst the nervus intermedius sinks into the superior part of the medulla oblongata between the facial and acoustic nerves, but alongside the latter, rather than the former, from which it is separated by the fasciculus obliquus pontis (Fig. 497). The three nerves, therefore, lie in intimate relation with each other, where they are attached to the surface of the brain, and they pass in company into the internal acoustic meatus.

The fibres of the **nervus intermedius** arise from the cells of the ganglion geniculi of the facial nerve. These, like the cells of a spinal ganglion, are unipolar, the single process in each case dividing into a peripheral and a central branch. The group of peripheral fibres represent parts of the greater superficial petrosal nerve and chorda tympani branch of the facial nerve, whilst the central fibres form the nervus intermedius. The central fibres penetrate the brain, and, passing either through or on the dorsal side of the tractus spinalis of the trigeminal nerve, they finally reach the superior part of the column of gray matter in connexion with the tractus solitarius, and in this they end. The nervus intermedius presents, therefore, the same terminal connexions within the brain as the glossopharyngeal nerve.

The motor nucleus of the facial nerve contains elements serially homologous with both the somatic (nucleus ambiguus) and splanchnic (nucleus dorsalis) efferent nuclei of the glossopharyngeal and vagus. It is composed partly of the larger cells characteristic of the former and the smaller cells distinctive of the latter. The axons of the somatic cells innervate the striated muscles of the face, whereas the splanchnic efferent fibres pass to the spheno-palatine, otic and submaxillary ganglia (as their white rami communicantes), and are largely concerned with the regulation of the secretory activity of the large salivary glands and other glands around the mouth.

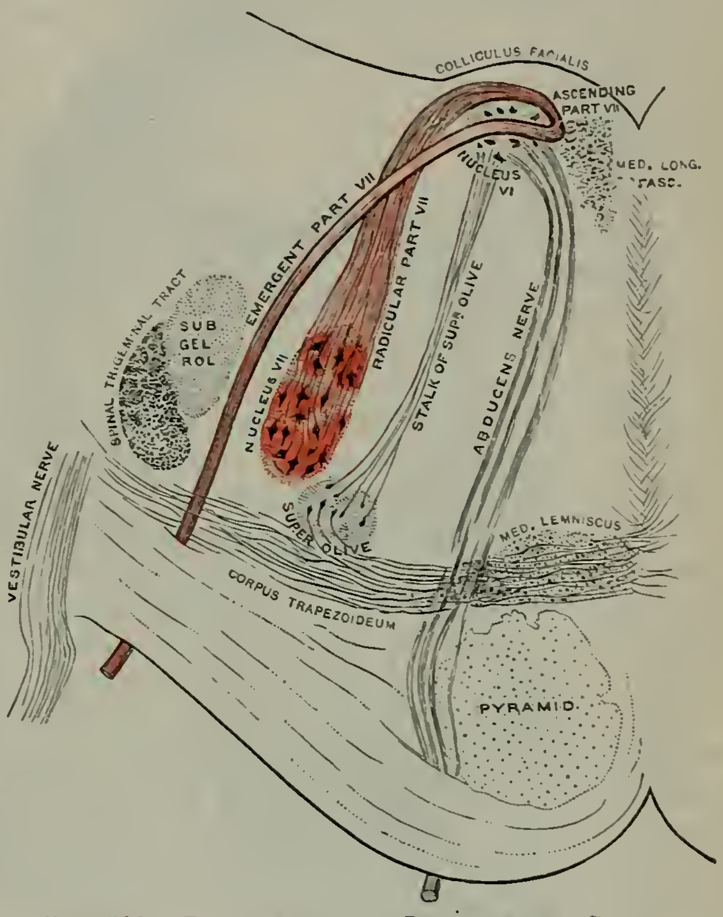

Fig. 500.—Diagram of the Intrapontine Course of the Facial Nerve.

Sub. gel. rol. refers to the nucleus of the spinal trigeminal tract.

The facial nucleus is situated close to the place where the nerve emerges from the brain, but the nerve does not at once pass to this point of exit. It pursues a long and devious path within the pons before it finally reaches the surface. This intrapontine part of the nerve may be divided into three parts, viz.: (1) a radicular part, (2) an ascending portion, and (3) an emergent part.

The **radicular part of the facial nerve** (Fig. 500) is composed of a large number of fine, loosely arranged bundles of fibres, which issue from the lateral and dorsal aspect of the nucleus and proceed backwards and slightly medially through the pons. Reaching the floor of the fourth ventricle they curve medially, and the bundles which lie highest up sweep over the lateral and dorsal aspect of the inferior part of the nucleus of the sixth nerve. Close to the median plane they turn sharply upwards and are collected into a single solid nerve-bundle, which constitutes the **ascending part of the facial nerve** (Figs. 499 and 500). This proceeds upwards immediately beneath the ependyma of the ventricular floor on the dorsal aspect of the medial longitudinal bundle, and along the medial side of the abducent nucleus for a distance of about five millimetres. Then the nerve bends laterally at a right angle, and curves a second time over the dorsal aspect of the abducent nucleus. This gives rise to a prominent hemispheral projection in the floor of the fourth ventricle, the **colliculus facialis** (Fig. 500 and Fig. 456, p. 551). The nerve now passes straight to the place of exit from the brain, and this part of the intrapontine trunk may be termed the emergent portion (Figs. 468 and 500). The facial nerve thus forms a curved loop over the dorsal aspect of the abducent nucleus. The **emergent part** of the nerve takes an oblique course through the pons to reach the surface. It inclines laterally and downwards as it proceeds towards the ventral aspect of the pons, and on its way it passes between its own nucleus and the tractus spinalis of the trigeminal nerve.

Entering the facial nucleus, and ending in fine terminal arborisations around its cells, are many fibres from the opposite pyramidal tract; fibres from the spinal tract of the fifth nerve; fibres from the corpus trapezoideum, etc. The nucleus is thus brought into connexion with the motor area of the cerebral cortex, with the trigeminal nerve or sensory nerve of the face, and with the acoustic nerve.

The peculiar course of the efferent fibres of the facial nerve within the pons is to be explained in accordance with the general principle regulating migrations of nerve-cells, to which reference has already been made (p. 555). In the embryo the nucleus facialis develops alongside the nucleus abducens. The latter, controlling one of the eye-muscles, receives most of its afferent impulses from the medial longitudinal bundle (descending from the optic centres in the superior colliculus), and therefore it remains alongside the medial longitudinal bundle and perhaps moves slightly upwards, *i.e.* towards the mesencephalon. The facial nucleus, however, receives most of its stimuli from the nucleus tractus spinalis nervi trigemini, and therefore, as the walls of the metencephalon thicken during their growth, this nucleus retains its proximity to the trigeminal nucleus (Fig. 500), and so migrates along a course which remains mapped out by its emerging fibres. Streeter, working with human embryos, and Ariëns-Kappers, on comparative and therefore broader lines, have elucidated the meaning of this peculiar intracentral course of the facial nerve.

Nervus Abducens (Figs. 468 and 500).—The **abducens nerve** is a small motor nerve which emerges from the brain at the inferior border of the pons above the lateral side of the pyramid of the medulla oblongata. It is the nerve of supply to the lateral rectus muscle of the eyeball. Its **nucleus** of origin is a small spherical mass of gray matter, containing large multipolar cells, which lies in the dorsal part of the tegmental portion of the pons, close to the median plane and immediately subjacent to the gray matter of the floor of the fourth ventricle. Its position can be easily indicated on the ventricular floor, seeing that it is placed subjacent to the colliculus facialis and immediately above the level of the striæ medullares. Its peculiar and intimate relation to the intrapontine portion of the facial nerve has already been indicated. It lies on the ventral aspect of, and within the concavity formed by, the two limbs of the loop of that nerve.

The axons of the multipolar cells of this nucleus emerge from the medial aspect of the nucleus in the form of several bundles, which proceed through the whole dorso-ventral thickness of the pons towards the place of exit. As they pass forwards they incline downwards and slightly laterally. In the dorsal part of the pons they proceed forwards on the medial side of the nucleus olivaris superior, whilst in the basilar part of the pons they keep for the most part to the lateral side of the pyramidal bundles, although several of the nerve fila pierce these on their way to the surface.

It would appear probable that certain of the axons of the cells of the abducens nucleus enter the medial longitudinal fasciculus and proceed upwards in it to end in the oculomotor nucleus of the opposite side. Fibres and collaterals from the basis pedunculi of the opposite side enter the nucleus, and, ending around the cells, bring the nucleus into connexion with the motor area of the cerebral cortex. The pedicle of the nucleus olivaris superior ends partly within the nucleus of the abducent nerve (Fig. 499).

Nervus Trigeminus.—The **trigeminal nerve** strikes its roots deeply into the brain and establishes a connexion with it which extends from the upper part of the mesencephalon above to the level of the second cervical nerve below. No other cerebral nerve presents so extensive a connexion (Fig. 499, p. 595). It is composed of two roots—a large afferent or sensory root and a small efferent or motor root. Both roots appear close together on the surface of the pons, rather nearer its superior than its inferior border, and in the same line as the facial, and glossopharyngeal and vagus nerves (Fig. 497, p. 592).

The **sensory root of the trigeminal nerve** is composed of fibres which arise outside the brain from the cells of the semilunar ganglion. They end within the brain in a somewhat tadpole-shaped terminal nucleus, the swollen body of which is situated in the pons and is termed the main sensory nucleus of the trigeminal nerve:

the tail is a long column of gray matter which is directly continuous below with the substantia gelatinosa of the spinal medulla.

The **main sensory nucleus** (Fig. 501) is an oval mass of gray matter placed half-way up the pons in the lateral part of its dorsal or tegmental portion. It lies close to the lateral surface of the pons and immediately subjacent to the ventral submerged margin of the brachium conjunctivum. It is directly continuous with the substantia gelatinosa, and may be regarded as being merely the enlarged superior end of that column of gray matter.

The fibres of the sensory root of the trigeminal nerve, on reaching the sensory nucleus, divide, in the same way as the fibres of the entering posterior roots of the spinal nerves, into a system of ascending and descending branches (Fig. 499, p. 595). The ascending fibres are short, and almost immediately enter the sensory nucleus and end within it; the descending fibres turn sharply downwards and form the **tractus spinalis.** This tract descends on the lateral side of the column of gray matter formed by the substantia gelatinosa, which constitutes its terminal nucleus, **nucleus tractus spinalis nervi trigemini.** Fibres constantly leave it to enter the nucleus, so that the lower it gets the smaller does the spinal tract become until, in the upper part of the spinal medulla, about the level of the first or second spinal nerve, it disappears altogether.

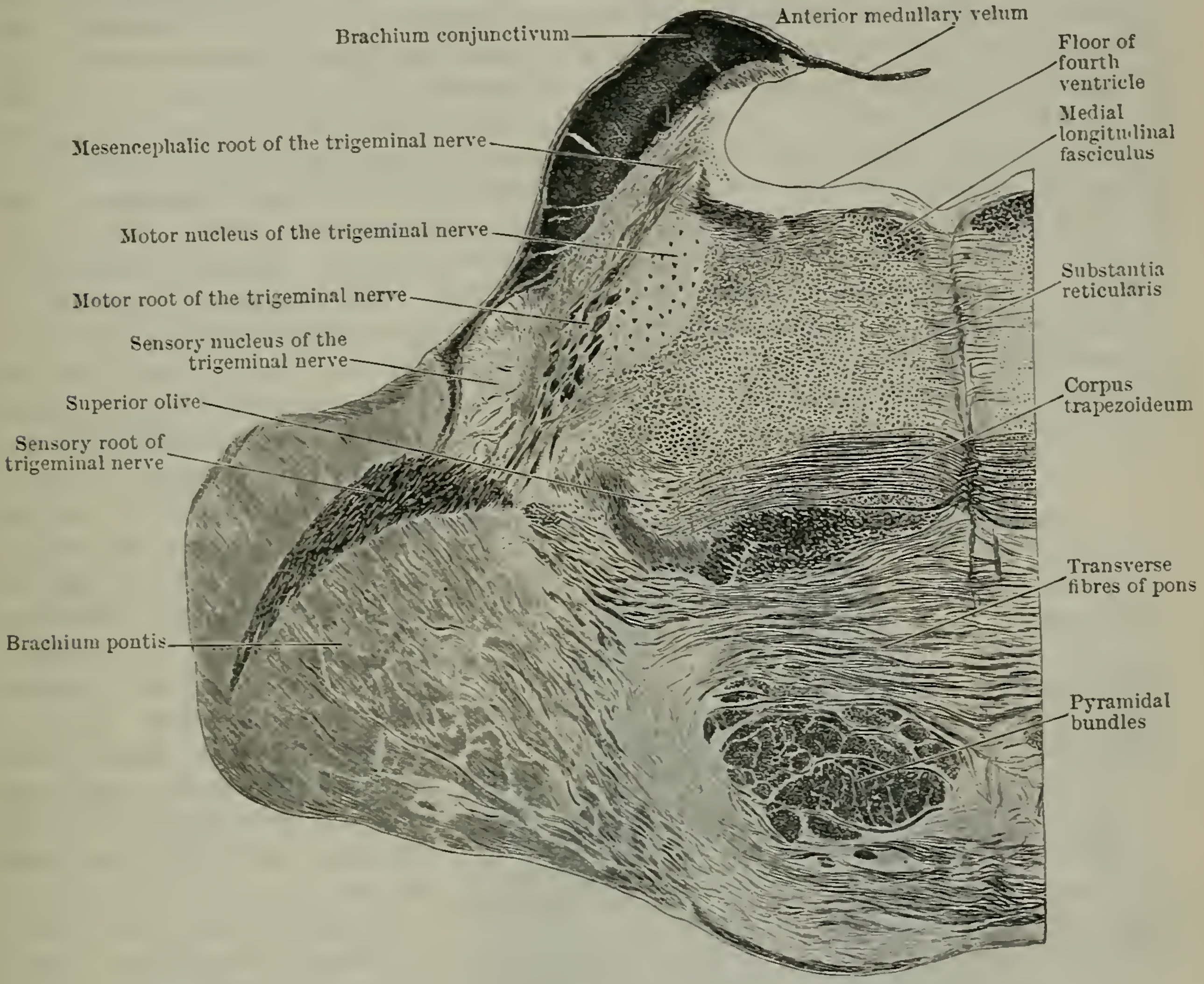
Brachium conjunctivum
Anterior medullary velum
Floor of fourth ventricle
Mesencephalic root of the trigeminal nerve
Medial longitudinal fasciculus
Motor nucleus of the trigeminal nerve
Substantia reticularis
Motor root of the trigeminal nerve
Sensory nucleus of the trigeminal nerve
Corpus trapezoideum
Superior olive
Sensory root of trigeminal nerve
Transverse fibres of pons
Brachium pontis
Pyramidal bundles

FIG. 501.—SECTION THROUGH THE PONS AT THE LEVEL OF THE NUCLEI OF THE TRIGEMINAL NERVE.

The large spinal tract of the trigeminal nerve is a conspicuous object in sections through the pons and medulla oblongata. In the pons it traverses the dorsal or tegmental part, first, between the emergent part of the facial nerve and the vestibular nerve; and then lower down, between the restiform body and the nucleus of the facial nerve (Fig. 468, p. 565). In cross sections it presents a well-defined semilunar or curved piriform outline. In the superior part of the medulla oblongata it lies on the ventral aspect of the restiform body, and therefore nearer the surface than in the pons (Fig. 466, p. 562). Here it is traversed and broken up into separate bundles by the olivo-cerebellar fibres and the roots of the glossopharyngeal and vagus nerves.

Finally, it comes to the surface and its fibres are spread over the area on the side of the medulla oblongata known as the tuberculum cinereum of Rolando (Fig. 465, p. 561).

The small **motor part of the trigeminal nerve** is distributed chiefly to the muscles of mastication, and derives its fibres from the motor nucleus.

The **motor nucleus** (Fig. 501) lies in the lateral part of the tegmental portion of the pons, close to the medial side of the main sensory terminal nucleus, but somewhat nearer the floor of the fourth ventricle. It is serially homologous with the motor nuclei of the lateral somatic group, namely, the facial and nucleus ambiguus. It does not become displaced so far forwards as these nuclei, because its chief source of sensory impulses—the terminal nucleus of the trigeminal afferent fibres—is placed alongside it, and there is no need for any definite migration (Fig. 501).

The **mesencephalic root** or **radix descendens nervi trigemini** takes origin from a column of loosely arranged pear-shaped unipolar cells which are placed in the extreme lateral part of the gray matter surrounding the aquæductus cerebri. As this root is traced downwards it gradually increases in size by the accession of new fibres, and it assumes a crescentic form in transverse section (Figs. 471, p. 569; 501, p. 599; 502; and 503, p. 601). In the inferior part of the mesencephalon it lies on the medial side of the brachium conjunctivum; and the trochlear nerve, on its way to the surface, runs downwards in its concavity and on its medial aspect. In the superior part of the pons it continues its course downwards on the lateral and deep aspect of the gray matter in the floor of the fourth ventricle. Finally, reaching the level of the nuclei of the trigeminal nerve, the fibres of the mesencephalic root turn forwards and are said to join the *sensory* part (Johnston) of the trigeminal nerve. Otto May and Horsley, however, confirm the usual description, viz., that it passes into the *motor* root; but, according to them, it cannot be traced beyond the semilunar ganglion.

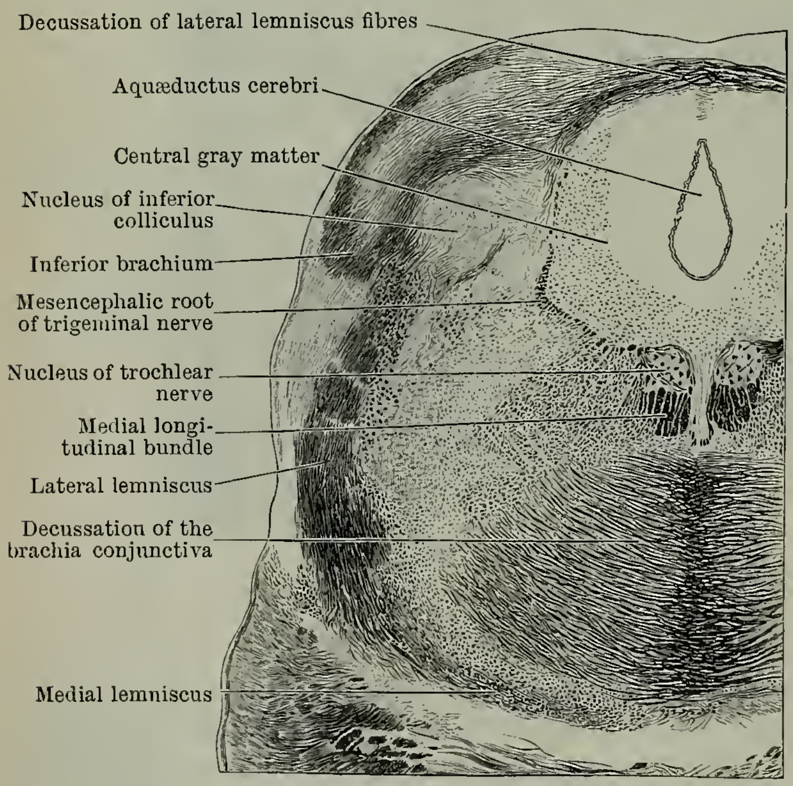
Decussation of lateral lemniscus fibres
Aquæductus cerebri
Central gray matter
Nucleus of inferior colliculus
Inferior brachium
Mesencephalic root of trigeminal nerve
Nucleus of trochlear nerve
Medial longitudinal bundle
Lateral lemniscus
Decussation of the brachia conjunctiva
Medial lemniscus

Fig. 502.—Section through the Inferior Colliculus and the Tegmentum of the Mesencephalon at the Level of the Middle Part of the Nucleus of the Trochlear Nerve.

It is customary to describe this mesencephalic root as belonging to the motor division of the trigeminal nerve; but Johnston has recently questioned this and claimed: (1) that its fibres become associated at their exit from the central nervous system with the sensory, and not with the motor, root; (2) that its nucleus develops in the alar and not in the basal lamina; and (3) that the pear-shaped unipolar cells, from which its fibres arise, conform to the sensory and not to the motor type.

The reason why its sensory nature has not been suspected hitherto is no doubt the fact that its fibres arise not in some **ganglion** outside the central nervous system, like other sensory nerves, but from cells in the tectum mesencephali. If Johnston's view is correct, the neural crest in the mesencephalic region must have been drawn into the neural tube during development and given rise to this sensory nucleus of origin (*not* a terminal nucleus) within the central nervous system.

Otto May and Sir Victor Horsley have shown that the mesencephalic root is a mixture of ascending and descending fibres, but there is no evidence to show that the latter may not be sensory like the former. These fibres are supposed to transmit to the brain-stem afferent impulses from the muscles of mastication.

Nervus Trochlearis.—The **trochlear nerve** supplies the superior oblique muscle of the eyeball. It emerges from the brain, on its dorsal aspect, at the superior part of the anterior medullary velum, immediately below the lower border of the inferior colliculus (Fig. 488, p. 582). The **nucleus** from which it arises is a small oval mass of gray matter, placed in the ventral part of the central gray matter, at the level of the superior part of the inferior colliculus. The close association of this nucleus with the medial longitudinal bundle has already been referred to. It is sunk deeply in a bay which is hollowed out on the dorsal and medial aspect of that tract. The nerve has a course of some length within the mesencephalon. The axons of the cells leave the lateral aspect of the nuclear mass, and curve backwards and laterally in the central gray matter until they reach the concave medial surface of the mesencephalic root of the trigeminal nerve. Here they are gathered together into one or two round bundles, which, bending sharply, turn downwards at a right angle and descend on the medial side of the trigeminal root. When the region below the inferior colliculus is reached, the nerve makes another sharp bend. This time it turns medially, enters the superior end of the anterior medullary velum, in which it decussates with its fellow of the opposite side. Having thus crossed the median plane, the trochlear nerve emerges at the medial border of the brachium conjunctivum. The course pursued by the trochlear nerve within the central gray matter may be traced by examining in succession Fig. 502; Fig. 503; Fig. 472, p. 570; and Fig. 483, p. 577.

Nervus Oculomotorius.—The **oculomotor nerve** supplies the levator palpebræ superioris, all the ocular muscles, with the exception of the superior oblique and the lateral rectus, and also two muscles within the eyeball, viz., the sphincter iridis and the musculus ciliaris. The **nucleus** of origin is placed in the ventral part of the central gray matter subjacent to the superior colliculus (Fig. 491, p. 585). In length it measures from 5 to 6 mm. Its inferior end is partially continuous with the nucleus of the trochlear nerve, whilst its superior end extends upwards for a short distance beyond the mesencephalon into the gray matter on the side wall of the third ventricle. Its relation to the medial longitudinal bundle is even more intimate than that of the trochlear nucleus. It is closely applied to the dorsal and medial aspect of this strand; many of its cells occupy a position in the intervals between the nerve-bundles of the tract, and some even are seen on its ventral or tegmental aspect. The axons of the nuclear cells leave the nucleus in numerous bundles, which describe a series of curves as they proceed forwards through the medial longitudinal bundle, the tegmentum, red nucleus, and medial margin of the substantia nigra, to emerge finally from the brain-stem along the bottom of the sulcus oculo-motorius on the medial aspect of the basis pedunculi.

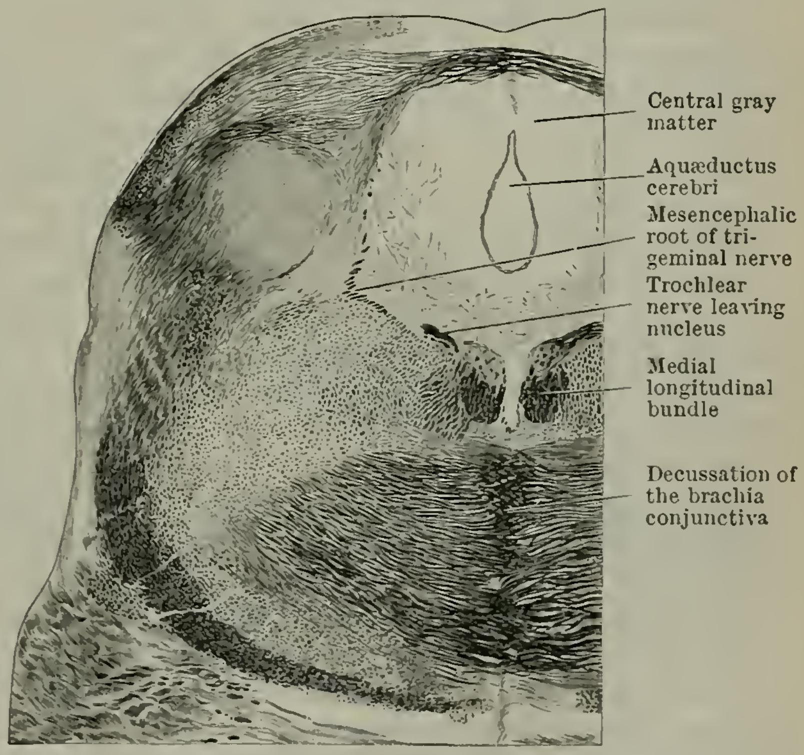
Central gray matter
Aquæductus cerebri
Mesencephalic root of trigeminal nerve
Trochlear nerve leaving nucleus
Medial longitudinal bundle
Decussation of the brachia conjunctiva

FIG. 503.—SECTION THROUGH THE INFERIOR COLLICULUS AND THE TEGMENTUM OF THE MESENCEPHALON AT THE LEVEL OF THE INFERIOR PART OF THE NUCLEUS OF THE TROCHLEAR NERVE.

The cells of the oculomotor nucleus are not uniformly distributed throughout it. They are grouped into several more or less distinct collections or clumps, some of which possess cells which differ in size and appearance from the others. These cell-clusters are very generally believed to possess a definite relation to the several branches of the nerve and the muscles which they supply. Perlia recognises no less than seven such cell-clusters in each nucleus, with a small median nucleus placed accurately on the median plane, and from which fibres for both nerves spring. Whilst the majority of the fibres in the oculomotor nerve arise from the cell-groups which lie on its own side of the median plane, it has been satisfactorily established that a certain proportion of its fibres are derived from the nucleus of the opposite side, thus forming a crossed connexion and giving rise to a median decussation. These crossed fibres are supposed by some to supply the medial rectus muscle; and we have seen that there is reason to believe that the part of the nucleus from which these fibres are derived stands in connexion through the medial longitudinal fasciculus with the abducens nucleus from which proceeds the nerve of supply for the lateral rectus muscle. The harmonious action of the medial and lateral recti in producing the conjugate movements of the eyeballs is thus explained.

The oculomotor nucleus is connected—(1) with the occipital part of the cerebral cortex by fibres which reach it through the optic radiation; (2) with the vestibular, trochlear and abducent nuclei (and probably with other nuclei) by fibres which come to it through the medial longitudinal bundle; (3) possibly with the facial nerve by fibres which pass out from it into the medial longitudinal bundle (p. 587); (4) with the visual system by fibres which enter it from the cells of the superior colliculus.

It is important to recognise that although the main part of the oculomotor nucleus belongs to the medial somatic group, which also includes the trochlear, abducent and hypoglossal nuclei, it also includes a representative (the Edinger-Westphal group of small cells) of the column of splanchnic efferent nuclei in series with those of the facial, glossopharyngeal, and vagus nerves. Its axons pass out along with the other fibres of the oculomotor nerve and enter the ciliary ganglion, where they end in relationship with the cells that innervate the ciliary muscle and the circular muscle of the iris.

Nervus Acusticus.—This large nerve enters the brain at the inferior border of the pons. Its fibres spring from bipolar ganglionic cells in the immediate neighbourhood of the labyrinth or internal ear (see section dealing with the Organs of Sense). One group of these forms the **spiral ganglion**, the peripheral branches of which are distributed to the organ of Corti in the cochlea: another group constitutes the **vestibular ganglion** (often called **Scarpa's**), which distributes fibres to the ampullæ of the semicircular ducts, the utricle, and the saccule. Although the central processes of the cells in these two ganglia accompany one another and are known collectively as the acoustic nerve they really remain distinct throughout, in their mode of termination in the brain as well as in their peripheral distribution. Reaching the brain the acoustic nerve divides into two parts, viz., the nervus cochlearis and the nervus vestibularis, which present totally different connexions, corresponding to their distinct functions. In their further course these two divisions deviate from each other so as to embrace the restiform body — the vestibular part entering the pons on the medial aspect of the restiform body, whilst the cochlear part sweeps round its lateral surface. Special nuclei of termination require to be studied in connexion with each part of the nerve.

The **cochlear nerve** is composed of finer fibres than the vestibular nerve, and its fibres acquire their medullary sheaths at a later period. It is the true nerve of hearing, and its fibres end in a nucleus which lies in intimate relation to the restiform body. It may be described as consisting of two parts. Of these one, called the **dorsal cochlear nucleus**, is a piriform mass which is placed on the dorsal aspect of the restiform body—between it and the flocculus of the cerebellum. The second part, termed the **ventral cochlear nucleus**, is placed on the ventral aspect of the restiform body in the interval between the cochlear and vestibular divisions of the acoustic nerve, after they have separated from each other. The fibres of the cochlear nerve enter these two ganglia and end around the cells in arborisations, which are finer, closer, and more intricate than those met with in any other nerve-ending in the brain.

The **vestibular nerve** enters the brain at a slightly higher level than the cochlear nerve and on the medial aspect of the ventral cochlear nucleus. It proceeds backwards through the pons between the restiform body, which lies on its lateral side, and the spinal tract of the trigeminal nerve, which is placed on its medial side. Its fibres end in a series of terminal nuclei (Fig. 499, p. 595), viz.: (1) the **nucleus vestibularis dorsalis**, often known as the principal nucleus, (2) its inferior prolongation, **nucleus tractus descendentis**, (3) the **nucleus vestibularis lateralis** (*Deiters'*), (4) the **nucleus vestibularis superior** (*Bechterew's*), and (5) the cerebellar cortex.

The **principal nucleus** (Figs. 468, p. 565, and 504, p. 603) is a large diffuse nuclear mass, which lies in the floor of the fourth ventricle subjacent to the surface district known as the **area acustica** (Fig. 456, p. 551). It is situated, therefore, in both the pons and the medulla oblongata to the lateral side of the fovea superior and the fovea inferior. In transverse section it is prismatic in outline, and crossing the surface of its upper or pontine part immediately under the ependyma of the ventricle are the striæ medullares.

When the nervus vestibularis, as it traverses the brain, reaches the medial aspect of the dorsal portion of the restiform body, its fibres bifurcate to form ascending and descending tracts. The latter pass vertically downwards in separate bundles and form the descending tract of the vestibular nerve (Figs. 468, p. 565; 466, p. 562; and 499, p. 595). This proceeds through the inferior part of the pons into the medulla oblongata, in which it may be traced as far as the level of the decussation of the medial lemniscus. Associated with the descending tract there is a column of gray matter, with nerve-cells strewn sparsely throughout it. This is the **nucleus of the descending tract**, and the fibres end in fine arborisations around these nerve-cells.

Some of the ascending fibres of the vestibular nerve end in the **nucleus lateralis.** This nucleus is composed of a number of large and conspicuous multipolar nerve-cells, which are scattered amidst the bundles of the vestibular nerve. As it is traced upwards into the pons the nucleus gradually inclines backwards, and finally it occupies a place in the side wall of the fourth ventricle. It attains its greatest development at the level of the emerging part of the facial nerve and this upper part is sometimes termed the **nucleus superior.**

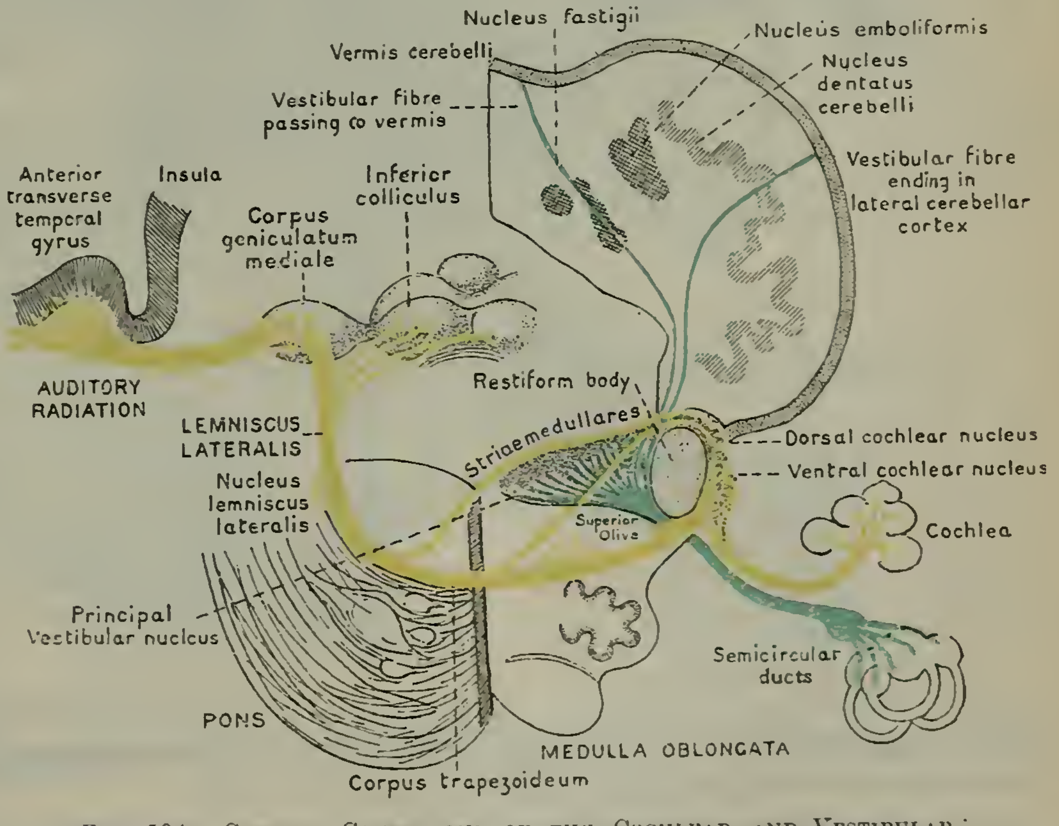

FIG. 504.—CENTRAL CONNEXIONS OF THE COCHLEAR AND VESTIBULAR DIVISIONS OF THE ACOUSTIC NERVE.

Vestibular fibres green. Cochlear fibres yellow.

Other ascending fibres pass without interruption into the cerebellum to terminate in the cortex of the vermis and hemisphere. In their course many of these fibres pass through the nucleus fastigii, and many writers describe them as terminating in this nucleus; but according to Ramon y Cajal they merely traverse it on their way to the cerebellar cortex.

From the large-celled **nucleus lateralis**—best known as **Deiters' nucleus**—a strand of fibres passes medially to reach the medial longitudinal fasciculus, of which it forms one of the most important constituent elements. Some of these fibres pass upwards to the nuclei of the oculomotor, trochlear, and abducens nerves; others downwards, probably to the nucleus of the accessory nerve, which are concerned in regulating the movements of the eyes and the head respectively, because they need to be thus closely linked to the receptive nucleus of the nerve (vestibular), which is concerned with the appreciation of movements of the head and the position of the body in space. Other fibres arise from the lateral nucleus and pass directly to the spinal medulla without passing through the medial longitudinal bundle; they form the **fasciculus vestibulospinalis**, which passes downwards in the funiculus anterior and distributes fibres to the various motor nuclei in the anterior column of the spinal medulla (Fig. 494, p. 588, and Fig. 448, p. 535).

The **nucleus superior (Bechterew's nucleus)** likewise emits a group of fibres which pass directly to the mid-brain (**fasciculus vestibulomesencephalicus**), chiefly to the oculomotor and trochlear nuclei (Fig. 494, p. 588).

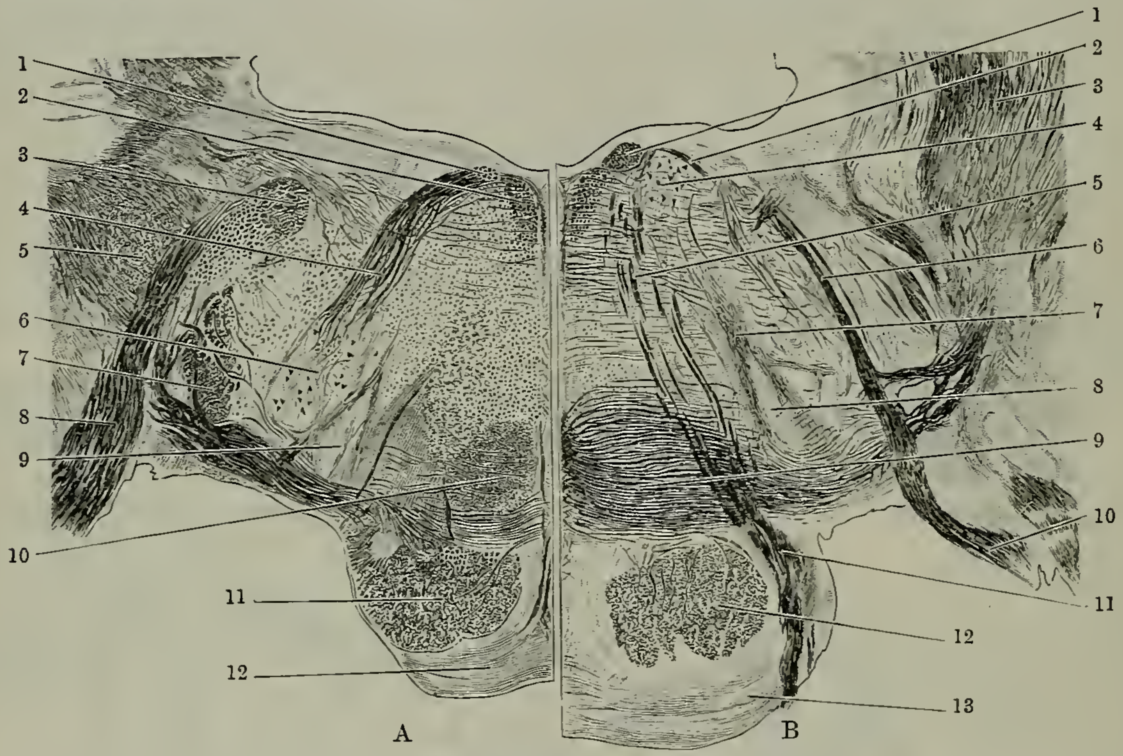

Fig. 505.—Section through the Pons.

The left side of the drawing is taken from a section at a level slightly inferior to the section from which the right side is taken.

A

1. Ascending part of facial nerve.
2. Medial longitudinal bundle.
3. Descending root of vestibular nerve.
4. Radicular fibres of facial nerve.
5. Restiform body.
6. Facial nucleus.
7. Spinal tract of trigeminal nerve.
8. Vestibular nerve.
9. Superior olive.
10. Lemniscus medialis.
11. Pyramidal tract.
12. Transverse fibres of pons.

B

1. Ascending part of facial nerve.
2. Emergent portion of facial nerve.
3. Restiform body.
4. Nucleus of abducens nerve.
5. Abducens nerve.
6. Emergent part of facial nerve.
7. Peduncle of superior olive.
8. Superior olive.
9. Corpus trapezoideum.
10. Facial nerve.
11. Abducens nerve.
12. Pyramidal tract.
13. Transverse fibres of pons.

Central Connexions of the Cochlear Nerve.—The cochlear nuclei are brought into connexion with the inferior colliculus and the medial geniculate body of the opposite side by the fibres of the corpus trapezoideum and the lateral lemniscus.

The fibres of the cochlear nerve end in the ventral cochlear nucleus and in the dorsal cochlear nucleus (tuberculum acusticum). From the cells of these nuclei two tracts arise, viz., a **ventral tract**, composed of the fibres of the corpus trapezoideum, and a **dorsal tract**, which is represented by the striæ medullares.

The **corpus trapezoideum** (Figs. 500 and 501) is formed of the axons of the cells of the ventral cochlear nucleus, as well as certain of the axons of the cells of the dorsal nucleus. In the midst of the corpus trapezoideum are lodged large cells which are known as the *nucleus trapezoideus*, and these give off axons which join the strand with which they are associated. Many of the fibres of the corpus trapezoideum end in a large mass of gray matter called the **nucleus olivaris superior**, which is placed immediately behind the trapezoid body. The trapezial fibres cross the median plane and decussate with the corresponding fibres of the opposite side. Reaching the opposite superior olivary nucleus, more fibres leave the trapezoid body, and almost immediately after this the strand bends upwards and forms the **lemniscus lateralis** (Figs. 504, p. 603; 506, p. 605). But still another nucleus is interposed in its path, viz., the **nucleus lemnisci lateralis.** Here some fibres are dropped, whilst from the nuclear cells others are acquired, and the lateral lemniscus then proceeds upwards until it reaches the inferior colliculus and the medial geniculate body, in which its fibres end.

Other fibres arise from the cells of the dorsal cochlear nucleus, and arrange themselves in the conspicuous bundles which sweep round the dorsal aspect of the restiform body and proceed medially across the floor of the fourth ventricle, often immediately beneath the ependyma (Fig. 456, p. 551). Reaching the median plane they dip forwards into the substance of the pons, and, crossing the median plane, they join the lateral lemniscus. It is important to remember that the striæ medullares are not always visible in the floor of the fourth ventricle (Fig. 504), but are often buried more or less deeply.

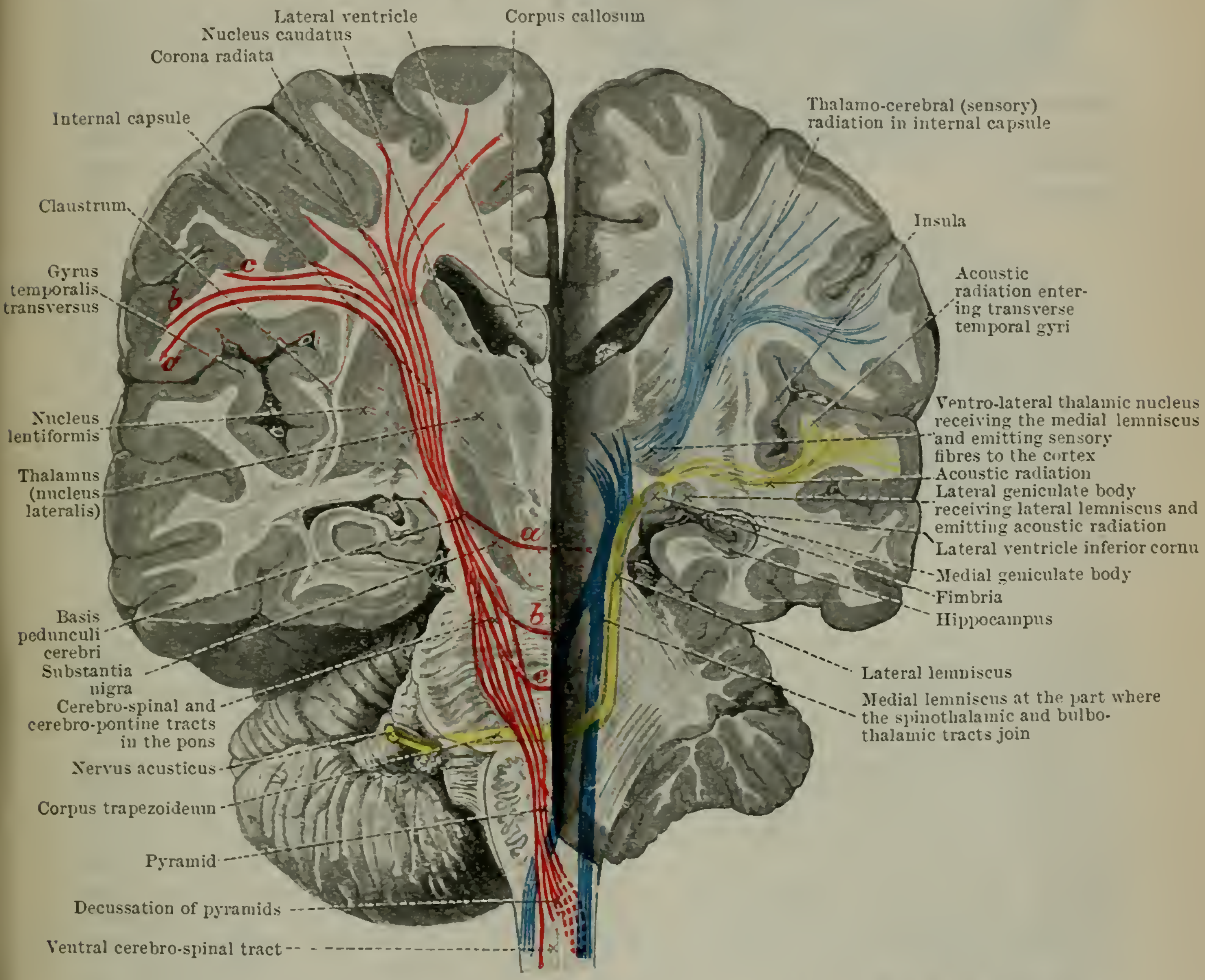
Lateral ventricle
Nucleus caudatus
Corona radiata
Corpus callosum
Internal capsule
Thalamo-cerebral (sensory) radiation in internal capsule
Claustrum
Insula
Gyrus temporalis transversus
Acoustic radiation entering transverse temporal gyri
c
b
a
Nucleus lentiformis
Thalamus (nucleus lateralis)
Ventro-lateral thalamic nucleus receiving the medial lemniscus and emitting sensory fibres to the cortex
Acoustic radiation
Lateral geniculate body receiving lateral lemniscus and emitting acoustic radiation
Lateral ventricle inferior cornu
a
Medial geniculate body
Fimbria
b
Hippocampus
Basis pedunculi cerebri
Substantia nigra
c
Lateral lemniscus
Cerebro-spinal and cerebro-pontine tracts in the pons
Medial lemniscus at the part where the spinothalamic and bulbo-thalamic tracts join
Nervus acusticus
Corpus trapezoideum
Pyramid
Decussation of pyramids
Ventral cerebro-spinal tract

Fig. 506.—A Vertical Transverse Section of the Brain to show the Whole of the Central Acoustic Path. The left hemisphere (right side of the figure) is cut on a plane posterior to that of the right. Motor fibres red. Sensory fibres blue. Acoustic fibres yellow.

The connexion between the terminal cochlear nuclei and the inferior colliculus is not altogether with that of the opposite side, as the foregoing description and the diagram (Fig. 503) might lead one to infer. A few fibres pass directly to the inferior colliculus of the same side, but none to the corresponding medial geniculate body: the connexion with the latter is entirely *crossed* (Ferrier and Turner).

From the medial geniculate body there proceeds a tract to the cerebral cortex of the transverse temporal gyri (Heschl's). The whole nervous apparatus is thus linked on to the cerebral cortex, and the succession of neurones which build up the entire chain are therefore: (1) in the cochlea of the internal ear, the bipolar cells of the spiral ganglion emit axons that terminate in the brain; in (2) the cochlear nuclei, from the nerve-cells of which fibres arise and cross to the lateral lemniscus of the opposite side, proceeding to (3) the medial geniculate body, from which fibres pass to the cerebral cortex.

It must be borne in mind that all the axons of the cells of the superior olive do not join the trapezoid strand. Many leave its dorsal aspect and pass backwards in a group called the **pedicle of the superior olive**, to end in the nucleus of the abducens nerve, and, through the medial longitudinal bundle, in the nuclei of the trochlear and oculomotor nerves. In this way the organ of hearing is brought into connexion with the nuclei which preside over the movements of the eyeballs (Figs. 500, p. 597, and 505, p. 604).

PROSENCEPHALON OR FORE-BRAIN.

The fore-brain vesicle in the embryo has been subdivided, somewhat arbitrarily, into two parts—an anterior, termed the **telencephalon**, and a posterior, called the **diencephalon**, which forms the greater part of the walls of the third ventricle. The extreme anterior part of the third ventricle belongs to the telencephalon, and this includes the anterior wall of the neural tube, which is known as the **lamina terminalis**.

Development of Parts derived from Fore-Brain.

The alar part of each side wall of the telencephalon is pushed out to form a diverticulum, which ultimately constitutes the cerebral hemisphere, and thus, from a very early period, the primitive position of this part of the side wall is indicated by the wide **foramen interventriculare**, or aperture of communication between the cavity of the cerebral hemisphere and the third ventricle (Fig. 507).

The alar part of the side wall of the diencephalon is utilised for the development of the thalamus, the epithalamus, and the metathalamus. Of these the thalamus is derived from the anterior and by far the greatest part of the alar wall. It arises as a large oval swelling, which gradually approaches its fellow of the opposite side, and thus diminishes the width of the third ventricle. Finally, the two bodies sometimes come into contact in the median plane and cohere over an area corresponding to the massa intermedia. This may occur about the end of the second month.

From that section of the side wall to which the name of metathalamus is given the two geniculate bodies arise. Each of these shows, in the first place, as a depression on the inside, and a slight elevation on the outside, of the wall of the diencephalon. As the thalamus grows backwards, it encroaches greatly upon the territory occupied by the geniculate bodies. It thus comes about that in the adult brain the medial geniculate body seems to hold a position on the lateral aspect of the mesencephalon, whilst the lateral geniculate body, viewed from the surface, appears to be a part of the thalamus.

From the epithalamic region of the wall of the diencephalon are developed the pineal body, its peduncle, and the habenular region. These parts are relatively much more evident in the embryonic than in the adult brain. The pineal body appears to be developed as a diverticulum of the posterior part of the roof of the diencephalon, but in reality it is a derivative of the alar lamina. Viewed from the dorsal aspect of the brain-tube, this diverticulum shows, in the first instance, as a rounded elevation, from each side of which a broad ridge runs forwards. This ridge becomes the tænia thalami, whilst in the region of its junction with the pineal elevation the trigonum habenulæ takes shape. The pineal diverticulum ultimately becomes solid, but a small portion of the original cavity is retained as the recessus pinealis of the third ventricle.

The part of the diencephalon and telencephalon which represents the basal lamina (*i.e.* lies below the level of the sulcus hypothalamicus) retains its primitive form, and undergoes only slight change. Consequently, when this region in the adult brain is compared with the corresponding region in the embryonic brain, the resemblance between the two is very striking.

In the fore-brain, therefore, it is the alar lamina which plays the predominant part in the formation of the cerebrum. The value, also, of the basal part of the wall of this portion of the neural tube is still further reduced by the fact that it no longer contains the nuclei of origin of efferent nerves. The highest of these nuclei (the oculomotor) is placed in the mesencephalon. [Johnston has recently announced the discovery of a sensory nerve (*nervus terminalis*) attached to the fore-brain in human embryos; and of course the optic and olfactory nerves enter the fore-brain.]

The region of the fore-brain which lies below the sulcus hypothalamicus is termed the hypothalamus. The part of this which corresponds to the diencephalon is called the pars mamillaris hypothalami, whilst the part in front, which belongs to the telencephalon, receives the name of pars optica hypothalami. From the pars mamillaris hypothalami are derived the corpus mamillare and a portion of the tuber cinereum. With the pars optica hypothalami are associated the following parts, viz., the tuber cinereum, with the infundibulum and the cerebral part of the hypophysis, the optic chiasma, the optic recess, and the lamina terminalis. The corpora mamillaria form, in the first instance, a relatively large ventral bulging of the floor of the brain-tube. As development goes on this bulging becomes relatively small, and about the fourth month the single projection becomes divided into the two tubercles. The infundibulum and posterior or cerebral lobe of the hypophysis are developed as a hollow downward diverticulum of the floor of the telencephalon (Fig. 507). A portion of the original cavity is retained in the upper part of the infundibulum, and constitutes the infundibular recess in the floor of the third ventricle.

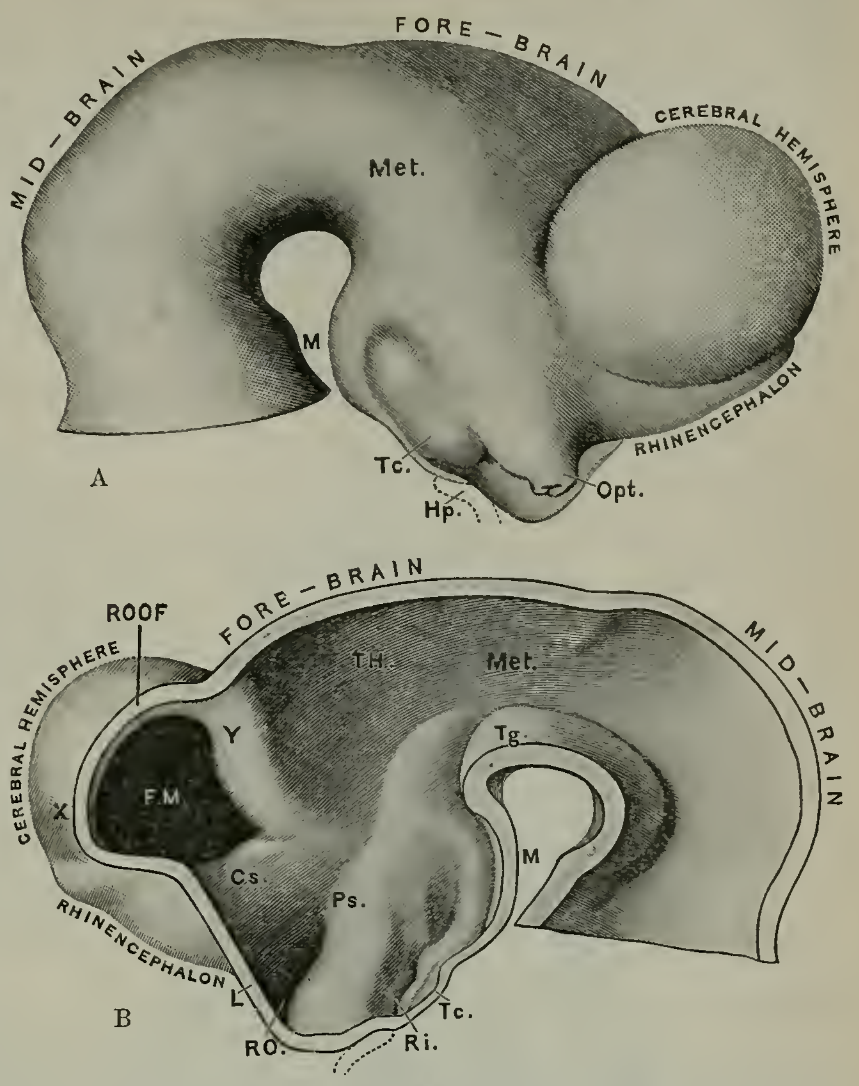

Fig. 507.—Two Drawings of the Embryonic Brain. (After His.)

A, Reconstruction of the fore-brain and mid-brain of His's embryo KO; profile view. B, Same brain as A, divided along the median plane and viewed upon its inner aspect.

M, Mamillary eminence; Tc, Tuber cinereum; Hp, Hypophysis (hypophyseal diverticulum from buccal cavity); Opt, Optic stalk; TH, Thalamus; Tg, Tegmental part of mesencephalon; Ps, Pars hypothalamica; Cs, Corpus striatum; FM, Foramen interventriculare; L, Lamina terminalis; RO, Recessus opticus; Ri, Recessus infundibuli.

The optic nerve is formed chiefly by the passage of fibres backwards from the retina in the wall of the original optic stalk, whilst the chiasma takes form by the transit of fibres across the median plane in front of the infundibulum and behind the optic recess. To a large extent these fibres are derived from the optic nerve. The optic recess of the third ventricle marks the spot where the hollow optic vesicle was originally attached to the inferior and lateral part of the fore-brain, and in the adult it therefore represents a portion of the primitive cavity of the tubular stalk of the optic vesicle. In the course of development the optic nerve fibres, which appear in the stalk of the optic vesicle to form the optic nerve, seek an attachment much further back, and through the optic tract they are even carried as far as the mesencephalon.

The **roof of the fore-brain** remains thin, and does not proceed to the development of nervous elements, although its posterior part becomes invaded by nervous tissue to form the pineal body and the posterior commissure. In front of these structures the roof of the fore-brain is epithelial, and remains so during life. It constitutes the epithelial roof of the third ventricle, and it becomes involuted along the median plane into the cavity to form the chorioid plexuses of the ventricle (Fig. 517, p. 619). The posterior commissure appears as a transverse thickening at the bottom of a transverse groove which appears in the roof of the early brain-tube, behind the pineal diverticulum.

Parts derived from the Diencephalon.

Under this heading we have to consider: (1) the **thalamus**; (2) the **epithalamus**, which comprises the pineal body and the habenular region; (3) the **metathalamus**, or the corpora geniculata; and (4) the **hypothalamus**.

The hypothalamus consists of two portions, viz., the **pars mamillaris hypothalami**, which comprises the corpus mamillare and the portion of the central gray matter which forms the floor of the third ventricle in its immediate vicinity; and the **pars optica hypothalami**, which embraces the tuber cinereum, the infundibulum, the hypophysis (O.T. pituitary body), and the lamina terminalis. Strictly speaking, the optic part of the hypothalamus does not belong to the diencephalon, but it is convenient to study the parts which it represents at this stage.

The original cavity of that part of the brain-tube which forms the diencephalon is represented by the greater part of the third ventricle of the brain.

Thalamus.—The thalamus is the principal object in this section of the brain

(Fig. 507). It is a large ovoid mass of gray matter, which lies obliquely across the path of the cerebral peduncle as it descends from the cerebral hemisphere. The smaller anterior end of the thalamus lies close to the median plane, and is separated from the corresponding part of the opposite side only by a very narrow interval. The enlarged posterior ends of the two thalami are placed more widely apart, and in the interval between them the corpora quadrigemina are situated.

The two thalami, in their anterior two-thirds, lie close together, one on each side of the deep median cleft which receives the name of the third ventricle of the brain. The inferior and lateral aspects are in apposition with, and, indeed, directly connected with, adjacent parts of the brain, and on this account it is customary to study them by means of sections through the brain. The superior and medial surfaces are free.

The *lateral surface* of the thalamus is applied to a thick layer of white matter interposed between it and the lentiform nucleus, called the **internal capsule**, and composed of fibres passing both upwards towards and downwards from the cerebral cortex. A large proportion of these fibres descend to form the basis pedunculi. From the entire extent of the lateral surface of the thalamus large numbers of fibres stream out and enter the internal capsule, to reach the cerebral cortex. They constitute what is termed the **thalamic radiation**. As the fibres leave the thalamus, over the whole of the lateral surface of the ganglionic mass they form a very distinct reticulated zone or stratum, which is termed the **external medullary lamina**.

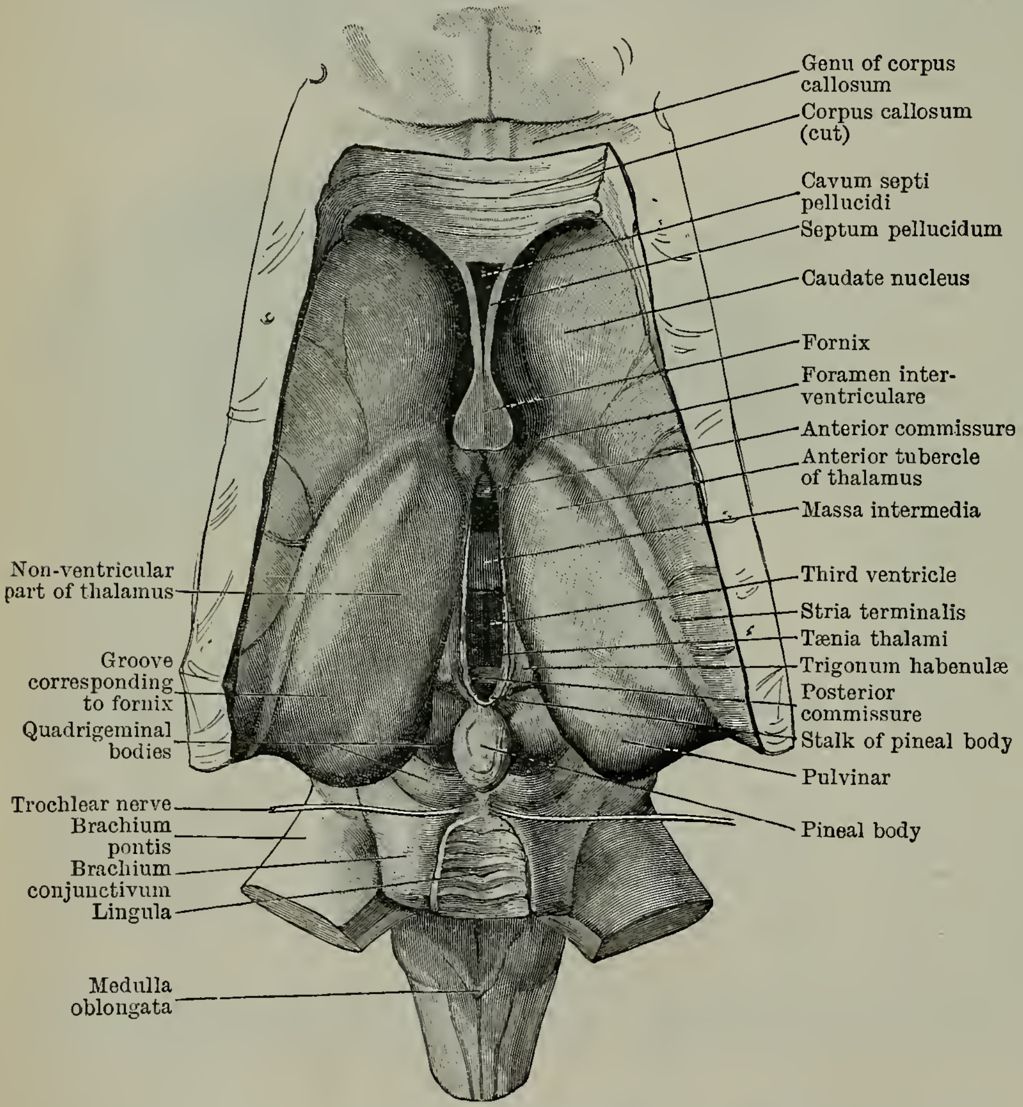

Fig. 508.—The Thalami and the Parts of the Brain surrounding them. Superior aspect.

The *inferior surface* of the thalamus rests on the hypothalamus. From the latter region many fibres enter the thalamus on its inferior aspect, whilst other fibres leave this surface of the thalamus to take part in the thalamic radiation.

The *superior surface* of the thalamus is free. Laterally it is bounded by a groove, which traverses the floor of the lateral ventricle of the brain and intervenes between the thalamus and the caudate nucleus. In this groove is placed a slender band of longitudinal fibres, termed the stria terminalis, and in its forepart the vena terminalis. Medially, the superior surface of the thalamus is separated from the medial surface in its anterior half by a sharp edge or prominent ledge of the ependyma of the third ventricle. This is termed the **tænia thalami**, and the ridge which it forms is accentuated by the presence of a subjacent longitudinal strand of fibres called the **stria medullaris.** When these two structures, viz., the ependymal ridge and the subjacent stria, are traced backwards, they are seen to turn medially and become continuous with the stalk or peduncle of the pineal body. Behind the portion of the tænia thalami which turns medially towards the pineal body a small depressed triangular area, the **trigonum habenulæ**, situated in front of the superior colliculus, forms a very definite medial boundary for the posterior part of the superior surface of the thalamus.

The superior surface of the thalamus is slightly bulging or convex, and is of a whitish colour, owing to the presence of a thin superficial covering of nerve-fibres, termed the **stratum zonale.** It is divided into two areas by a faint oblique groove, which begins in front at the medial border, a short distance behind the anterior extremity of the thalamus, and extends laterally and backwards to the lateral part of the posterior extremity. This groove corresponds to the edge of the fornix. The two areas which are thus mapped out are very differently related to the ventricles of the brain, and also to the parts which lie above the thalamus. The *lateral area,* which includes the anterior extremity of the thalamus, forms a part of the floor of the lateral ventricle. It is covered with ependyma, overlapped by the chorioid plexus of this ventricle, and lies immediately subjacent to the corpus callosum. Along the line of the groove the epithelial lining of the lateral ventricle is reflected over the chorioid plexus of this cavity. The *medial area,* which includes the posterior end of the thalamus, intervenes between the lateral and third ventricles of the brain, and takes no part in the formation of the walls of either. It is covered by a fold of pia mater, termed the tela chorioidea of the third ventricle, above which is the fornix, and these two structures intervene between the thalamus and the corpus callosum.

The *anterior extremity* of the thalamus, called the **tuberculum anterius thalami,** forms a marked bulging. It projects into the lateral ventricle, behind and to the lateral side of the free portion of the column of the fornix. The foramen interventriculare, a narrow aperture of communication between the lateral and third ventricles of the brain, is bounded in front by the column of the fornix and behind by the anterior tubercle of the thalamus.

The *posterior extremity* of the thalamus is very prominent and forms a cushion-like projection, which overhangs the brachia of the corpora quadrigemina. This prominence is called the **pulvinar.** Another oval bulging on the posterior part of the thalamus receives the name of the **corpus geniculatum laterale.** It is situated below, and to the lateral side of, the pulvinar, and presents a very intimate connexion with the optic tract.

The *medial surfaces* of the two thalami are placed close together, and are covered not only by the lining ependyma of the third ventricle, but also by a moderately thick layer of gray matter, continuous below with the central gray substance which surrounds the aquæductus cerebri in the mesencephalon. A band of gray matter, termed the **massa intermedia,** crosses the third ventricle and joins the medial surfaces of the two thalami together.

Intimate Structure and Connexions of the Thalamus.—The upper surface of the thalamus is covered by the **stratum zonale,** a thin coating of white fibres derived to some extent from the optic tract, and probably also from the optic radiation. The medial surface has a thick coating of central gray matter, whilst intervening between the internal capsule and the lateral surface is the **lamina medullaris externa.** The lower surface merges into the hypothalamus.

The gray matter of the thalamus is marked off into three very apparent parts —termed the anterior, the medial, and the lateral thalamic nuclei—by a thin vertical sheet of white matter, continuous with the stratum zonale, termed the **lamina medullaris interna.** The **lateral nucleus** (nucleus lateralis thalami) is by far the largest of the three. It is placed between the medial and the lateral medullary laminæ, and it stretches backwards beyond the medial nucleus, and thus includes the whole of the pulvinar (Fig. 510). The **medial nucleus** (nucleus medialis thalami) reaches only as far back as the habenular region. It is placed between the central gray matter of the third ventricle and the internal medullary lamina. The lateral nucleus is more extensively pervaded by fibres than the medial nucleus.

From the lateral nucleus by far the greatest number of the fibres which form the **radiatio thalami** pass, and these are seen crossing it in various directions towards the lamina medullaris externa. The **anterior nucleus** (nucleus anterior thalami) is the smallest of the three thalamic nuclei. It forms the prominent anterior tubercle, and is prolonged in a wedge-shaped manner, for a short distance, downwards and backwards between the anterior parts of the medial and lateral nuclei. The internal medullary lamina splits into two parts and partially encloses the anterior nucleus. In connexion with its large cells a very conspicuous bundle of fibres, the **fasciculus thalamomamillaris**, comes to an end. [As this bundle arises in the corpus mamillare, it ought to be called " fasciculus mamillo-thalamicus."]

A diffuse gray mass, imperfectly marked off from the inferior surface of the lateral nucleus, receives the name of the *ventral nucleus*. Its inferior part is composed of the **central nucleus of Luys** and the **nucleus arcuatus**. In section the former appears as a circular mass of gray matter, which comes into view immediately behind the point where the internal medullary lamina disappears. It would seem to be intimately connected with fibres which reach it from the red nucleus and from the posterior commissure. These fibres pass round it so as to mark it off from the rest of the thalamus, and in front of the nucleus many of them enter the internal medullary lamina. The **nucleus arcuatus** is a small semilunar mass of gray matter placed below and to the lateral side of the central nucleus of Luys.

The **connexions of the thalamus** are of an extremely intricate kind. It would appear to be a ganglionic mass interposed between the tegmental corticipetal tracts and the cerebral cortex. In its posterior part, and through its stratum zonale, it also has important connexions with the optic tract. The corticipetal tegmental tracts, which enter it from below, will be noticed in connexion with the hypothalamic region. Suffice it to say, for the present, that these fibres end in the midst of the thalamus in connexion with the thalamic cells. In addition to these, enormous numbers of fibres, arising within the thalamus as the axons of its cells, stream out from its lateral and inferior surfaces to form the thalamic radiation. These **thalamo-cortical fibres** pass to every part of the cortex; and although there is no separation of them into distinct groups as they leave the thalamus, it is customary to regard them as constituting a frontal stalk, a parietal stalk, an occipital stalk, and a ventral stalk. But fibres from the cortex, **cortico-thalamic fibres**, likewise stream into the thalamus in large numbers, and end in fine arborisations around its cells. A double connexion with the cerebral cortex is thus established by the thalamus.

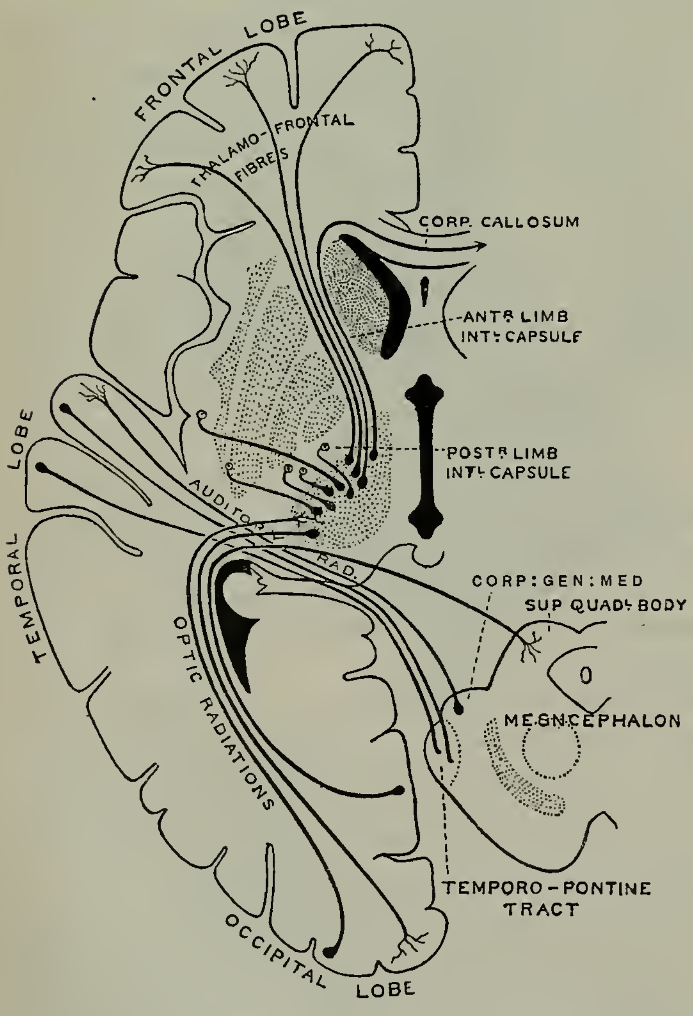

Fig. 509.—Schema. Founded on the observations of Flechsig, and Ferrier and Turner.

The **frontal stalk** of the thalamic radiation emerges from the anterior part of the lateral surface of the thalamus and passes through the anterior limb of the internal capsule, to reach the cortex of the frontal lobe. Many of these fibres end in the caudate and lentiform nuclei, between which they proceed. The **parietal stalk** issues from the lateral surface of the thalamus, and, passing through the internal capsule (and to some extent, also, through the lentiform nucleus and the external capsule), gains the cortex of the posterior part of the frontal lobe and of the parietal lobe. The **occipital stalk** emerges from the lateral aspect of the pulvinar and constitutes the so-called optic radiation. These fibres sweep laterally and backwards round the lateral side of the posterior horn of the lateral ventricle to gain the cortex of the occipital lobe. The

ventral stalk streams out from the under aspect of the anterior part of the thalamus, in front of the hypothalamic tegmental region and the corpus mamillare. Its fibres arise in both the medial and lateral nuclei, and sweep downwards and laterally to reach the region below the lentiform nucleus. One very distinct band which lies dorsal to the other fibres **(ansa lenticularis)** comes from the lentiform nucleus to the thalamus, whilst the remainder **(ansa peduncularis)** proceed in a lateral direction from the thalamus below the lentiform nucleus and gain the cortex of the temporal lobe and of the insula.

Flechsig divides the thalamo-cortical fibres of ordinary sensation into three sensory systems. These he has been able to distinguish by studying the order in which they assume their sheaths of myelin in the fœtus and infant.

Ferrier and Turner, by the degenerative method of investigation, corroborate Flechsig's results. They confirm the observation of Flechsig that, while thalamic fibres are distributed to the several regions of the cerebral cortex to an almost equal extent, there is one district, viz., the frontal pole, to which the supply is scanty. Another very important result has been obtained by these authors. They have established the fact that many of the thalamic fibres cross the median plane in the corpus callosum, and thus gain the cortex of the opposite cerebral hemisphere. Hamilton's crossed callosal tract thus receives confirmation.

Intimate Structure of the Corpus Geniculatum Laterale.—Sections through the lateral geniculate body reveal the fact that it is composed of a series of alternately placed gray and white curved laminæ. This gives it a very characteristic appearance. The white laminæ are composed of fibres which enter the body from the optic tract. The connexions of the geniculate bodies will be studied with the optic tract.

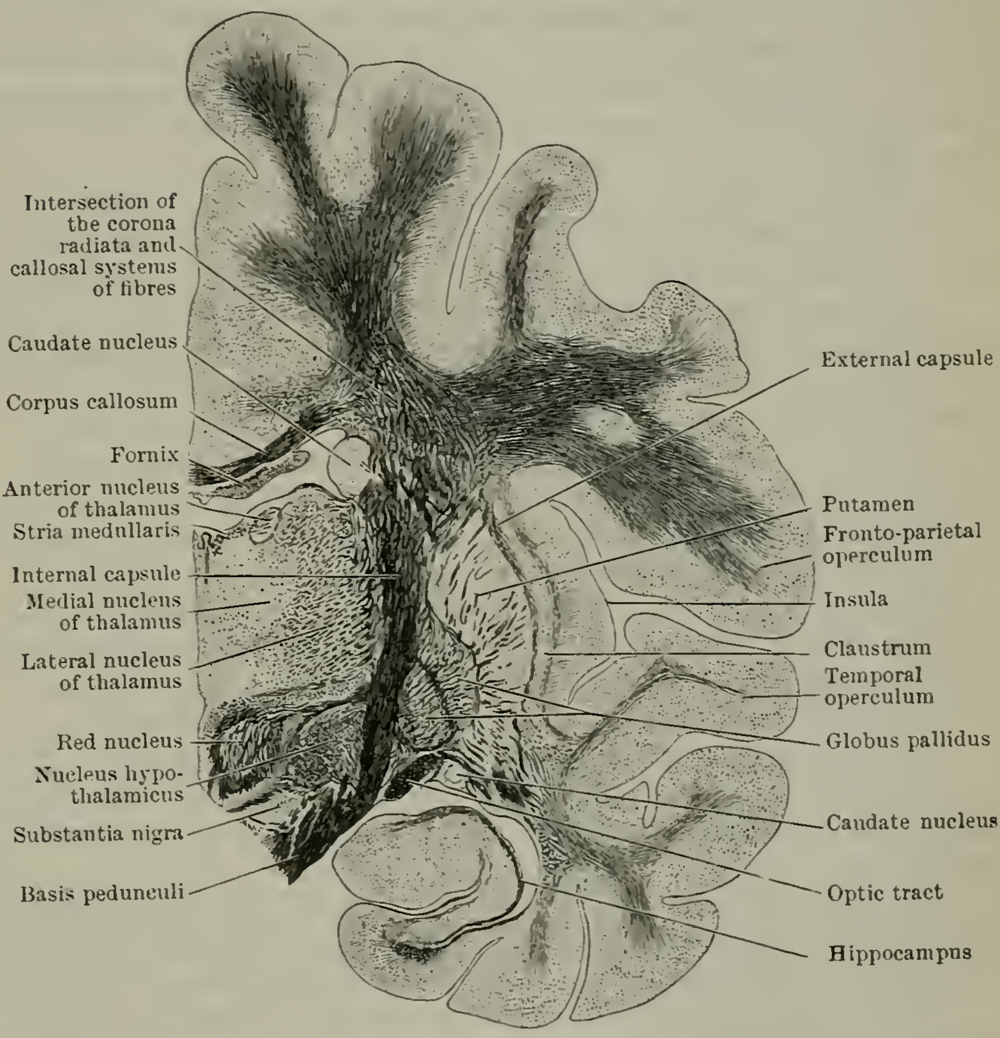

FIG. 510.—FRONTAL SECTION THROUGH THE CEREBRUM OF AN ORANG PASSING THROUGH THE HYPOTHALAMIC TEGMENTAL REGION.

Hypothalamic Region.—The tegmental part of the pedunculus cerebri is prolonged upwards and assumes a position below the posterior part of the thalamus. The **red nucleus** is a conspicuous object in sections through the lower part of this region (Fig. 510). It presents the same appearance as lower down in the mesencephalon, and, gradually diminishing, it disappears before the level of the corpus mamillare is reached. Carried up around it are the same longitudinal tracts of fibres which have been studied in relation to it in the tegmental part of the mesencephalon. Certain of these fibres, placed in immediate relation to the red nucleus, form a coating or capsule for it. This coating is partly derived from those fibres of the brachium conjunctivum which pass directly up into the thalamus and also partly from fibres which issue from the nucleus itself. The **medial lemniscus**, also, which in the superior part of the mesencephalon is observed to take up a position on the lateral and dorsal aspect of the red nucleus, maintains a similar position in the hypothalamic region. When the red nucleus comes to an end these various fibres are continued onwards and form, in the position previously occupied by the nucleus, a very evident and dense mass of fibres. The fibres of the medial lemniscus, of the brachium conjunctivum, and of the red nucleus are prolonged upwards into the ventral part of the thalamus, where they end in connexion with the thalamic cells (ventro-lateral nucleus).

The **substantia nigra** is likewise carried into the hypothalamic region, where it maintains its original position on the dorsal aspect of the basis pedunculi. As it is traced upwards, it is seen gradually to diminish in amount. It shrinks from the medial to the lateral side, and finally disappears when the posterior part of the corpus mamillare is reached.

In frontal sections through the hypothalamic region, the most conspicuous object which comes into view is the **nucleus hypothalamicus** or the **nucleus of Luys** (Fig. 510). It is a small mass of gray matter, shaped like a biconvex lens, which makes its appearance on the dorsal aspect of the basis pedunculi immediately to the lateral side of the substantia nigra. At first it lies in an angle which is formed by the meeting of the cerebral peduncle and the internal capsule; but, rapidly enlarging in a medial direction, it takes the place of the diminishing substantia nigra on the dorsal surface of the basis pedunculi at the level of the inferior part of the corpus mamillare. The nucleus hypothalamicus is rendered all the more evident by the fact that it is sharply defined by a thin capsule of white fibres. On its medial aspect these fibres proceed medially and form a very evident decussation across the median plane in the floor of the third ventricle, immediately above the posterior ends of the corpora mamillaria.

The nucleus hypothalamicus, in the fresh condition, presents a brownish colour, partly from the fact that its cells are pigmented, and partly also on account of the numerous capillary blood-vessels which pervade its substance.

Corpus Pineale.—This is a small, dark, reddish body, about the size of a cherry-stone and shaped after the fashion of a fir-cone. Placed between the posterior ends of the two thalami, it occupies the depression on the dorsal aspect of the mesencephalon, which intervenes between the two superior colliculi. Its base, which is directed upwards, is attached by a hollow stalk or peduncle. This stalk is separated into a dorsal and a ventral part by the prolongation backwards into it of a small pointed recess of the cavity of the third ventricle. The dorsal part of the stalk curves laterally and forwards, and, on each thalamus, becomes continuous with the tænia thalami; the ventral part is folded round a narrow but conspicuous cord-like band of white matter, which crosses the median plane immediately below the base of the pineal body and receives the name of the **posterior commissure** of the cerebrum (Fig. 451, p. 543).

The pineal body is not composed of nervous elements. The only nerves in its midst are the sympathetic filaments which enter it, with its blood-vessels. It is composed of spherical and tubular follicles, filled with epithelial cells, and containing a variable amount of gritty, calcareous matter.

The pineal body is a rudimentary structure, but in certain vertebrates it attains a much higher degree of development than in man. In the lamprey, lizard, etc., it is present in the form of the so-called pineal eye. In structure it resembles, in these animals, an invertebrate eye, and it possesses a long stalk, in which nerve-fibres are developed. Further, it is carried through an aperture in the cranial wall, and consequently lies close to the surface on the dorsum of the head between the parietal bones.

Trigonum Habenulæ.—The small, triangular, depressed area which receives this name is placed immediately in front of the superior colliculus in the interval between the peduncle of the pineal body and the posterior end of the thalamus (Fig. 508, p. 608). It marks the position of an important collection of nerve-cells, which constitute the **ganglion habenulæ**. The axons of these cells are collected on the ventral aspect of the ganglion into a bundle, called the **fasciculus retroflexus**, which takes a curved course downwards and forwards in the tegmentum of the mesencephalon. The fasciculus retroflexus lies close to the medial side of the red nucleus, and finally comes to an end in a group of cells termed the **ganglion interpedunculare**, situated in the inferior part of the substantia perforata posterior (see p. 589).

The ganglion habenulæ is likewise intimately connected with the striæ medullares (tænia thalami) and the dorsal part of the stalk of the pineal body.

As previously stated, the **stria medullaris**—a very evident band of white matter—lies on the thalamus, subjacent to the ependymal ridge termed the tænia thalami. When traced backwards, many of the fibres of the stria medullaris are observed to end amongst the cells of the ganglion habenulæ, whilst others are continued past the ganglion to enter the peduncle of the pineal body, and, through it, to reach the ganglion habenulæ of the opposite side, in connexion with the cells of which they terminate. The stria medullaris, therefore, ends partly in the ganglion habenulæ of its own side and partly in the corresponding ganglion of the opposite side. The decussation of fibres across the median plane forms the dorsal part of the pineal stalk or peduncle, and is termed the **commissura habenularum.**

When the stria medullaris is traced in the opposite direction, it is noticed to split into dorsal and ventral parts near the column of the fornix. The *dorsal part* arises from cells in the hippocampus: these fibres pass into the fornix and when they reach its column they turn abruptly backwards to enter the stria medullaris. The *ventral part* springs from a collection of cells in the gray matter on the base of the brain close to the optic chiasma. The striæ medullares are believed to form a part of the olfactory apparatus.

Commissura Posterior.—The posterior commissure is a slender band of white matter, which crosses the median plane under cover of the stalk of the pineal body and overlies the entrance of the aqueduct of the brain into the third ventricle. The fibres which enter into the formation of the posterior commissure are believed to arise in a special nucleus, which is placed in the central gray matter immediately above the oculo-motor nucleus. They decussate with each other across the median plane and thus the commissure is formed. The other connexions of this little band are not satisfactorily established, but Held believes that some of its ventral fibres pass downwards into the medial longitudinal bundle.

Substantia Perforata Posterior.—This has already been described on p. 542. Some delicate bands of white matter, termed the **tænia pontis,** may frequently be seen emerging from the gray matter of this region; they then curve round the pedunculus cerebri in close relation to the superior border of the pons, with which they enter the cerebellum to end in the nucleus dentatus (Horsley).

Corpora Mamillaria.—The corpora mamillaria are two round white bodies, each about the size of a pea, which lie side by side in the interpeduncular fossa on the base of the brain, immediately in front of the substantia perforata posterior.

Each corpus mamillare is coated on the outside by white matter derived from the column of the fornix, and contains, in its interior, a composite gray nucleus with numerous nerve-cells. Several important strands of fibres are connected with the corpus mamillare: (1) The **column of the fornix** curves downwards in the side wall of the third ventricle to reach the corpus mamillare, and its fibres end amidst the cells of that body. (2) A bundle of fibres, the **fasciculus mamillo-thalamicus,** takes origin in the midst of each corpus mamillare and extends upwards into the thalamus, to end in fine arborisations around the large cells in the anterior thalamic nucleus. (3) Another bundle of fibres, the **pedunculus corporis mamillaris,** takes form within the corpus mamillare and extends downwards in the gray matter of the floor of the third ventricle, to reach the tegmentum of the mesencephalon. These tracts, together with the striæ medullares (thalami) and the fasciculi retroflexi, are amongst the most ancient fibre-systems in the brain. They represent the paths by which olfactory impulses may reach the brain-stem, and perhaps the spinal medulla also, and so influence the muscles of the body.

Tuber Cinereum and Infundibulum.—The tuber cinereum is a small, slightly prominent field of gray matter, which occupies the anterior part of the interpeduncular fossa between the corpora mamillaria behind and the optic chiasma in front. From its anterior part the **infundibulum,** or stalk of the hypophysis, projects downwards and connects the hypophysis with the base of the brain. In its upper part the infundibulum is hollow, a small, funnel-shaped diverticulum of the cavity of the third ventricle being prolonged downwards into it.

Hypophysis (O.T. **Pituitary Body**).—This is a small oval structure, flattened from above downwards, and with its long axis directed transversely, which occupies the fossa hypophyseos in the floor of the cranium. It is composed of two lobes—a large anterior lobe and a smaller posterior lobe, which are closely applied the one to the other. The infundibulum, which extends downwards from the tuber cinereum, is attached to the posterior lobe.

The infundibulum and posterior lobe of the hypophysis are developed in the form of a hollow diverticulum, which grows downwards from the floor of that part of the embryonic brain which afterwards forms the third ventricle. The original cavity of this diverticulum becomes obliterated, except in the superior part of the infundibulum. In structure, the posterior lobe of the hypophysis shows little trace of its origin from the wall of the brain-tube. It is chiefly composed of connective tissue and blood-vessels, with branched cells scattered throughout it (see Ductless Glands).

The anterior lobe has quite a different origin, and may be regarded as the functional part of the hypophysis. It is derived from a tubular diverticulum which grows upwards from the primitive buccal cavity or stomatodæum. Its connexion with the latter (canalis craniopharyngeus) is in the course of time cut off, and the diverticulum becomes encased within the cranial cavity in intimate association with the cerebral portion of the organ. Structurally, it consists of tubules or alveoli, lined with epithelial cells and surrounded by capillary vessels. Its structure is in some respects not unlike that of the parathyreoid bodies. In the disease known as acromegaly, the hypophysis is usually greatly enlarged.

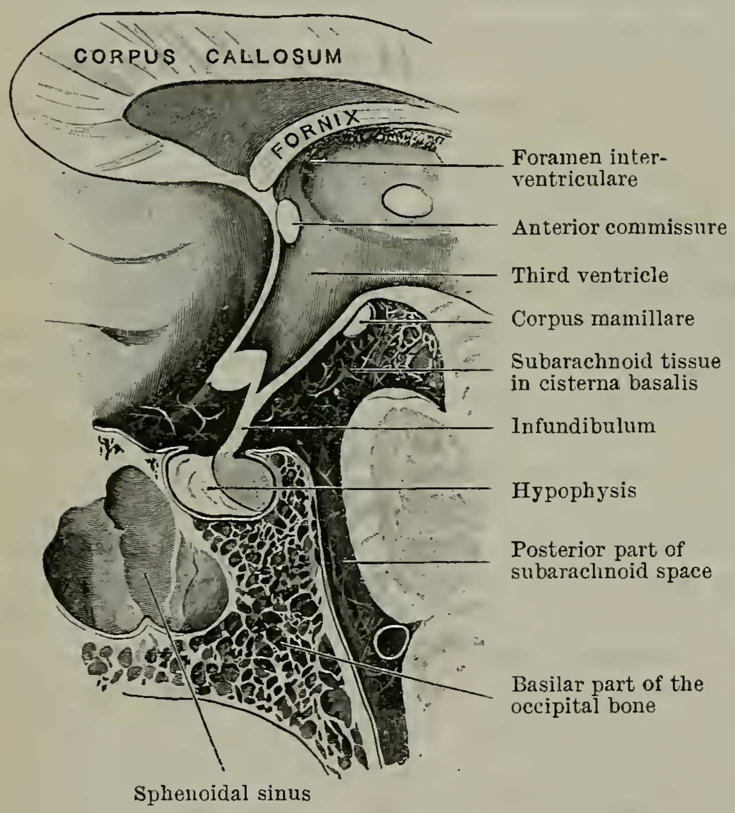
CORPUS CALLOSUM
FORNIX
Foramen interventriculare
Anterior commissure
Third ventricle
Corpus mamillare
Subarachnoid tissue in cisterna basalis
Infundibulum
Hypophysis
Posterior part of subarachnoid space
Basilar part of the occipital bone
Sphenoidal sinus

FIG. 511.—MEDIAN SECTION THROUGH THE HYPOPHYSEAL REGION.

Lamina Terminalis.—This is a thin, delicate lamina which may be seen on the basal aspect of the brain, stretching from the upper aspect of the optic chiasma in an upward direction to become connected with the anterior end of the corpus callosum.

Anterior Commissure of the Cerebrum.—In the anterior part of the cleft between the two thalami, and immediately in front of the columns of the fornix, a round bundle of fibres crosses the median plane. This is the anterior commissure.

Ventriculus Tertius. — The **third ventricle** is the narrow cleft which separates the two thalami. Its depth rapidly increases from behind forwards, and it may be said to extend from the pineal body behind to the lamina terminalis in front. Its *floor* is formed by the tuber cinereum and the corpora mamillaria: the gray matter of the substantia perforata posterior, and the tegmenta of the cerebral peduncles may also be looked upon as forming part of the floor (Figs. 511 and 512). It is interesting to note that the central gray matter which surrounds the aqueduct is directly continuous with the gray matter of the substantia perforata posterior and tuber cinereum, and in this way it comes to the surface in the base of the brain. The optic chiasma crosses the floor in front and marks the place where the latter becomes continuous with the anterior wall of the cavity. The *anterior wall* of the third ventricle is formed by the lamina terminalis, which extends upwards from the optic chiasma. The anterior commissure, as it crosses from one side to the other, projects into the ventricle, but, of course, it is excluded from the cavity by the ventricular epithelial lining. It may be taken as indicating the place where the roof joins the anterior wall. The *roof* of the third ventricle is formed by a thin epithelial layer which stretches across the median plane from one tænia thalami to the other, and is part of the thin epithelial lining of the cavity. Applied to the superior surface of the epithelial roof is the fold of pia mater, termed the tela chorioidea, and the roof is invaginated into the cavity along its whole length by two delicate chorioid plexuses, which hang down from the under surface of this fold. When the pia mater is removed the thin epithelial roof is torn away with it, leaving only the lines of attachment in the shape of the tænia thalami (Fig. 512).

The *side wall* of the third ventricle is formed for the greater part of its extent by the medial surface of the thalamus, covered by a thick layer of central gray matter continuous with the central gray matter of the mesencephalon. A little in front of the middle of the ventricle the cavity is often crossed by the **massa intermedia**, which connects the thalami one with the other, and in front of this the columna fornicis is seen curving downwards and backwards in the side wall. At first the bulging which it forms is distinctly prominent, but it gradually subsides as the strand, on its way to end in the corpus mamillare, becomes more and more sunk in the gray matter on the side of the ventricle.

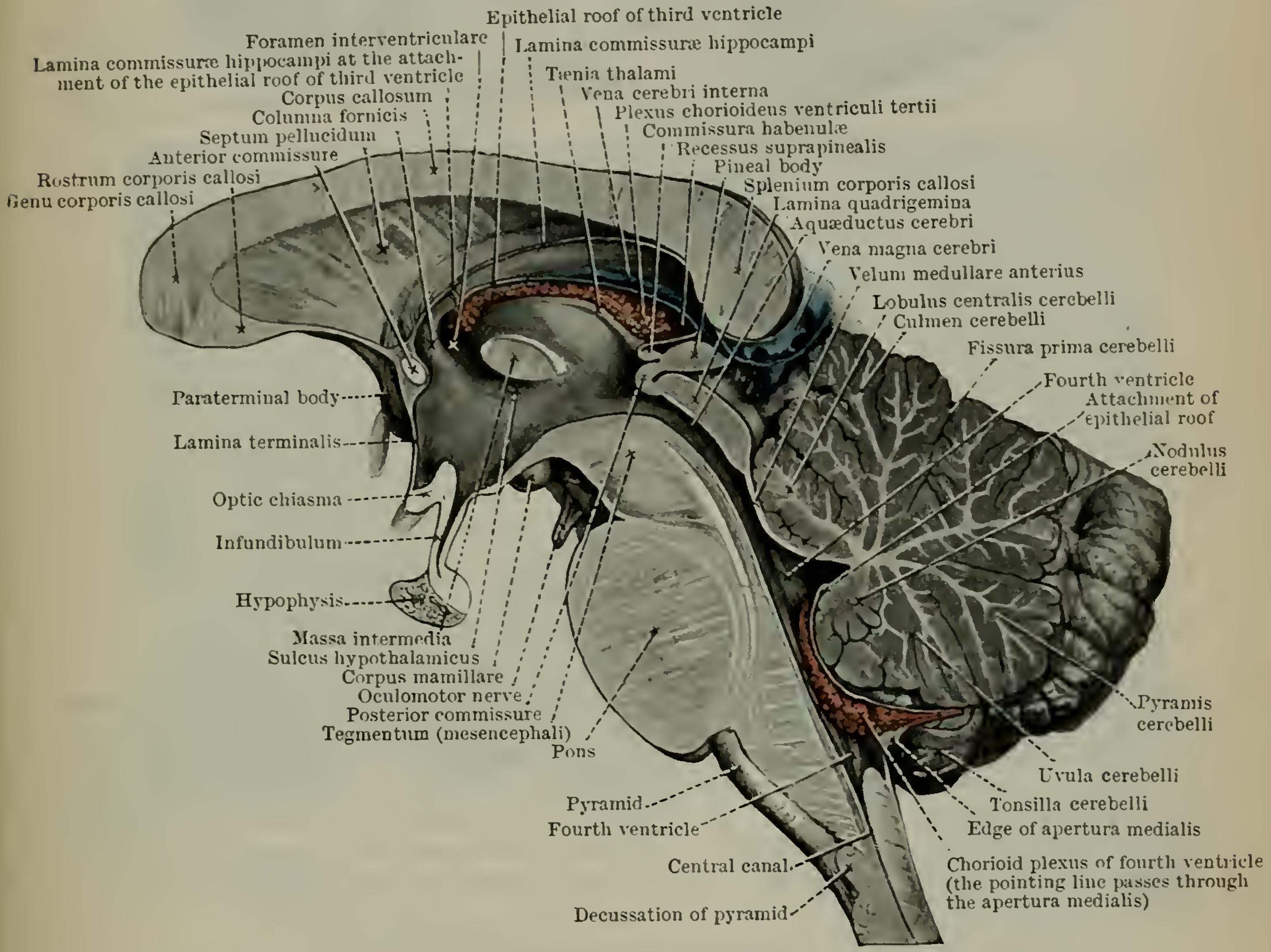

FIG. 512.—THE PARTS OF THE BRAIN CUT THROUGH IN A MEDIAN SAGITTAL SECTION. The side walls of the ventricular cavities are also shown.

The third ventricle communicates with both of the lateral ventricles, and also with the fourth ventricle. The **aquæductus cerebri**, the narrow channel which tunnels the mesencephalon, brings it into communication with the fourth ventricle. The opening of this aqueduct is placed at the posterior part of the floor of the third ventricle, immediately below the posterior commissure. The **foramina interventricularia** bring it into communication with the lateral ventricles. These apertures are placed at the upper and anterior parts of the side walls, and lead laterally and slightly upwards between the most prominent parts of the columns of the fornix and the anterior tubercles of the thalami. They are just large enough to admit a crow-quill, and through these passages the epithelial lining of the three ventricles becomes continuous. From the foramen a distinct groove on the side wall of the ventricle leads backwards towards the mouth of the aqueduct. It is termed the **sulcus hypothalamicus**, and is of interest, inasmuch as it is considered by His to represent in the adult brain the furrow which divides the side wall of the embryonic brain-tube into an alar and a basal lamina.

The outline of the third ventricle, when viewed from the side in a median section through the brain (Fig. 512), or as it is exhibited in a plaster cast of the ventricular system of the brain (Fig. 513), is seen to be very irregular. It presents several diverticula or recesses. Thus, in the anterior part of the floor there is a funnel-shaped pit or recess, leading down through the tuber cinereum into the infundibulum of the hypophysis. Another recess, the *recessus opticus*, leads forwards immediately in front of this, above the optic chiasma. Posteriorly two diverticula are present. One, the *recessus pinealis*, passes backwards above the posterior commissure and the mouth of the aquæductus cerebri for a short distance into the stalk of the pineal body. The second is placed above this and is carried backwards for a greater distance. It is a diverticulum of the epithelial roof, and, therefore, is difficult to demonstrate. It is termed the *recessus suprapinealis*.

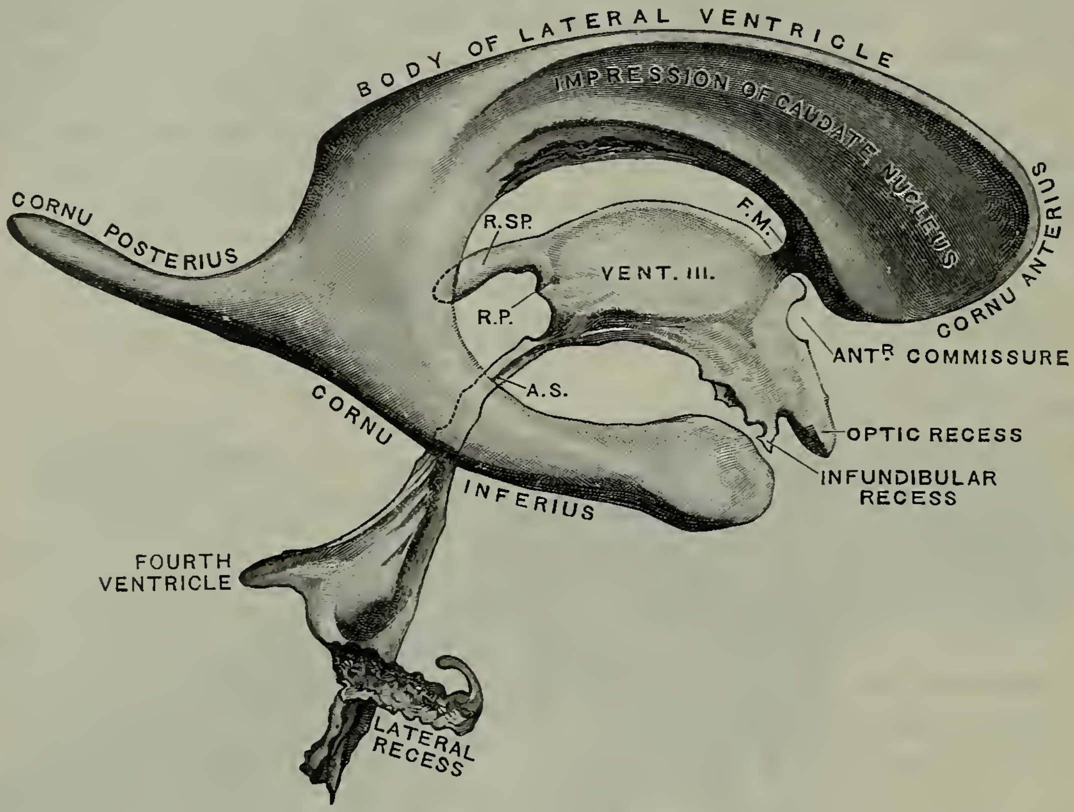

Fig. 513.—Profile View of a Cast of the Ventricles of the Brain. (From Retzius.)

This figure faces in the direction opposite to that of Fig. 512.

R.SP. Recessus suprapinealis.
R.P. Recessus pinealis.
A.S. Aquæductus cerebri.
F.M. Foramen interventriculare.

Cerebral Connexions of the Optic Tract.

At the optic chiasma the optic nerves of the two sides are joined together and a partial decussation of fibres takes place. The fibres which arise in the medial half of each retina cross the median plane and join the optic tract of the opposite side. The optic tract proceeds backwards round the cerebral peduncle, and in the neighbourhood of the geniculate bodies appears to divide into two roots, viz., a lateral and a medial (Fig. 514), but only the former is really part of the tract.

Commissure of Gudden.—The so-called medial root disappears under cover of the medial geniculate body and a large proportion of its fibres arise or end in this nuclear body. The medial root, although it is composed of fibres which are intermingled with those of the optic tract, has nothing to do with the optic nerve. These fibres, when traced forwards, cross the median plane in the posterior angle of the optic chiasma and are carried backwards alongside the opposite optic tract. The fibres constitute a bond of union, called the **commissure of Gudden**, between the medial geniculate body of one side and the colliculus inferior of the other (Fig. 515).

The Optic Tract.—The optic tract is composed of fibres which come—(1) from the lateral half of the retina of its own side; and (2) from the medial half of the retina of the opposite side, which have crossed the median plane in the optic chiasma. But in addition to the afferent retinal fibres there are a certain number of efferent fibres in the optic tract—fibres which take their origin in the brain and end in the retina. These are distinguished from the afferent retinal fibres by their exceeding fineness.

The fibres of the optic tract end in the superior colliculus, in the lateral geniculate body, and in the pulvinar of the thalamus (Fig. 514). The fibres to the **superior colliculus** reach it through the superior brachium (p. 585), and for the most part sink into its substance to end in terminal arborisations around its cells. The **corpus geniculatum laterale** receives the largest contribution of fibres from the optic tract. These partly sink into its interior and partly spread out over its surface. The former enter into the construction of the curved lamellæ of white matter which traverse this nuclear mass, and to a large extent end in the gray matter which intervenes between these lamellæ. The deep fibres which are not exhausted in this way proceed onwards through the lateral geniculate body and enter the pulvinar. Of the superficial fibres which spread over the surface of the lateral geniculate body some dip into its substance and end there, but the majority are carried over it and enter the stratum zonale of the pulvinar. Most of the fibres of the optic tract, which end in the **pulvinar**, therefore reach their destination by passing either over or through the lateral geniculate body.

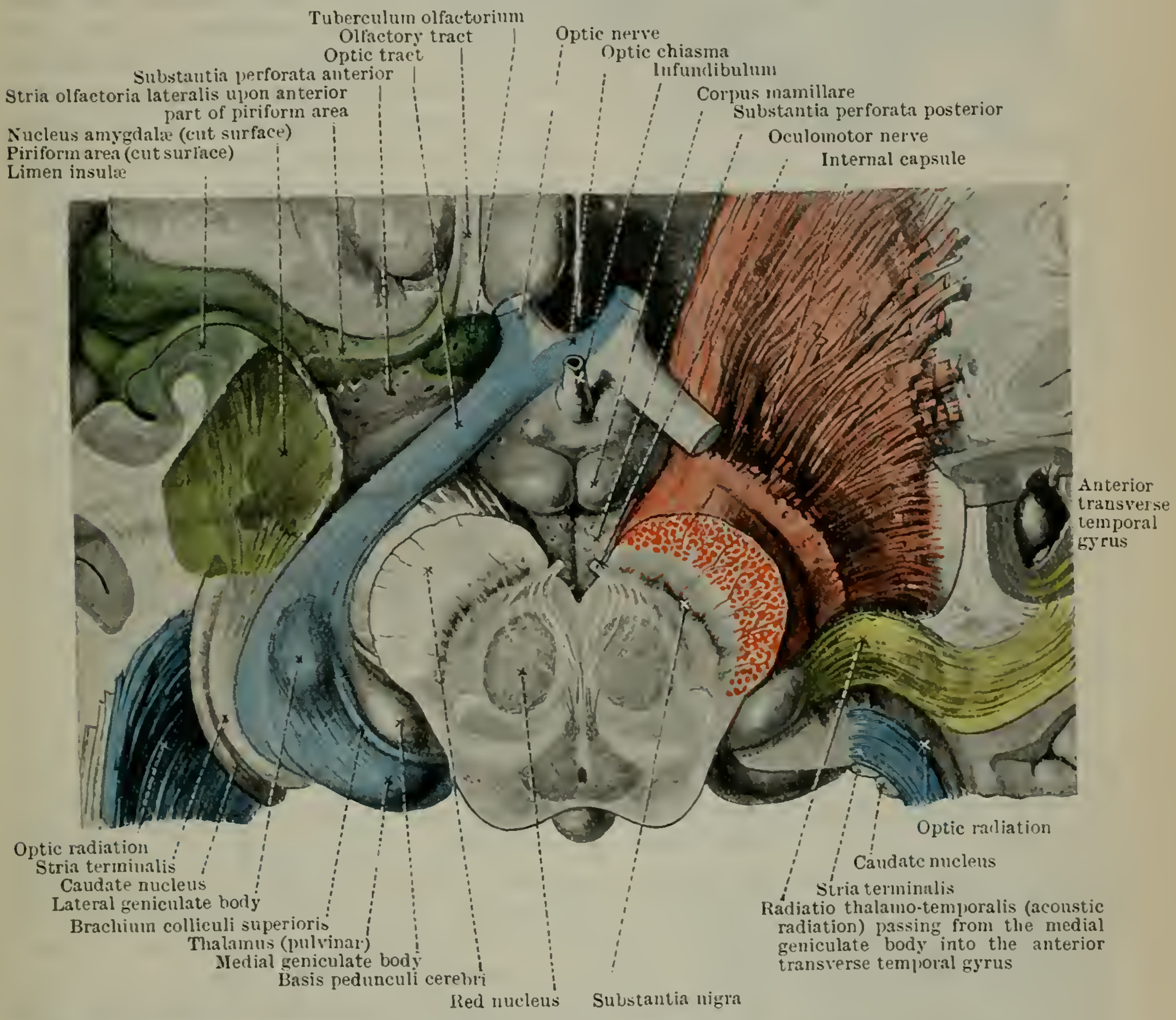
Tuberculum olfactorium
Olfactory tract
Optic tract
Substantia perforata anterior
Stria olfactoria lateralis upon anterior part of piriform area
Nucleus amygdalæ (cut surface)
Piriform area (cut surface)
Limen insulæ
Optic nerve
Optic chiasma
Infundibulum
Corpus mamillare
Substantia perforata posterior
Oculomotor nerve
Internal capsule
Anterior transverse temporal gyrus
Optic radiation
Stria terminalis
Caudate nucleus
Lateral geniculate body
Brachium colliculi superioris
Thalamus (pulvinar)
Medial geniculate body
Basis pedunculi cerebri
Red nucleus
Substantia nigra
Optic radiation
Caudate nucleus
Stria terminalis
Radiatio thalamo-temporalis (acoustic radiation) passing from the medial geniculate body into the anterior transverse temporal gyrus

FIG. 514.—THE VENTRAL ASPECT OF PART OF THE PROSENCEPHALON, SHOWING THE RIGHT OPTIC TRACT. The mesencephalon has been cut across. Olfactory area, dull yellow; optic fibres, blue; motor fibres, red; acoustic fibres, bright yellow.

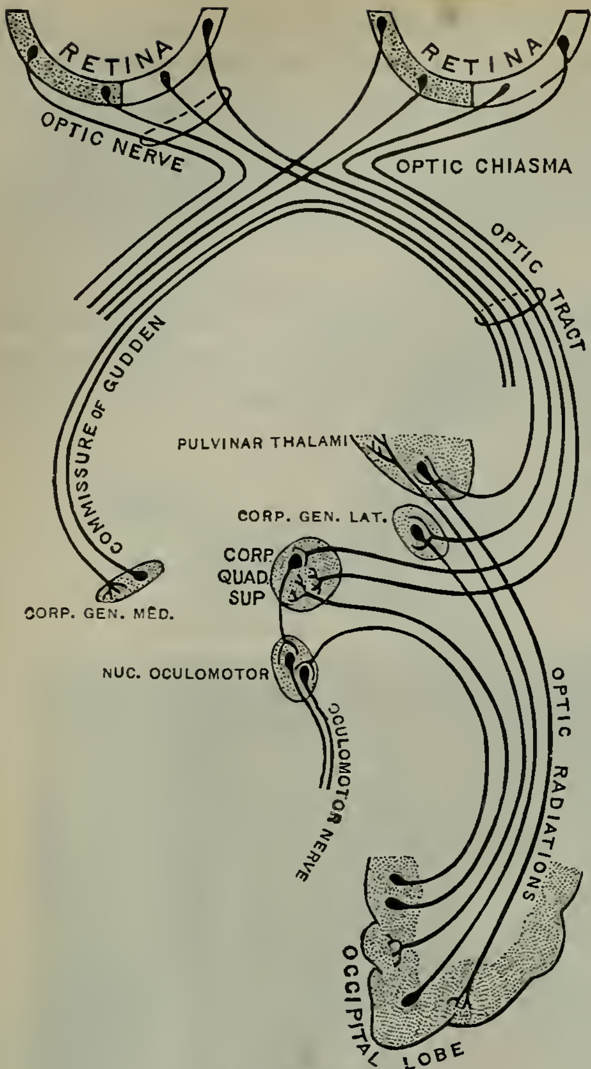

Fig. 515.—Diagram of the Central Connexions of the Optic Nerve and Optic Tract.

Cortical Connexions of the Optic Path.—The superior colliculus, the lateral geniculate body, and the pulvinar constitute the lower visual centres or terminal nuclei of the optic tract. The higher visual centre is placed in the cortex of the occipital region of the cerebral hemisphere, and the connexions between this and the lower centres are established by a large strand of fibres which runs in the central white matter of the posterior part of the cerebral hemisphere, and which constitutes the **optic radiation**. The optic radiation is composed both of corticipetal and corticifugal fibres. The former arise as the axons of the cells in the lateral geniculate body and the pulvinar, around which the retinal fibres end, and they terminate in the cortex of the occipital lobe. The corticifugal fibres take origin in the cortex of the occipital lobe and end in the pulvinar and superior quadrigeminal body (Ferrier and Turner). Thus constituted, the optic radiation forms a conspicuous strand (Figs. 514, p. 617; 520, p. 622; 534, p. 635), which, reaching the retrolenticular part of the internal capsule, sweeps backwards into the occipital lobe of the cerebral hemisphere on the lateral side of the posterior horn of the lateral ventricle. Its connexions will be studied more fully at a later stage.

THE PARTS DERIVED FROM THE TELENCEPHALON.

Cerebral Hemispheres.

The cerebral hemispheres form the largest part of the fully developed brain. When viewed from above they form an ovoid mass, the broadest end of which is directed backwards, and the longest transverse diameter of which will be found in the vicinity of the parts which lie subjacent to the parietal tuberosities of the cranium. The massive rounded character of the anterior or frontal end of each cerebral hemisphere constitutes a leading human characteristic; but the posterior or occipital end is narrow and pointed, and is directed somewhat downwards. The two cerebral hemispheres are separated from each other by a deep median cleft, termed the longitudinal fissure.

The cerebral hemisphere is formed from a small area of the extreme anterior end of the alar lamina, in the angle between the foremost part of the roof and the upper end of the lamina terminalis (Fig. 516, L), which becomes continuous with the roof (at the point marked X).

The rapid expansion of this area leads to the development of a lateral bulging containing a diverticulum of the third ventricle, which is known as the **ventriculus lateralis**. This at first communicates with the third ventricle by means of a wide opening (F.M.), the **foramen inter-ventriculare [Monro]**, corresponding in size to the extent of the area of the side wall that was bulged outwards to form the hemisphere vesicle. The thin epithelial roof of the telencephalon takes no share in the formation of the two cerebral hemispheres, but serves with the lamina terminalis (L) as a bond of union between them. At a somewhat later stage in development two folds become invaginated from this epithelial roof in the whole extent of the prosencephalon, both its telencephalic and diencephalic parts. In the greater part of their length these folds project into the third ventricle, and form its **chorioid plexus** (Fig. 517); but the anterior parts of the two chorioidal folds, namely, those parts formed from the roof of the interventricular foramina (F.M.), become greatly enlarged and project each into the corresponding lateral ventricle. The furrow corresponding to this invagination of the roof is called the **fissura chorioidea.** When the hemisphere vesicle first begins to expand, the thinner part of the hemisphere wall, which is called the **pallium,** is freely continuous around the vertical caudal margin of the foramen interventriculare (Fig. 516, Y) with the thalamus (TH).

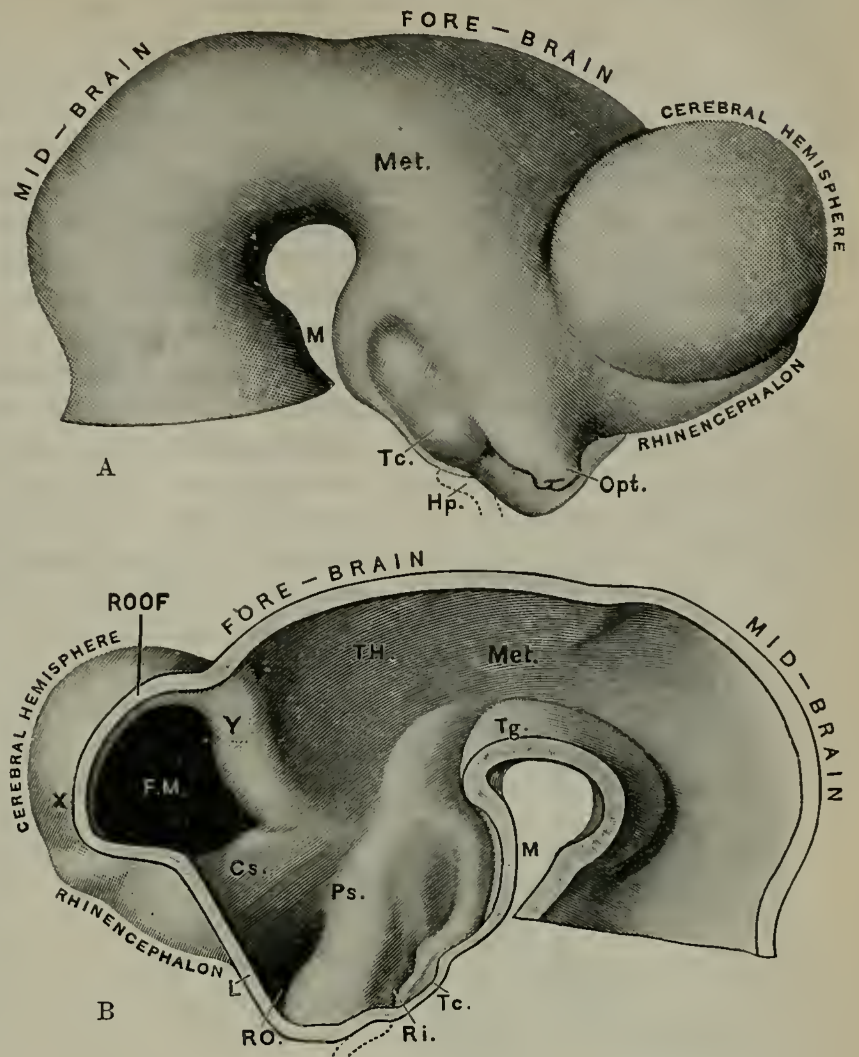

Fig. 516.—Two Drawings of the Embryonic Brain. (After His.)

A, Reconstruction of the fore-brain and mid-brain of His's embryo KO; profile view. B, Same brain as A, divided along the median plane and viewed upon its inner aspect.

M, Mamillary eminence; Tc, Tuber cinereum; Hp, Hypophysis (hypophyseal diverticulum from buccal cavity); Opt, Optic stalk; TH, Thalamus; Tg, Tegmental part of mesencephalon; Ps, Pars hypothalamica; Cs, Corpus striatum; FM, Foramen interventriculare; L, Lamina terminalis; RO, Recessus opticus; Ri, Recessus infundibuli; Met, Metathalamus.

But as development proceeds the wall of the prosencephalon becomes attenuated along the line of this pallio-thalamic junction, and eventually the edge of the pallium fringing this attachment to the thalamus becomes reduced to a thin layer of epithelium which is continuous at its superior end with the lamina chorioidea of the roof. Into this secondarily formed caudal extension of the chorioid lamina the invagination that commenced in the roof of the foramen interventriculare extends until it reaches the inferior extremity of the deep cleft separating the cerebral hemisphere from the thalamus (Fig. 516, A). Below this point the thalamus remains in uninterrupted continuity with the floor of the cerebral hemisphere (Cs), which is becoming thickened to form the **corpus striatum.**

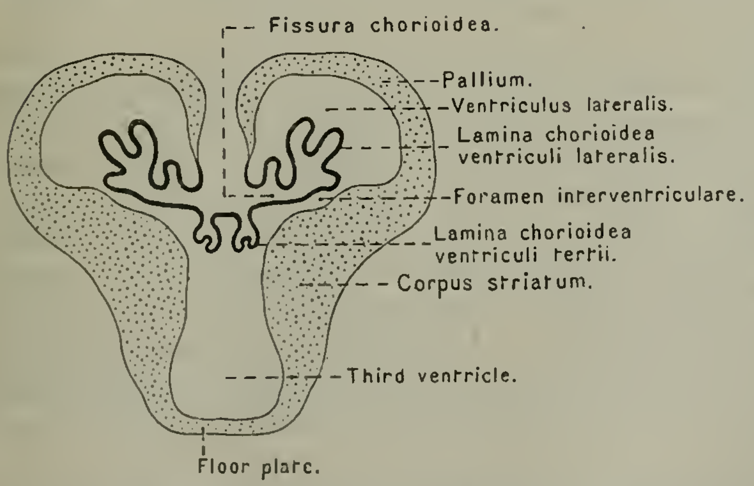
Fissura chorioidea.
Pallium.
Ventriculus lateralis.
Lamina chorioidea ventriculi lateralis.
Foramen interventriculare.
Lamina chorioidea ventriculi tertii.
Corpus striatum.
Third ventricle.
Floor plate.

Fig. 517.—Diagram of a Transverse Section through a Fœtal Brain to show the Invagination of the Roof through each Interventricular Foramen.

At a very early stage in the development of the embryo, long before there is any sign of the hemisphere vesicles, the ectoderm upon each side of the anterior neuropore (see p. 502) becomes thickened to form the **area olfactoria** (see Fig. 417, D, p. 503). Certain of the epithelial cells in this area become converted into bipolar sensory cells, which become specially adapted to be affected by certain kinds of air-borne chemical stimuli that awaken a consciousness of smell. These cells always remain *in situ* in the olfactory epithelium, just as the most primitive sensory cells do in Hydra (Fig. 414, p. 499). But other nerve-cells seem to be derived from the area olfactoria which do not remain in the parent epithelium, but become attached to the adjoining part of the neural tube. These cells form the **olfactory ganglion**, which acts as the receptive organ for the impressions brought into it by the processes of the sensory cells in the olfactory epithelium; and the area of the neural tube to which it becomes attached is destined to become part of the cerebral hemisphere. At the end of the first month this portion of the hemisphere becomes drawn out as a hollow protrusion, the distal end of which is coated with a layer of olfactory ganglion and is known as the **bulbus olfactorius**; the rest forms a peduncle. In the course of its subsequent development in the human brain (though not in those of most mammals) the cavity in the bulb and peduncle becomes completely obliterated. The peduncle becomes so greatly elongated and attenuated that, to the unaided eye, it appears to be wholly formed of white nerve-fibres passing to and fro between the olfactory bulb and the hemisphere; hence it is called the **tractus olfactorius.**

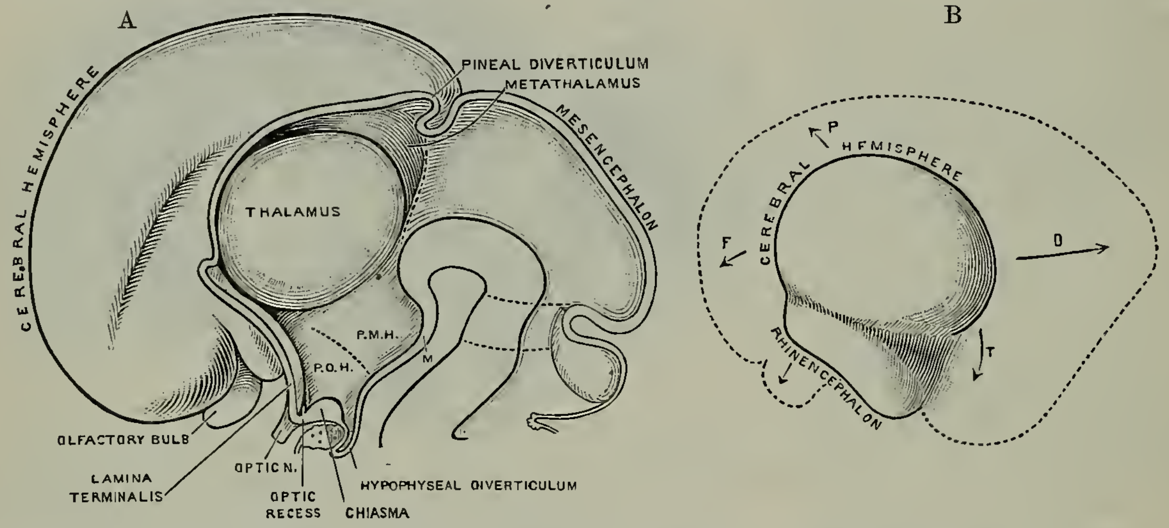

FIG. 518.—TWO DRAWINGS BY HIS, ILLUSTRATING THE DEVELOPMENT OF THE HUMAN BRAIN.

A, Median section through a fœtal human brain in the third month of development.
B, Schema showing the directions in which the cerebral hemisphere expands during its growth.

P.M.H. Pars mamillaris hypothalami.
P.O.H. Pars optica hypothalami.
M. Mamillary region.
F. Frontal lobe.
P. Parietal lobe.
O. Occipital lobe.
T. Temporal lobe.

The cerebral hemisphere first appears in the form of a slight bulging upon each side of the fore-brain, but it soon assumes large dimensions. At first it grows forwards and upwards (Fig. 518), and a distinct cleft, the floor of which is the roof-plate and lamina terminalis, appears between the two hemispheres: this is known as the **fissura longitudinalis cerebri.** The separation of the two cerebral vesicles by the longitudinal fissure begins at the end of the first month. This fissure becomes occupied by mesodermic tissue, which later on forms the falx cerebri. The cerebral hemisphere, in its further growth, is carried progressively backwards over the posterior parts of the developing brain. At the end of the third month it has covered the thalamus. A month later it reaches the corpora quadrigemina, and by the seventh month it has not only covered these, but also the entire upper surface of the cerebellum.

In the earlier stages of its development the cerebral hemisphere is a thin-walled vesicle with a relatively large cavity, which represents the primitive condition of the lateral ventricle. At first the vesicle is bean-shaped and the cavity is curved. As development proceeds the posterior portion of the hemisphere grows backwards over the cerebellum in the shape of a hollow protrusion, and a distinct occipital lobe enclosing the posterior horn of the lateral ventricle is the result. This developmental stage begins about the fourth month.

The Connexions of the Olfactory Nerves.

The olfactory nerves are the axons of the spindle-shaped bipolar cells situated in the olfactory mucous membrane (Fig. 519). These axons collect in the submucous layer to form small bundles, which enter the cranial cavity through the foramina in the lamina cribrosa of the ethmoid bone. They at once enter the inferior surface of the bulbus olfactorius, and each fibre breaks up into a tuft of terminal filaments. Towards these tufts dendrites proceed from large **mitral cells** placed in a deeper plane within the bulb, and each dendrite also breaks up into numerous terminal branches intertwined with those of the olfactory nerves. In this way are formed a large number of globular bodies, each consisting of the arborescent terminations of a mitral dendrite and of certain olfactory nerve-fibres. These are the **olfactory glomeruli** of the bulb. Each mitral cell gives off several dendrites and one axon. Only one dendrite enters into the formation of a glomerulus, but several nerve-fibres may be connected with such a body. It thus happens that, through its dendrite, a mitral cell may stand in connexion with several olfactory nerve-fibres. The axon of the mitral cell passes upwards to the white matter of the bulb, enters this, and, bending backwards, is conducted through the tract towards the cerebral cortex.

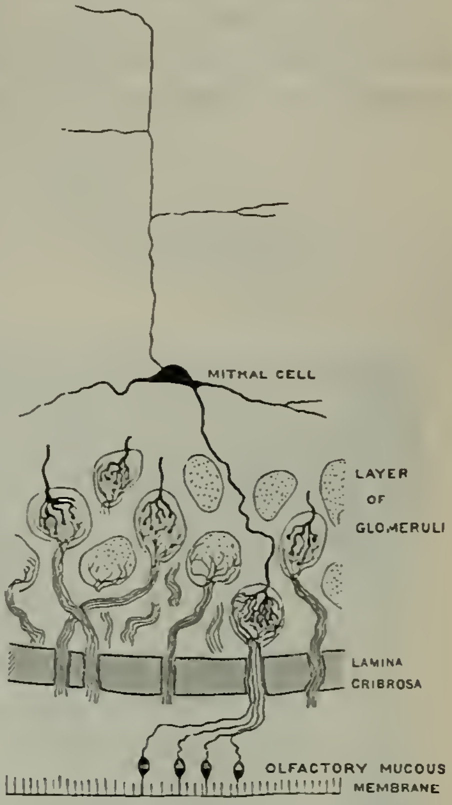

Fig. 519.—Diagram of the Minute Structure of the Olfactory Bulb.

The **olfactory bulb** is a small, flattened, elliptical mass of gray substance placed upon the upper surface of the lamina cribrosa of the ethmoid. Its posterior extremity is attached to the rest of the cerebral hemisphere by the long **tractus olfactorius** (Fig. 450), a prismatic band of white substance placed in a furrow (**sulcus olfactorius**) on the under surface of the frontal region of the cerebral hemisphere. A short distance in front of the optic chiasma each olfactory tract becomes inserted into the hemisphere (Fig. 520). The swollen pyramidal-shaped attached end of the peduncle is called the **trigonum olfactorium.** Immediately behind the trigone a small obliquely placed ovoid area of gray matter, the **tuberculum olfactorium,** can sometimes be detected in the human brain; but in the brains of most mammals with a greater development of the organs of smell this swollen area is much more prominent and constant. In most human brains, however, it is difficult to distinguish it from a much more extensive area, which is situated behind it and to its lateral side, and is named the **substantia perforata anterior** (Fig. 520). Along the anterior margin of this perforated substance there can sometimes be detected a small, rounded, rope-like strand of gray matter, the medial end of which passes into the trigonum olfactorium. This is the anterior part of the **area piriformis**—the stalk of the pear-shaped lobe—and upon its surface is placed a very well-defined narrow band of nerve-fibres, the **stria olfactoria lateralis,** which is composed of axons of mitral cells (in the olfactory bulb) proceeding to the piriform area. Even when the anterior part of the piriform area is not distinguishable, the stria lateralis is always a prominent feature.

The piriform area extends transversely laterally in the deep valley between the orbital and temporal regions of the hemisphere (**fossa cerebri lateralis**); becoming slightly broader, and reaching what is known as the **insula** (of which it forms the **limen insulæ**), it becomes sharply bent upon itself (Figs. 520, and 521, C). It then passes medially and backwards, and emerges from the fossa as a broad area upon the under surface of the temporal region (Fig. 521, C). This greatly expanded caudal extremity of the pear is the **area piriformis** in the strict sense of the term.

If the brain of almost any other mammal is examined (take the rabbit's as an example), the area piriformis will be found to constitute relatively an enormously larger proportion of the cerebral hemisphere than it does in the human brain; and it is separated from the part of the hemisphere (**neopallium**) that lies above it by a longitudinal furrow called the **fissura rhinalis**. The enormous expansion of the neopallium in the human brain accentuates the flexure of the piriform area at the point *x* (Fig. 521), and at the point *y* the exuberant growth of neopallium relegates the swollen posterior part of the piriform area on to the medial surface (Fig. 522), where the posterior part of the rhinal fissure persists to separate it from the neopallium.

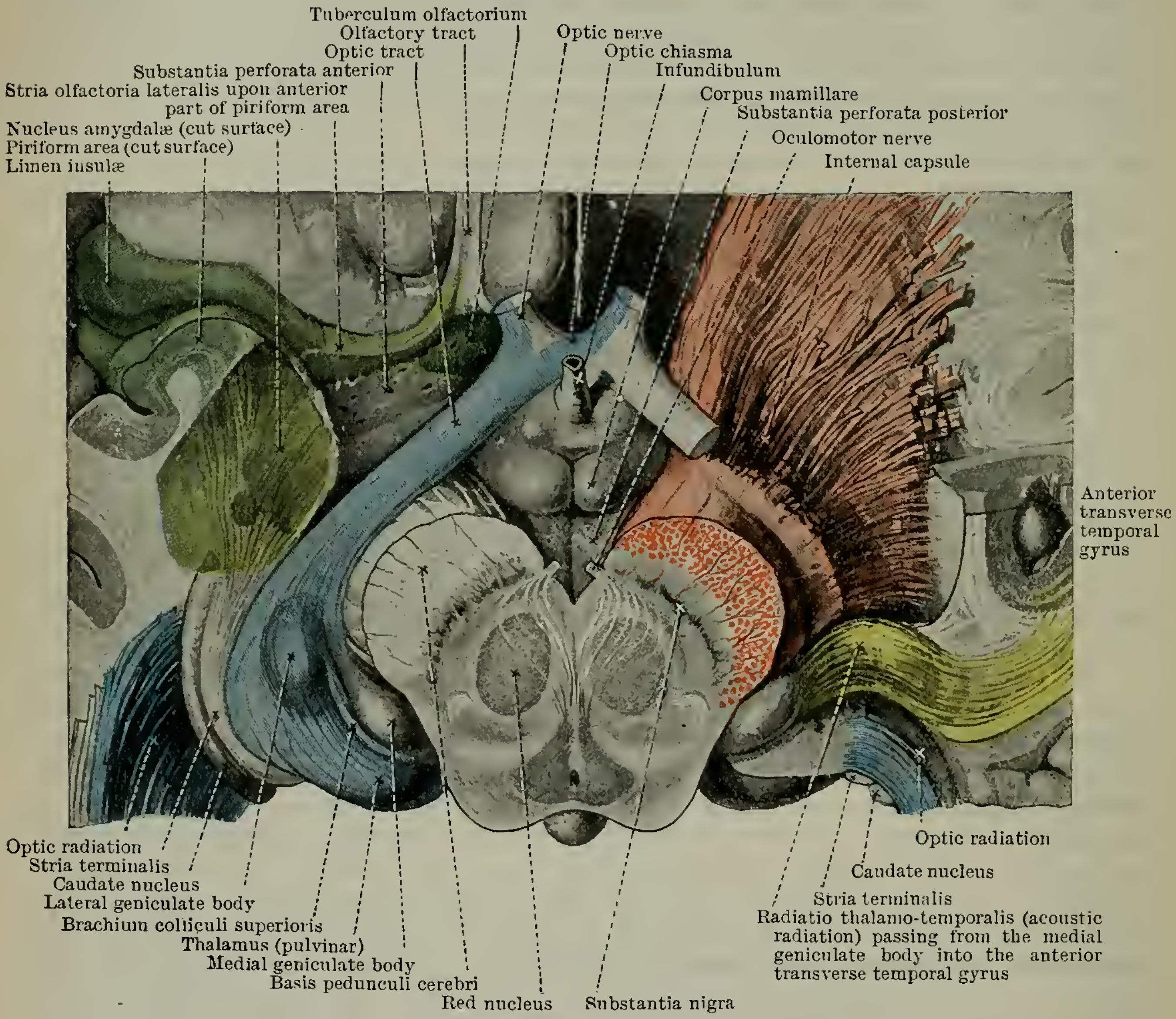
Tuberculum olfactorium
Olfactory tract
Optic tract
Substantia perforata anterior
Stria olfactoria lateralis upon anterior part of piriform area
Nucleus amygdalæ (cut surface)
Piriform area (cut surface)
Limen insulæ
Optic nerve
Optic chiasma
Infundibulum
Corpus mamillare
Substantia perforata posterior
Oculomotor nerve
Internal capsule
Anterior transverse temporal gyrus
Optic radiation
Stria terminalis
Caudate nucleus
Lateral geniculate body
Brachium colliculi superioris
Thalamus (pulvinar)
Medial geniculate body
Basis pedunculi cerebri
Red nucleus
Substantia nigra
Optic radiation
Caudate nucleus
Stria terminalis
Radiatio thalamo-temporalis (acoustic radiation) passing from the medial geniculate body into the anterior transverse temporal gyrus

FIG. 520.—PART OF THE VENTRAL SURFACE OF THE PROSENCEPHALON, SHOWING THE ATTACHMENT OF THE OLFACTORY TRACT.

Olfactory area, dull yellow; optic, blue; motor fibres, red; acoustic fibres, bright yellow.

The surface of the piriform area often presents numerous small wart-like excrescences; and it is whitened by a thin layer of fibres (**substantia reticularis alba**) prolonged backwards from the stria olfactoria lateralis. By these fibres olfactory impulses are poured directly from the mitral cells of the bulb into the piriform area. If we call the olfactory nerves the **primary olfactory neurones**, the fibres which pass from the bulb to the piriform area would then be **secondary olfactory neurones**.

Formatio Hippocampalis.—From all parts of the area piriformis, as well as the trigonum and tuberculum olfactorium, fibres arise (**tertiary olfactory neurones**), and proceed on to the medial aspect of the hemisphere, where they terminate in the edge of the pallium, alongside the lamina chorioidea. In the human brain the vast majority of these tertiary neurones proceed from the posterior extremity of the piriform area, but a certain number arise in the neighbourhood of the substantia perforata anterior and proceed at once on to the medial surface of the hemisphere. The large number of small nerve-cells that collect in the medial edge of the pallium become specially modified in structure to form a receptive organ for impressions of smell, known as the **fascia dentata**; and the axons of these cells pass into the part of the pallium which immediately surrounds the peripheral edge of the fascia dentata and is known as the **hippocampus** (Fig. 524). In the hippocampus impressions of smell are brought into relation with those of other senses (probably taste); and from the hippocampal cells fibres are emitted to form a system known as the **fornix**, which establishes connexions with the hippocampus of the other hemisphere and with the hypothalamus, thalamus, and more distant parts of the brain.

The rudiment of the hippocampal formation (coloured orange in Fig. 522) that develops on the medial surface begins in front, alongside the place where the stalk of the olfactory peduncle (which becomes the trigonum olfactorium) is inserted; it passes upwards to the superior end of the lamina terminalis, from the rest of which it is separated by a triangular mass of gray matter called the **corpus paraterminale** (shown in blue in Fig. 522); and then it proceeds upward to the rostrum of the corpus callosum and passes forward around the genu to reach the upper surface of the corpus callosum. Extending backward it passes around the splenium to join the fully developed part of the hippocampal formation. The anterior part of this great hippocampal fringe of the pallium does not attain its full development in the human brain and remains as a more or less vestigial aborted structure; but the posterior part undergoes a peculiar transformation. The tertiary olfactory neurones, coming mainly from the posterior part of the area piriformis (green in the figure), enter the margin of the hippocampal formation, and the small cells which receive these incoming fibres multiply rapidly during the third month, and arrange themselves in a densely packed row of granules, which represent the distinctive feature of the **fascia dentata** (Fig. 524). At first this cell-column is continuous at

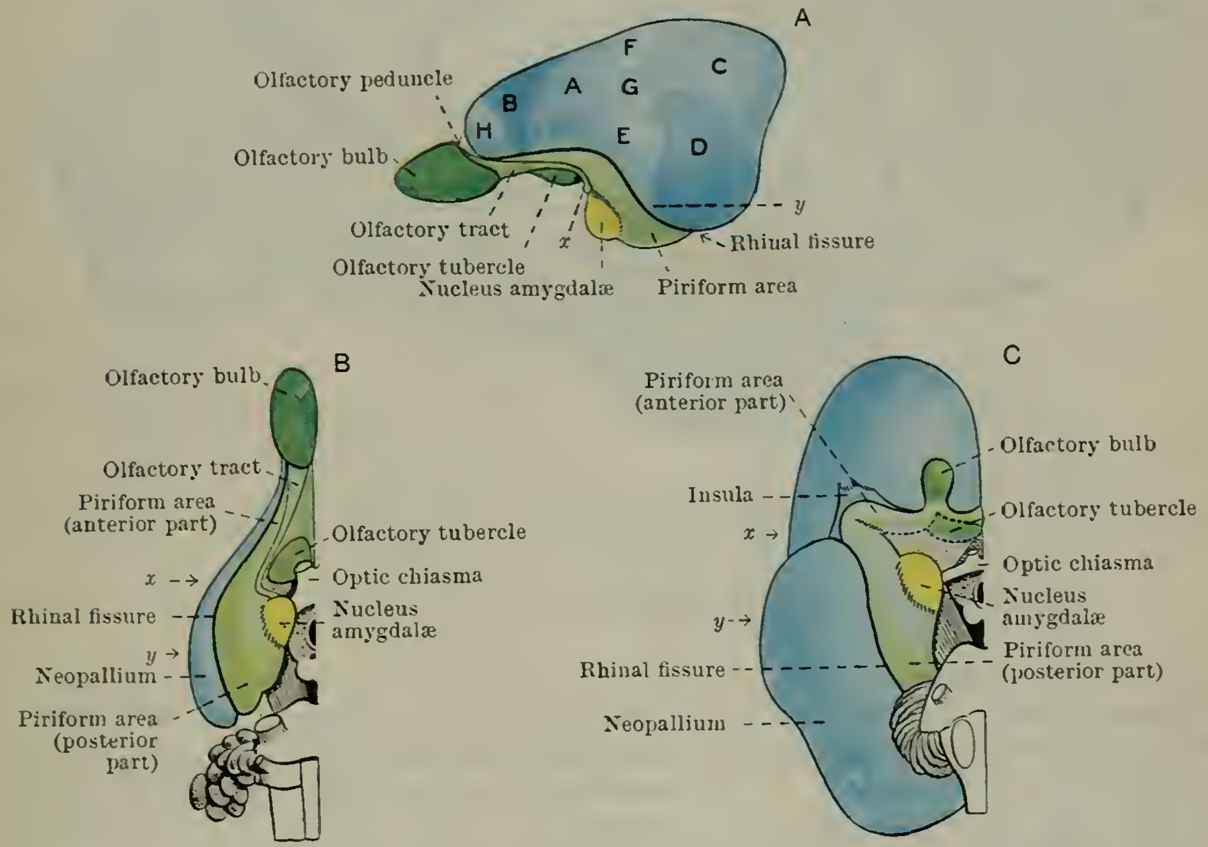

FIG. 521.

A, The lateral aspect of the left cerebral hemisphere of a rabbit. B, The inferior aspect of the right half of a rabbit's brain. C, The corresponding view of a human fœtal brain at the fifth month.

Olfactory areas, green ; neopallium, blue.

its peripheral margin with a much more loosely packed column of larger and less numerous cells, which represent the **hippocampus**; and these in turn give place to the more diffusely arranged and laminated cells of the typical **cortex cerebri**, which we call the **neopallium**. As development proceeds both the dentate and hippocampal columns of cells rapidly increase in length, and both appear to push their way towards the ventricle (Fig. 524, B) into the substance of the wall, which becomes correspondingly thickened. The ventricular swelling thus formed is the hippocampus; and it is important to recognise that this swelling is not produced by any invagination of the surface, such as is usually described under the name of the **fissura hippocampi**. *There is no fissura hippocampi in the human brain.* What is usually described under this name is an artificial cleft made by pushing the handle of a scalpel into the hippocampal formation at the edge of the exposed part of the fascia dentata (Fig. 524, B and C, at *x*) and separating the morphological surface of the hippocampus from that of the buried part of the fascia dentata. Cleavage readily occurs along this line because there are numerous nerve-fibres, hippocampal and dentate respectively, upon each side of it.

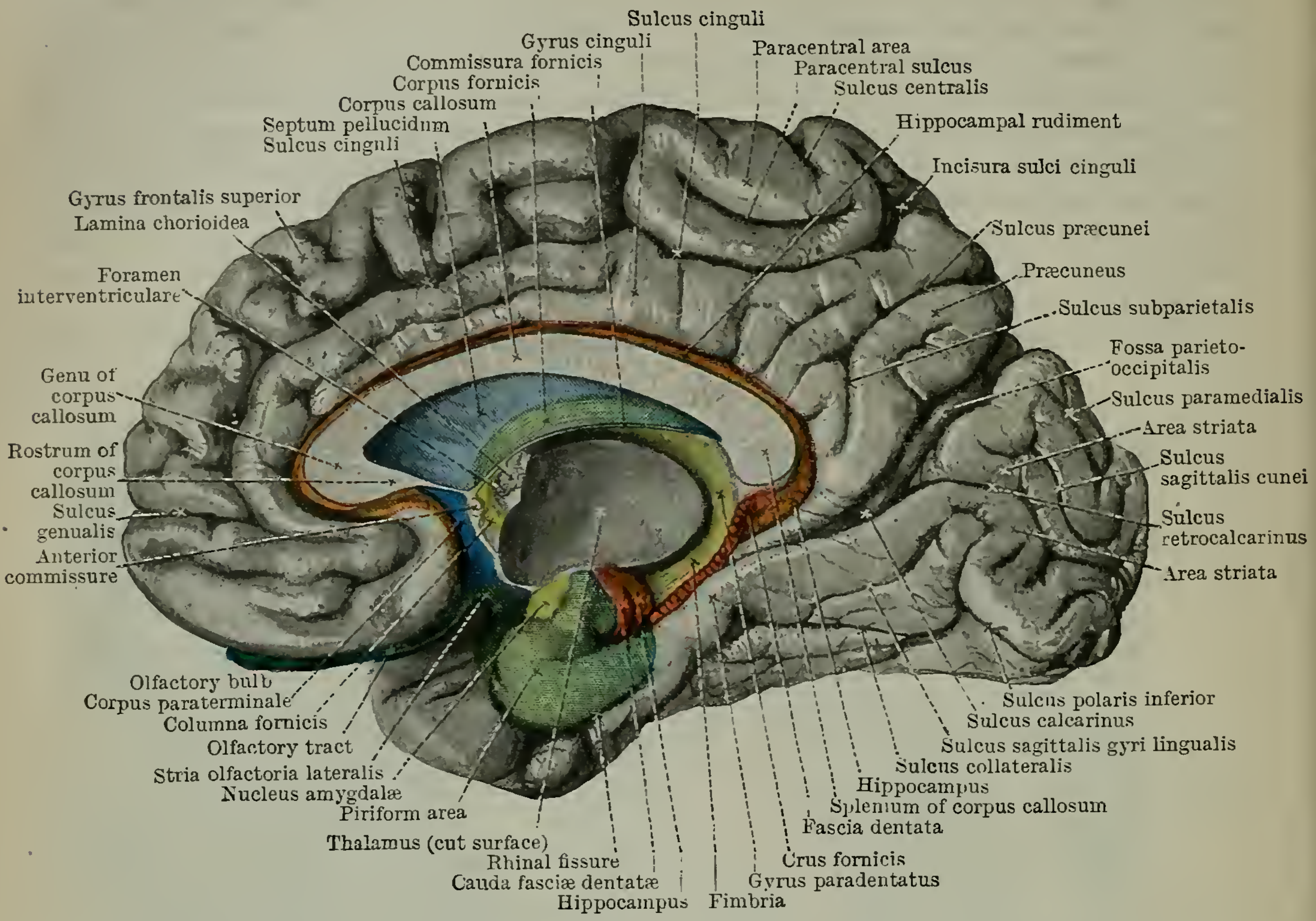

Fig. 522.—Medial Aspect of the Right Cerebral Hemisphere, with the Olfactory Parts coloured.

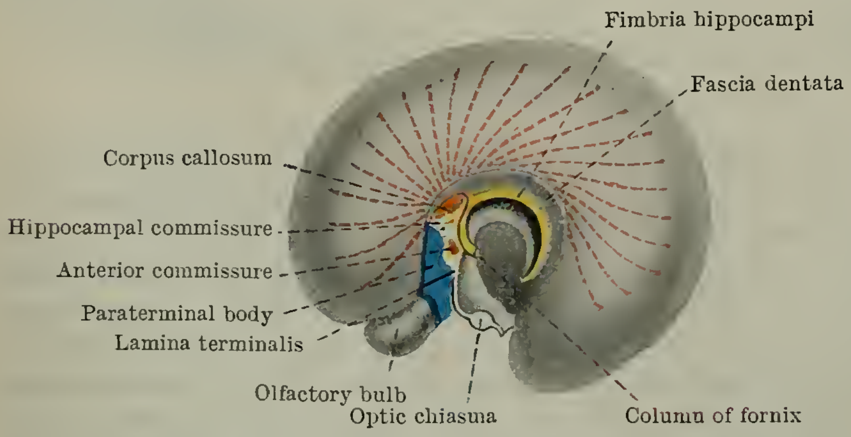

Fig. 523.—Medial Aspect of the Right Cerebral Hemisphere of a Human Fœtus of the Fourth Month.

The broken red lines indicate the paths taken by callosal fibres in the neopallium to reach the upper end of the lamina terminalis.

As development proceeds a break occurs in the cell-column at the junction of its hippocampal and dentate parts, and the two columns (Fig. 524, C) become partially interlocked.

THE FORNIX.

The Fornix is the efferent tract from the hippocampus to (*a*) the hippocampus in the other hemisphere, and (*b*) to the brain-stem.

The axons of the hippocampal cells collect upon the ventricular surface to form the *alveus* (Fig. 524), the fibres of which converge towards the margin of the fascia dentata, where they bend into the longitudinal direction (*i.e.* parallel to the edge of the pallium and the lamina chorioidea) to form a prominent white marginal fringe, the **fimbria** (Fig. 524).

The fibres of the fimbria pass upwards and forwards (Fig. 523), and ultimately reach the upper end of the lamina terminalis, which provides a bridge to conduct a certain number of them across the median plane into the fornix or fimbria of the other hemisphere, so as to link together in functional association the two hippocampi. These crossing fibres are known as the **commissura hippocampi.**

Most of the fibres that go up in the fimbria from the hippocampus do not pass into the hippocampal commissure, but bend downwards in the anterior lip of the foramen interventriculare to enter the thalamic region. They are collected into a vertical rounded column, which is called the **columna fornicis**; when it reaches the hypothalamus it bends backward to end in the corpus mamillare, and from the latter fibres arise which descend in the tegmentum and establish connexions with the lower parts of the brain.

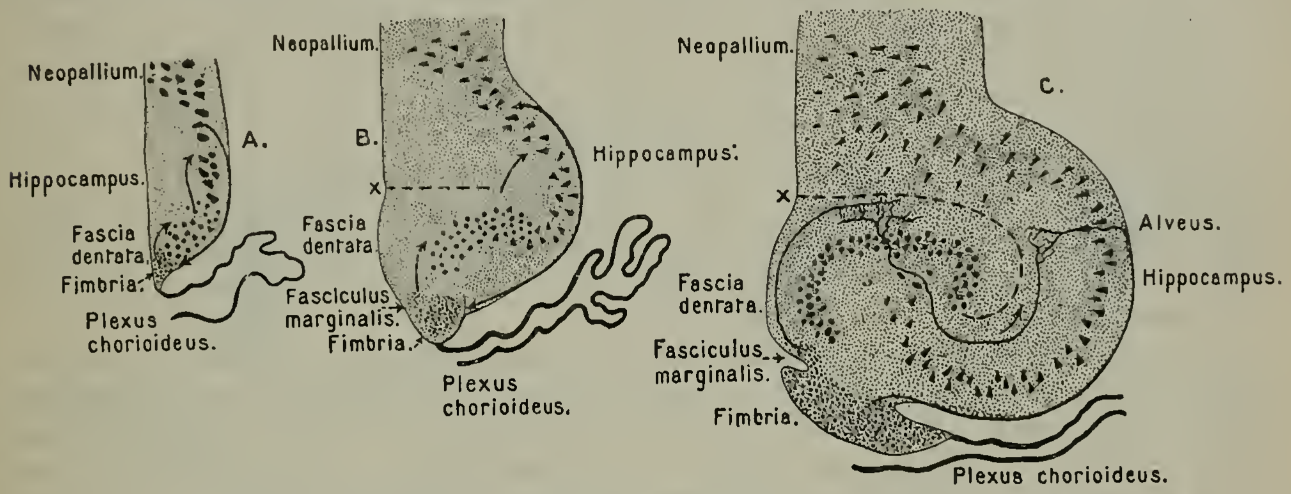

Fig. 524.—Diagrams representing three Stages in the Development of the Hippocampal Formation.

The olfactory bulb and tract, the area piriformis, tuberculum olfactorium, corpus paraterminale, and the formatio hippocampalis together form a part of the hemisphere, which is concerned mainly with the function of smell. Hence they may be grouped together as the **rhinencephalon**; but this term has been used in so many different ways that it is of doubtful utility.

In the lowest vertebrates the whole hemisphere is practically rhinencephalon. Nevertheless, fibres coming from other parts of the nervous system and conveying impressions from other sense organs than those of smell make their way into the cerebral hemisphere and influence the state of its activities. In other words, the hemisphere is primarily an olfactory receptive nucleus, but is also the place where impressions of smell are brought under the modifying influences of other sensory impressions before they make their effects manifest in behaviour.

But it is only in the most highly organised types of brain, more especially those of mammals and birds, that the non-olfactory senses acquire a representation in the hemisphere which is relatively independent of, or at any rate not wholly subservient to, the influence of the sense of smell. In the mammalian brain a definite area of pallium is set apart to receive impressions of the tactile, visual, acoustic, and other senses. This area is the **neopallium**. In the human brain it has grown to such an extent that it forms almost the whole of the hemispheres—a mass far greater than the whole of the rest of the central nervous system.

THE CEREBRAL COMMISSURES AND THE SEPTUM PELLUCIDUM.

We have seen that certain fibres from the hippocampi cross from one hemisphere to the other, using the upper part of the lamina terminalis as a bridge across the median plane. But at an earlier stage of development other fibres can be detected at a slightly lower level in the lamina terminalis forming a bundle, of oval outline in sagittal section, called the **commissura anterior.** Its fibres come from the olfactory bulb, area piriformis, tuberculum olfactorium, and a small temporal area of neopallium. If the composition of the hippocampal commissure is analysed in a fœtus of the third month, it will be found that there are intermingled with the truly hippocampal fibres some which come from the neopallium. During the fourth month the bulk of the neopallial element in this dorsal commissure outgrows the hippocampal element. The latter fibres become crowded into the postero-inferior corner of the commissure and the neopallial fibres come to form a flattened transverse bridge—the **corpus callosum**—above them. These fibres are enclosed in a neuroglial matrix derived from the lamina terminalis and the adjoining paraterminal bodies. Some nerve-cells also may make their way into this matrix. As it elongates, the corpus callosum pushes its way forwards in the upper part of the paraterminal body of each hemisphere, and as development proceeds a small area of this body becomes almost completely circumscribed by the corpus callosum and commissura hippocampi. As these commissural bands increase in size this small circumscribed patch of paraterminal body becomes greatly stretched and expanded to form a thin translucent leaf. The two leaves thus formed in the medial walls of the two hemispheres are known as the **septum pellucidum**; and the narrow cleft that separates them the one from the other in the median plane is called the **cavum septi pellucidi.**

There is still an element of uncertainty concerning the precise manner in which these changes are brought about, and especially as to the precise mode of closure of the cavum septi. As the cerebral hemisphere expands, some parts of it grow forwards, others upwards, and others again backwards. Such growth in each part will naturally tend to exert traction upon its commissural fibres that pass through the corpus callosum. Hence the anterior part of this great commissure becomes drawn forwards, its posterior part backwards, and the greater intermediate part upwards, so that it comes to assume the form shown in Fig. 525, C. As the posterior part of the corpus callosum pushes its way backwards, it exerts traction upon the fibres of the hippocampal commissure and their matrix, which becomes enormously stretched so as to form a thin lamella (the floor of the cavum septi) stretching from a point just above the anterior commissure to the under surface of the swollen posterior end of the corpus callosum, which is called the **splenium** (Fig. 522). The hippocampal commissural fibres are scattered throughout this lamella. The backward growth of the splenium also thrusts back the upper end of the hippocampal formation so that it becomes removed far from the lamina terminalis. The fibres of the fimbria which are prolonged forwards under the corpus callosum and septum pellucidum to bridge this great gap form the **crus fornicis** on each side. As a rule in the human adult brain the crura fornicis of the two hemispheres become crowded together at the median plane so as to obscure the connecting lamella which serves as a matrix for the commissura hippocampi (Fig. 525, C); but the true arrangement can be seen in the brains of fœtuses of the sixth, seventh, and eighth months, and is at once revealed in the adult if the corpus callosum is raised up by an accumulation of fluid in the lateral ventricles (hydrocephalus), so as to put a strain upon the septum pellucidum. The mass formed by the crura fornicis and their commissure is called the **corpus fornicis.**

The fascia dentata appears as a notched band behind and below the fimbria; its upper end passes on to the under surface of the splenium of the corpus callosum, where it tapers and ends **(fasciola cinerea)**; but as it dwindles the upper end of the hippocampus emerges upon the surface below and behind it and passes into a thin film of gray matter—**indusium griseum**—which is prolonged on to the upper surface of the corpus callosum. It proceeds forwards, becoming as a rule still more attenuated, and after surrounding the anterior end **(genu)** of the corpus callosum it passes downwards towards the trigonum olfactorium along the line that separates the corpus paraterminale from the neopallium. The indusium represents the atrophied remains of the anterior part of the hippocampal arc of the fœtal brain (Fig. 523), from which the fascia dentata has entirely disappeared. It is accompanied by longitudinal fibres homologous to the fornix system: in other words, the fornix fibres of the atrophied supracallosal hippocampus; they form the **striæ longitudinales** of the corpus callosum (Fig. 522; Fig. 531, p. 633; Fig. 526, p. 628).

The inferior (or anterior) extremity of the fascia dentata dips into a deep furrow, around which the area piriformis is bent in a hook-like manner **(uncus)**; in this it becomes considerably reduced in diameter and then emerges (at right angles to its previous direction) to form Giacomini's "**banderella**," which we may call the **cauda fasciæ dentatæ**. Behind this the inferior end of the hippocampus comes to the surface, but is turned inside out, *hippocampus inversus*. Just in front of the upper ending of the **cauda fasciæ dentatæ** a little knob of solid gray matter appears upon the surface, surrounded by the area piriformis. It is the **nucleus amygdalæ** (Fig. 522).

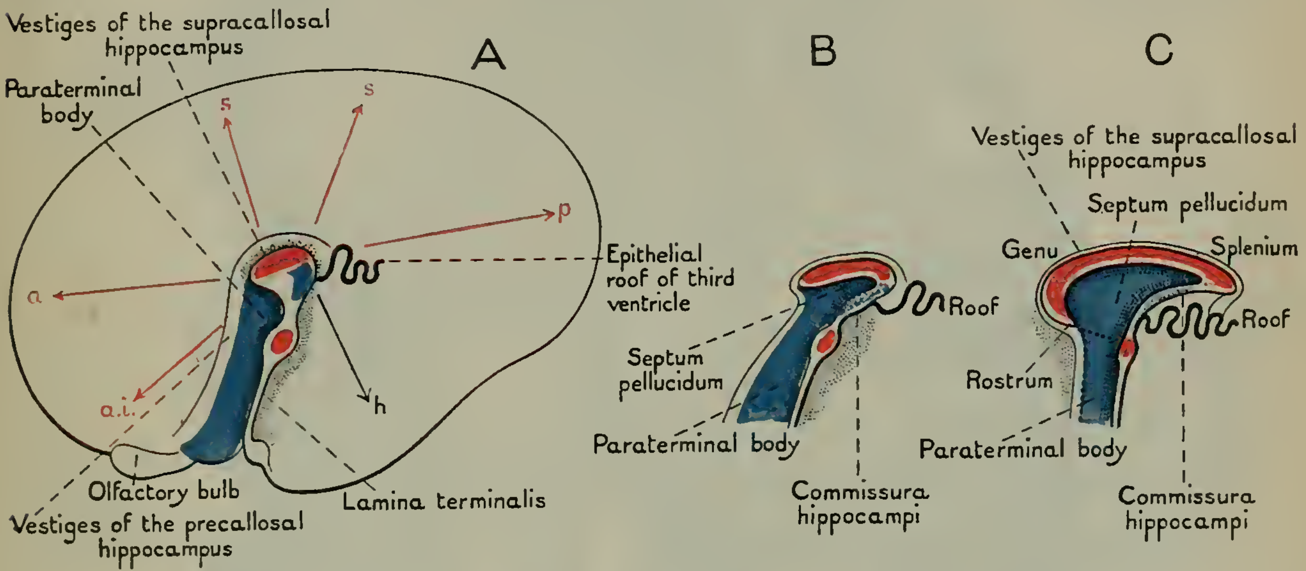

Fig. 525.—Three Stages in the Development of the Corpus Callosum.

Corpus Callosum.—The corpus callosum is the great transverse commissure which passes between the two cerebral hemispheres. It is placed nearer the anterior than the posterior aspect of the brain, and it unites the medial surfaces of the hemispheres throughout very nearly a half of their antero-posterior length. The corpus callosum is highly arched from before backwards, and presents a convex superior surface and a concave inferior surface when viewed from the side (Fig. 522).

The *superior surface* of the corpus callosum forms the bottom of the longitudinal fissure, and on each side of this it is covered by the gyrus cinguli. Only in its posterior part is it approached by the falx cerebri; in front, this process of dura mater falls considerably short of it. The superior surface of the corpus callosum is covered by a thin layer of indusium continuous at the bottom of the sulcus corporis callosi with the gray cortex on the surface of the hemisphere. In this there are embedded, on each side of the median plane, two delicate longitudinal bands of fibres, called respectively the stria longitudinalis medialis and lateralis. The **stria longitudinalis medialis** is the more strongly marked of the two, and it is separated from its fellow of the opposite side by a faint median furrow. The **stria longitudinalis lateralis** is placed farther out, under cover of the gyrus cinguli. The thin coating of gray matter, with the two striæ, represents the aborted remains of the hippocampus (see p. 624). So thin is this gray coating that the transverse direction pursued by the callosal fibres proper can be easily perceived through it.

The two extremities of the corpus callosum are much thickened, whilst the intermediate part or **body** is considerably thinner. The massive *posterior end*, which is full and rounded, lies over the mesencephalon and extends backwards as far as the highest point of the cerebellum. It is called the **splenium**, and it consists of a superior and inferior part. The latter is bent forwards under the upper part, to the inferior surface of which it is closely applied. The *anterior end* of the corpus callosum is not quite so massive, and it is folded downwards and backwards on itself. It is termed the **genu**. The recurved inferior part of the genu is separated from the part of the corpus callosum which lies above, by an interval. It rapidly thins as it passes backwards and receives the name of the **rostrum**. The fine terminal edge of the rostrum becomes connected by means of a band of neuroglial tissue with the lamina terminalis on the antero-superior aspect of the anterior commissure (Fig. 522).

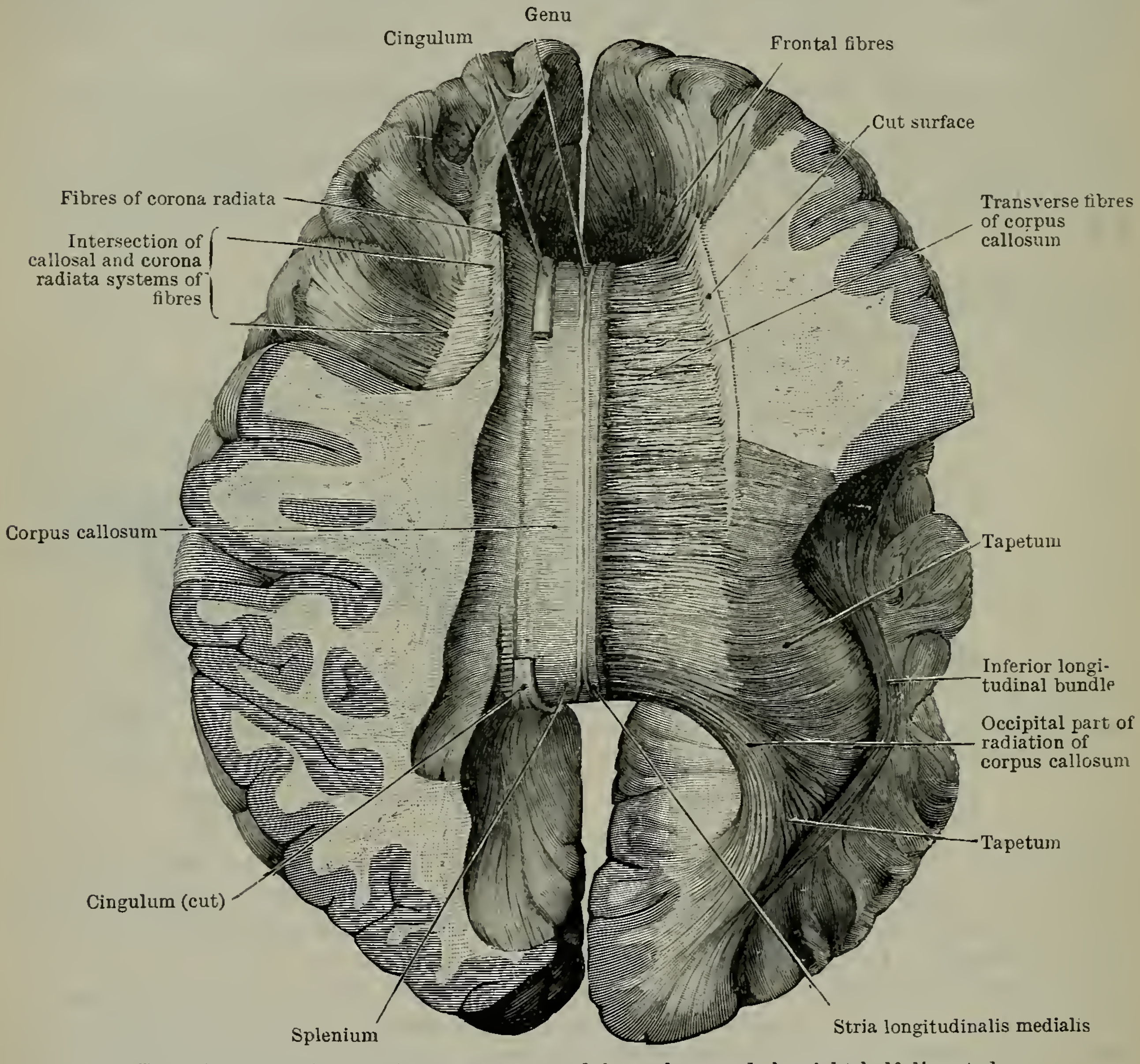
Genu
Cingulum
Frontal fibres
Cut surface
Fibres of corona radiata
Intersection of callosal and corona radiata systems of fibres
Transverse fibres of corpus callosum
Corpus callosum
Tapetum
Inferior longitudinal bundle
Occipital part of radiation of corpus callosum
Tapetum
Cingulum (cut)
Splenium
Stria longitudinalis medialis

FIG. 526.—THE CORPUS CALLOSUM, exposed from above and the right half dissected, to show the course taken by its fibres.

The lateral longitudinal stria (which lies near the cingulum) is not shown.

The *inferior surface* of the corpus callosum, on each side of the median plane, is coated with ependyma (Fig. 531, p. 633), and forms the roof of the anterior horn and the central part of the lateral ventricle. In the median plane, however, it is attached to subjacent parts, viz., to the septum pellucidum in front and directly or indirectly (Fig. 522) to the body of the fornix behind (Fig. 522, p. 624).

The transverse fibres of the corpus callosum, as they enter the white medullary centre of the cerebral hemisphere, separate from each other so as to reach most parts of the cerebral cortex. These diverging fibres are termed the **radiatio corporis callosi**, and they intersect those which form the corona radiata or, in other words, the fibres which extend between the internal capsule and the cerebral cortex (Figs. 535, p. 636, and 536, p. 637). The more anterior of the fibres which compose the genu of the corpus callosum sweep forwards in a series of curves into the anterior frontal region of the hemisphere. A large part of the splenium, forming a solid bundle termed the **occipital part of the radiation of the corpus callosum** (O.T. **forceps major**), bends suddenly and abruptly backwards into the occipital lobe (Fig. 526). Fibres from the body and superior part of the splenium, curving round the lateral ventricle, form a very definite stratum, called the **tapetum**. This is a thin layer in the medullary centre of the hemisphere, which constitutes the immediate roof and lateral wall of the posterior horn and the lateral wall of the posterior part of the inferior horn of the lateral ventricle. In frontal sections through the occipital and posterior temporal regions the tapetum stands out very distinctly (Fig. 526, p. 628; see also Figs. 532, p. 633, and 534, p. 635).

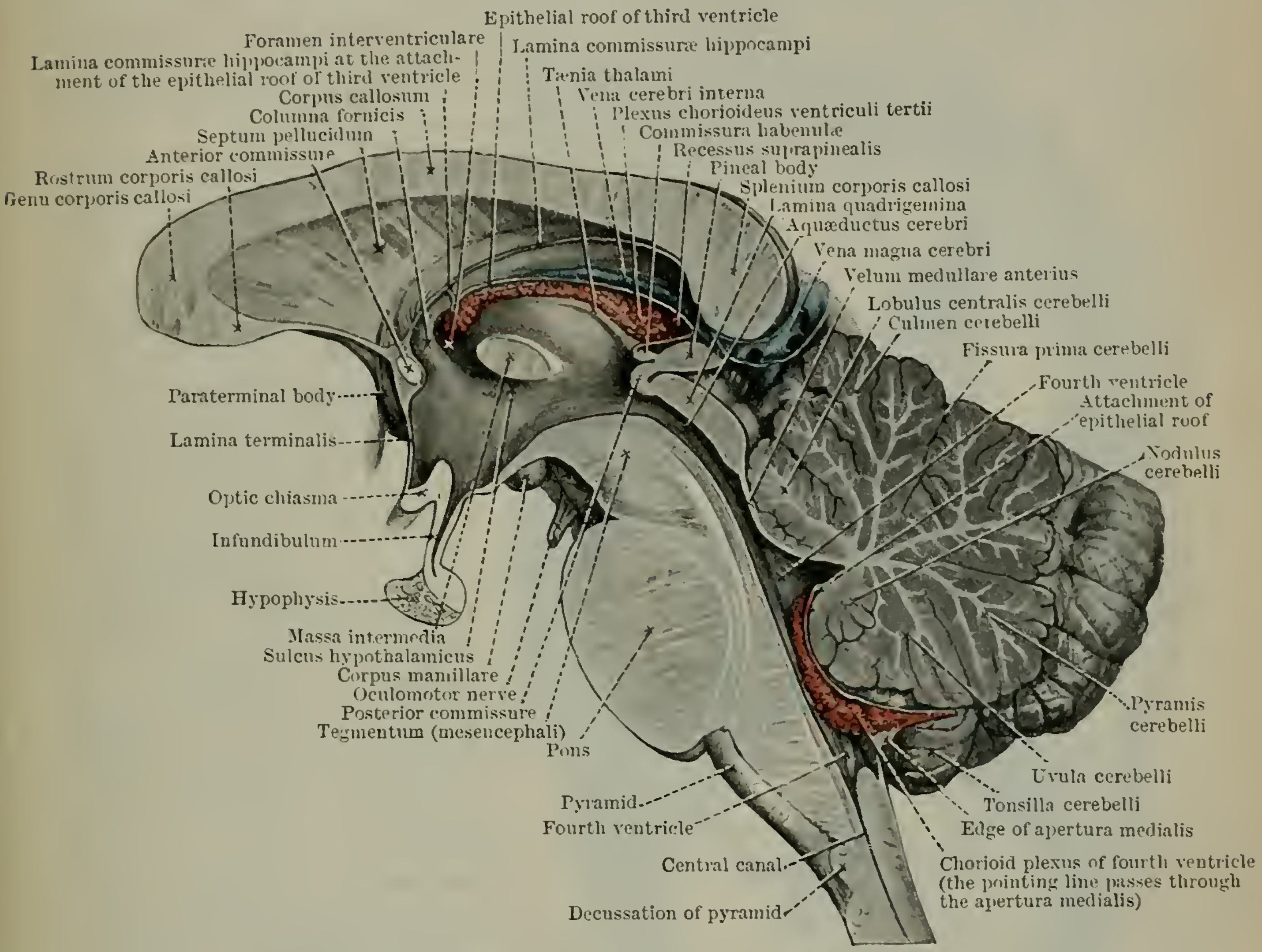

FIG. 527.—THE PARTS OF THE BRAIN CUT THROUGH IN A MEDIAN SAGITTAL SECTION.
The side walls of the ventricular cavities are also shown.

Septum Pellucidum.—The septum pellucidum is a thin vertical partition which intervenes between the two lateral ventricles. It is triangular in shape, and posteriorly it is prolonged backwards for a variable distance between the body of the corpus callosum and the fornix, to both of which it is attached. In front it occupies the gap behind the genu of the corpus callosum, whilst below, in the narrow interval between the posterior edge of the rostrum of the corpus callosum and the fornix, it is prolonged downwards in the paraterminal body towards the base of the brain. The septum pellucidum is composed of two thin laminæ in apposition with each other in the median plane (Fig. 529; Fig. 531, p. 633).

Cavum Septi Pellucidi.—This name is applied to the median cleft between the two laminæ of the septum pellucidum. It varies greatly in size in different brains.

VENTRICULUS LATERALIS.

The cavity in the interior of the cerebral hemisphere is called the **lateral ventricle**. It is lined throughout by ependyma continuous with the ependymal lining of the third ventricle. In some places the walls of the cavity are in apposition, whilst in other localities spaces of varying capacity, and containing cerebro-spinal fluid, are left between the bounding walls.

The **lateral ventricle** communicates with the third ventricle of the brain by means of a small foramen, just large enough to admit a crow-quill, which is termed the **foramen interventriculare.** This aperture is placed in front of the anterior end of the thalamus and behind the column of the fornix.

The highly-irregular shape of the lateral ventricle can be best understood by the study of a cast of its interior (Figs. 528 and 513, p. 616). It is usual to describe it as being composed of a body and three horns, viz. an anterior, a posterior, and an inferior horn. The **cornu anterius** is that part of the cavity which lies in front of the interventricular foramen. The **body** or **pars centralis** is the portion of the ventricle which extends from the interventricular foramen to the splenium of the corpus callosum. At this point the posterior and inferior horns diverge from the posterior part of the body. The **cornu posterius** curves backwards and medially into the occipital lobe. It is very variable in its length and capacity: the chief reason for this variability is that adhesions between the walls of this part of the ventricle are of common occurrence. The **cornu inferius** proceeds with a bold sweep round the posterior end of the thalamus, and then tunnels in a forward and medial direction through the temporal lobe towards the temporal pole.

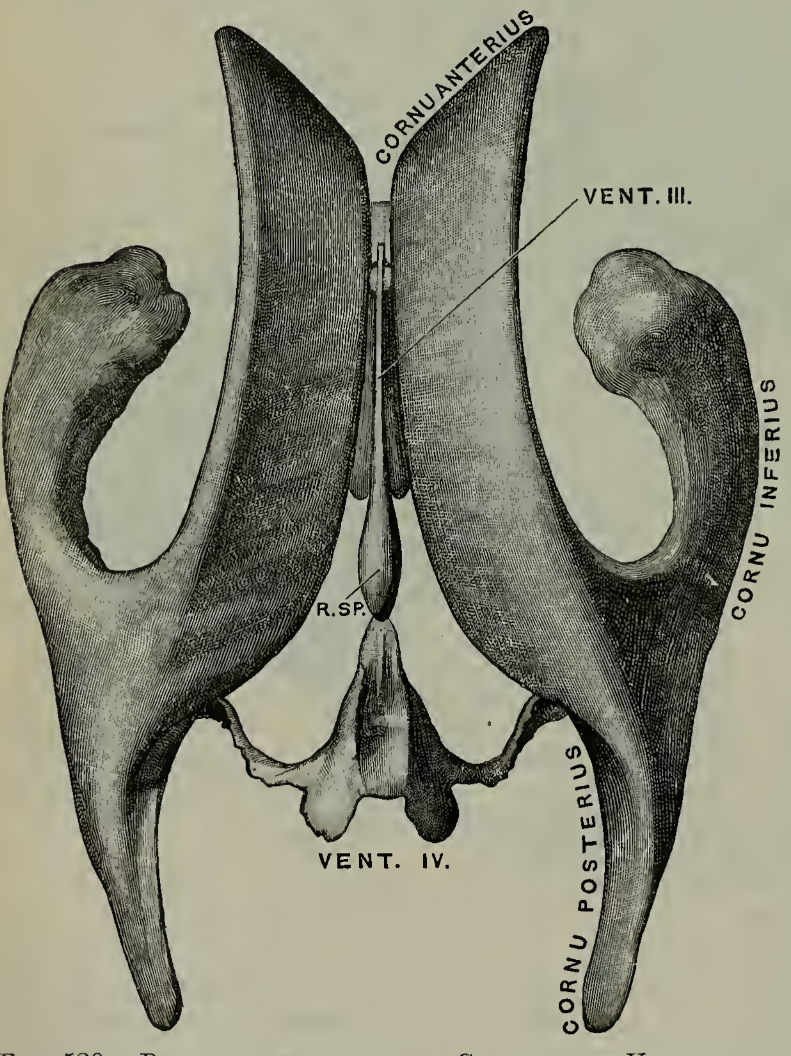

FIG. 528.—DRAWING TAKEN FROM A CAST OF THE VENTRICULAR SYSTEM OF THE BRAIN, as seen from above. (After Retzius.)

Vent. III. Third ventricle. Vent. IV. Fourth ventricle. R.SP. Recessus suprapinealis.

The early fœtal lateral ventricle is very capacious and presents an arched or semilunar form. It is composed of parts which correspond to the anterior horn, the central part and the inferior horn, and there is little or no demarcation between them. The posterior horn is a later production. It comes into existence as a diverticulum or elongated pouch, which grows backwards from the superior and posterior part (*i.e.* the convexity) of the primitive cavity.

Cornu Anterius.—The anterior horn forms the foremost part of the cavity, and extends in a forward and lateral direction in the frontal lobe. When seen in frontal section (Fig. 528) it presents a triangular outline, the floor sloping upwards and laterally to meet the roof at an acute angle. It is bounded *in front* by the posterior surface of the genu of the corpus callosum; the *roof* also is formed by the corpus callosum. The *medial wall*, which is vertical, is formed by the septum pellucidum; whilst the sloping *floor* presents a marked elevation or bulging, viz., the smooth, rounded, and prominent extremity of the pear-shaped caudate nucleus.

Pars Centralis.—The central part or body of the cavity is likewise *roofed* by the corpus callosum. On the *medial side* it is bounded by the posterior part of the septum pellucidum which attaches the fornix to the inferior surface of the corpus callosum. On the *lateral side* it is closed, as in the case of the anterior horn, by the meeting of the floor and the roof of the cavity. On the *floor* a number of important objects may be recognised. From the lateral to the medial side these are met in the following order: (1) the caudate nucleus; (2) a groove which extends obliquely from before backwards and laterally between the caudate nucleus and the thalamus, in which are placed the vena terminalis and a white band called the stria terminalis; (3) a portion of the superior surface of the thalamus; (4) the chorioid plexus; (5) the thin, sharp edge of the fornix (Fig. 531).

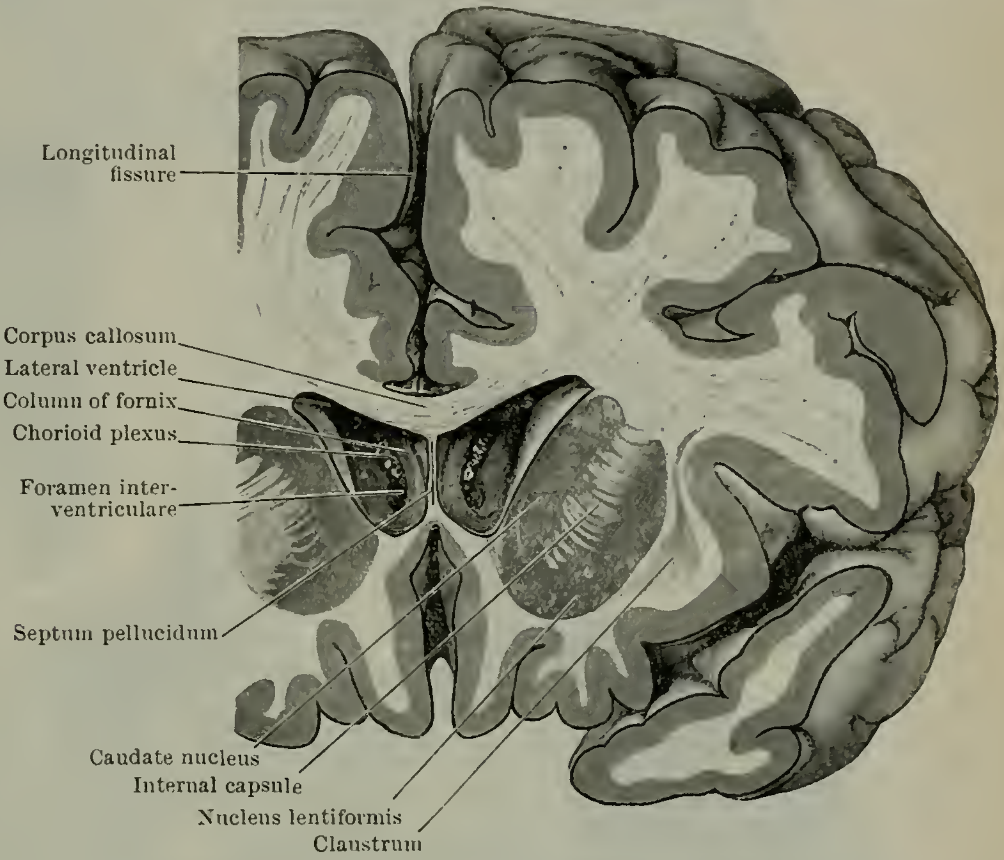

Fig. 529.—Frontal Section through the Cerebral Hemispheres so as to cut through the anterior horns of the lateral ventricles, through which the central part of the ventricles, the columns of the fornix, and the interventricular foramina can be seen.

The **caudate nucleus** narrows rapidly as it proceeds backwards on the lateral part of the floor of the lateral ventricle. The **vena terminalis** (O.T. **vein of the corpus striatum**) is covered over by ependyma. It joins the **vena cerebri interna** close to the foramen interventriculare. The connexions of the **stria terminalis** will be dealt with later. The portion of the superior surface of the **thalamus** which appears in the floor of the ventricle is in great part hidden by the chorioid plexus, which lies upon it. The **lamina chorioidea** is an epithelial fringe which is attached to the sharp edge of the fornix superiorly, and after surrounding a rich vascular fold of pia mater becomes fixed to the superior surface of the thalamus. The vascular fold is the chorioid plexus. In front it is continuous, in the interventricular foramen, with the corresponding chorioid plexus of the third ventricle (Fig. 522), whilst behind, it is carried into the inferior horn of the ventricle. Although the chorioid plexus has all the appearance of lying free within the ventricle, it must be borne in mind that it is invested by the epithelial chorioidal lamina which represents a portion of the hemisphere wall and excludes it from the cavity.

Cornu Posterius.—The posterior horn is an elongated diverticulum carried backwards into the occipital lobe from the posterior end of the ventricle. It tapers to a point and describes a gentle curve, the convexity of which is directed laterally. The *roof* and *lateral wall* of this portion of the ventricular cavity are formed by the tapetum of the corpus callosum. In frontal sections through the occipital lobe this is seen as a thin but distinct layer of white fibres, which lies immediately lateral to the ependyma and to the medial side of a much larger strand of fibres in the medullary substance of the occipital lobe, viz., the optic radiation.

On the *medial wall* two elongated curved elevations may be observed. The uppermost of these is termed the **bulb of the cornu (bulbus cornu posterioris)**, and is produced by the fibres of the radiation of the corpus callosum as they curve abruptly backwards from the lower part of the splenium of the corpus callosum into the occipital lobe. Below this is the elevation known as the **calcar**. It varies greatly in size in different brains, and is caused by an infolding of the ventricular wall in correspondence with the anterior part of the calcarine sulcus on the exterior of the hemisphere. It may come into contact with and adhere to the lateral wall of the ventricle in a part or even the whole of its extent.

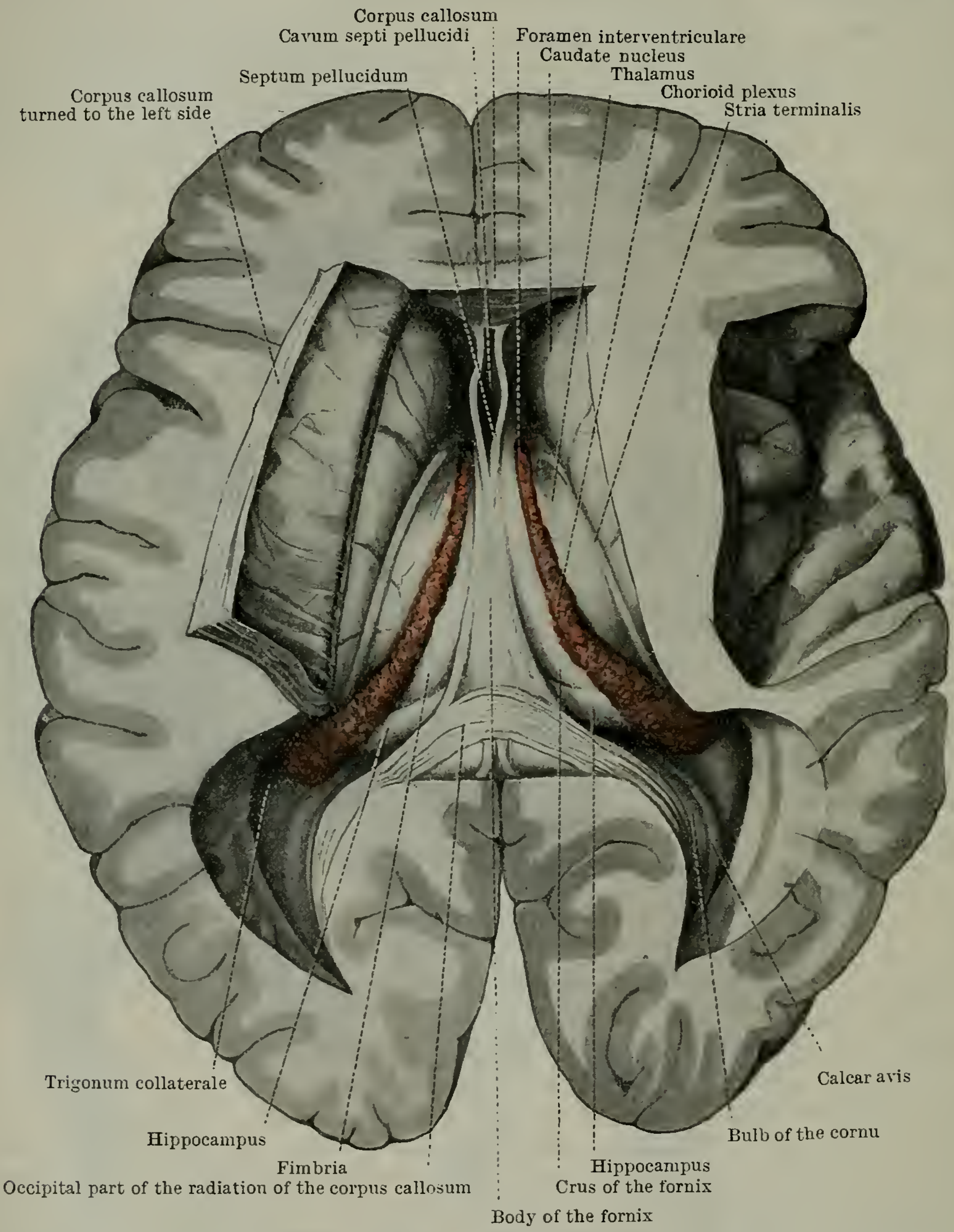

FIG. 530.—DISSECTION, to show the fornix and lateral ventricles; the body of the corpus callosum has been turned over to the left.

Cornu Inferius.—The **inferior horn** is the continuation of the cavity into the temporal region. At first directed backwards and laterally, the inferior horn suddenly sinks downwards behind the thalamus into the temporal region, in the centre of which it takes a curved course forwards and medially to a point about an inch behind the extremity of the temporal pole.

In the angle between the diverging posterior and descending horns the cavity of the ventricle presents an expansion of a somewhat triangular shape. To this the name of **trigonum collaterale** is sometimes given.

The *roof* of the inferior horn is formed for the most part by the tapetum of the corpus callosum. At the extremity of the horn the roof presents a bulging into the cavity. This is produced by a collection of gray matter termed the amygdaloid nucleus. The **stria terminalis** and the attenuated **tail of the caudate nucleus** are both prolonged into the inferior horn and are carried forwards, in its roof, to the amygdaloid nucleus.

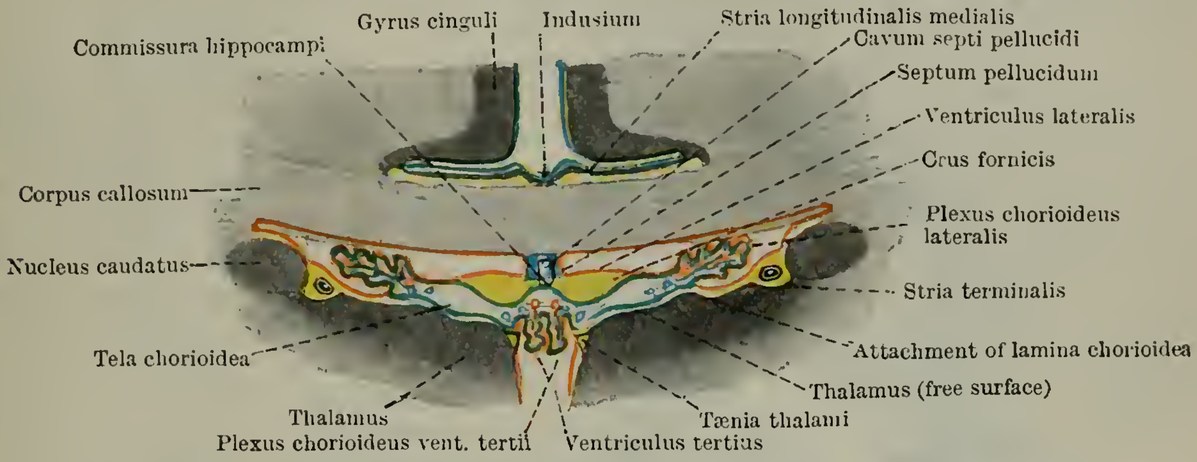

FIG. 531.—DIAGRAM OF TRANSVERSE SECTION ACROSS THE CENTRAL PARTS OF THE LATERAL VENTRICLES.

On *the floor* of the inferior horn the following structures are seen: (1) hippocampus; (2) the chorioid plexus; (3) the fimbria; and (4) the eminentia collateralis.

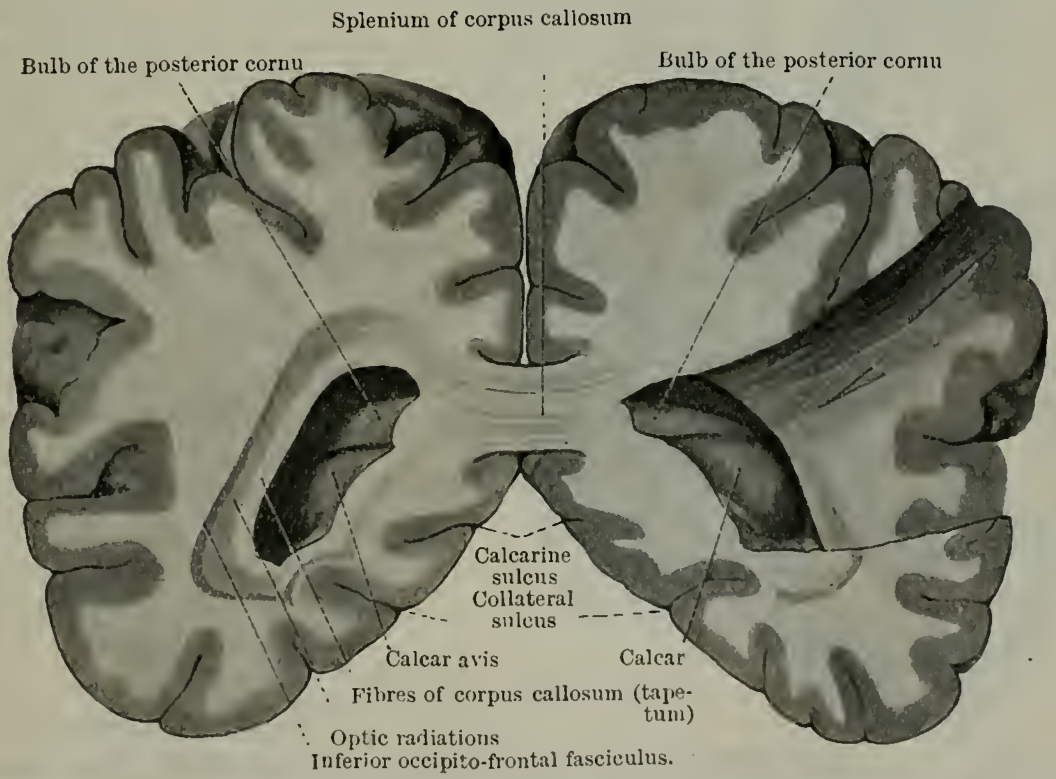
Splenium of corpus callosum
Bulb of the posterior cornu
Bulb of the posterior cornu
Calcarine sulcus
Collateral sulcus
Calcar avis
Calcar
Fibres of corpus callosum (tapetum)
Optic radiations
Inferior occipito-frontal fasciculus.

FIG. 532.—FRONTAL SECTION THROUGH THE POSTERIOR HORNS OF THE LATERAL VENTRICLES, VIEWED FROM THE FRONT.

The **hippocampus** is for the most part covered by the chorioid plexus of the lateral ventricle. If this is detached a fissure appears between the fimbria and the roof of the ventricular horn. This is the **chorioid fissure**. It appears at a very early date in the development of the cerebral hemisphere, and takes an arcuate course round the posterior end of the thalamus. In the region of the pars centralis of the lateral ventricle it extends as far forwards as the foramen interventriculare and is formed by the involution of an epithelial part of the wall of the ventricle over the chorioid plexus (p. 619). In the region of the inferior horn, when the chorioid plexus, with the involuted epithelial layer which covers it, is withdrawn, the chorioid fissure is converted into an artificial gap which leads directly into this part of the ventricular cavity.

The **chorioid plexus** is a convoluted system of blood-vessels in connexion with a fold of pia mater, which is prolonged into the inferior horn of the lateral ventricle. It lies on the surface of the hippocampus and is continuous, behind the posterior part of the thalamus, with the chorioid plexus in the pars centralis of the lateral ventricle. But it must not be supposed that the chorioid plexus lies free in the ventricular cavity. It is clothed in the most intimate manner by an epithelial layer, which represents the medial wall of the inferior horn involuted into the cavity over the chorioid plexus. The ventricle, therefore, opens on the surface only through the chorioid fissure when this thin epithelial layer is torn away by the withdrawal of the chorioid plexus. From the above, it will be understood that the arcuate chorioid fissure, throughout its whole length (viz., from the interventricular foramen to the extremity of the inferior horn of the lateral ventricle), is formed by the involution of the roof and a portion of the wall of the hemisphere which remains epithelial. In the central part of the ventricle this layer is attached, on the one hand, to the sharp margin of the fornix, and on the other to the superior surface of the thalamus; in the inferior horn it is attached, in like manner, to the edge of the fimbria hippocampi or crus of the fornix, whilst, above, it joins the roof of this portion of the ventricle along the line of the stria terminalis (Fig. 531).

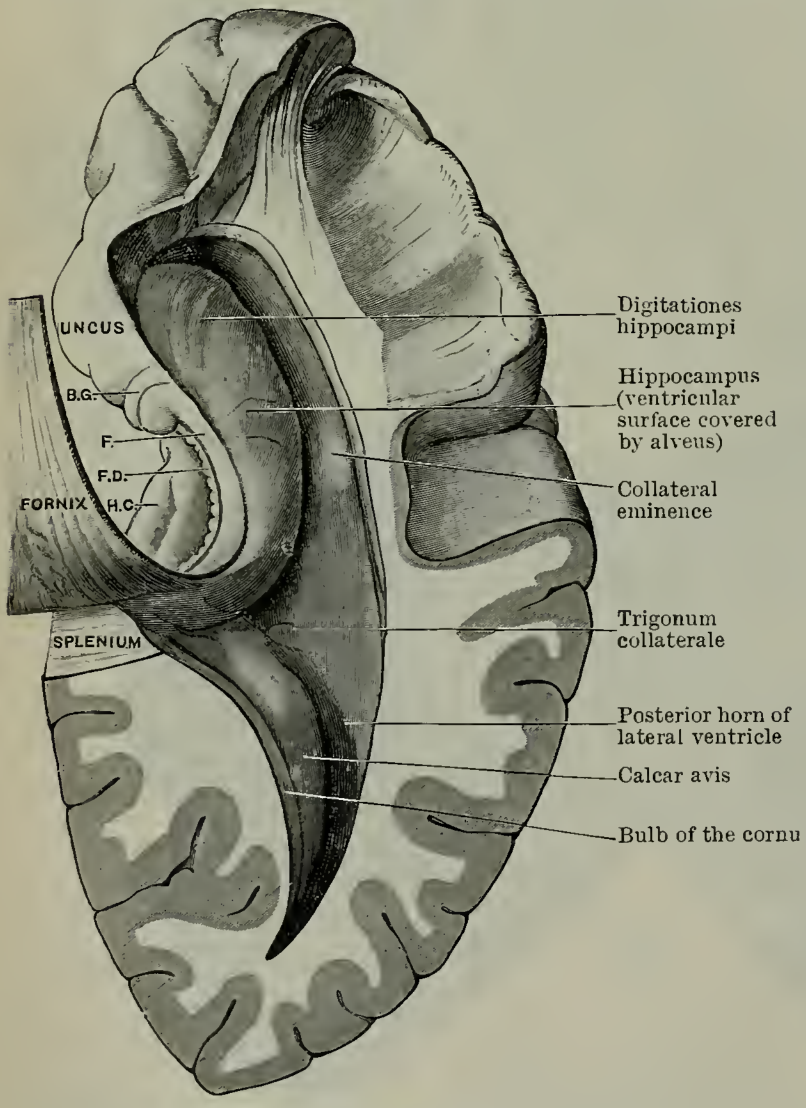

FIG. 533.—DISSECTION from above, to show the posterior and inferior cornua of the lateral ventricle.

B.G. Cauda fasciæ dentatæ.
F. Fimbria hippocampi.
F.D. Fascia dentata hippocampi.
H.C. Gyrus hippocampi.

The **eminentia collateralis** shows very great differences in its degree of development.

The **trigonum collaterale** is a smooth elevation in the floor of the ventricle, in the interval which is left between the calcar avis and the hippocampus as they diverge one from the other.

BASAL GANGLIA OF THE CEREBRAL HEMISPHERE.

Under this heading are included certain masses of gray matter more or less completely embedded in the white medullary substance of the hemisphere, and which are developed in its wall. They compose the caudate and lentiform nuclei, which together form the corpus striatum, and the amygdaloid nucleus.

The **nucleus caudatus** bulges into the lateral ventricle. It is a piriform, highly arched mass of gray matter, which presents a thick, swollen head, or anterior extremity, and a long, attenuated tail. The head projects into the anterior horn of the lateral ventricle, whilst its narrower part is prolonged laterally and posteriorly in the floor of the ventricle, where it is separated from the thalamus by the stria terminalis. Finally, its tail curves downwards with a bold sweep and enters the inferior horn of the lateral ventricle. In the roof of this horn it is prolonged forwards to the amygdaloid nucleus, the lower part of which it joins. The caudate nucleus thus presents a free ventricular surface, covered with ependyma, and a deep surface embedded in the white substance of the cerebral hemisphere, and for the most part related to the internal capsule.

Owing to its arched form it follows that, in horizontal sections through the cerebral hemisphere below a particular level, it is cut at two points, and both the head and the tail appear on the field of the section (Fig. 534). In frontal sections behind the amygdaloid nucleus, it is also divided at two places.

The anterior extremity of the head of the caudate nucleus coincides very nearly with that of the anterior horn of the lateral ventricle. In the region of the substantia perforata anterior, the head of the caudate nucleus gains the surface and its gray matter becomes continuous with that of the cerebral cortex.

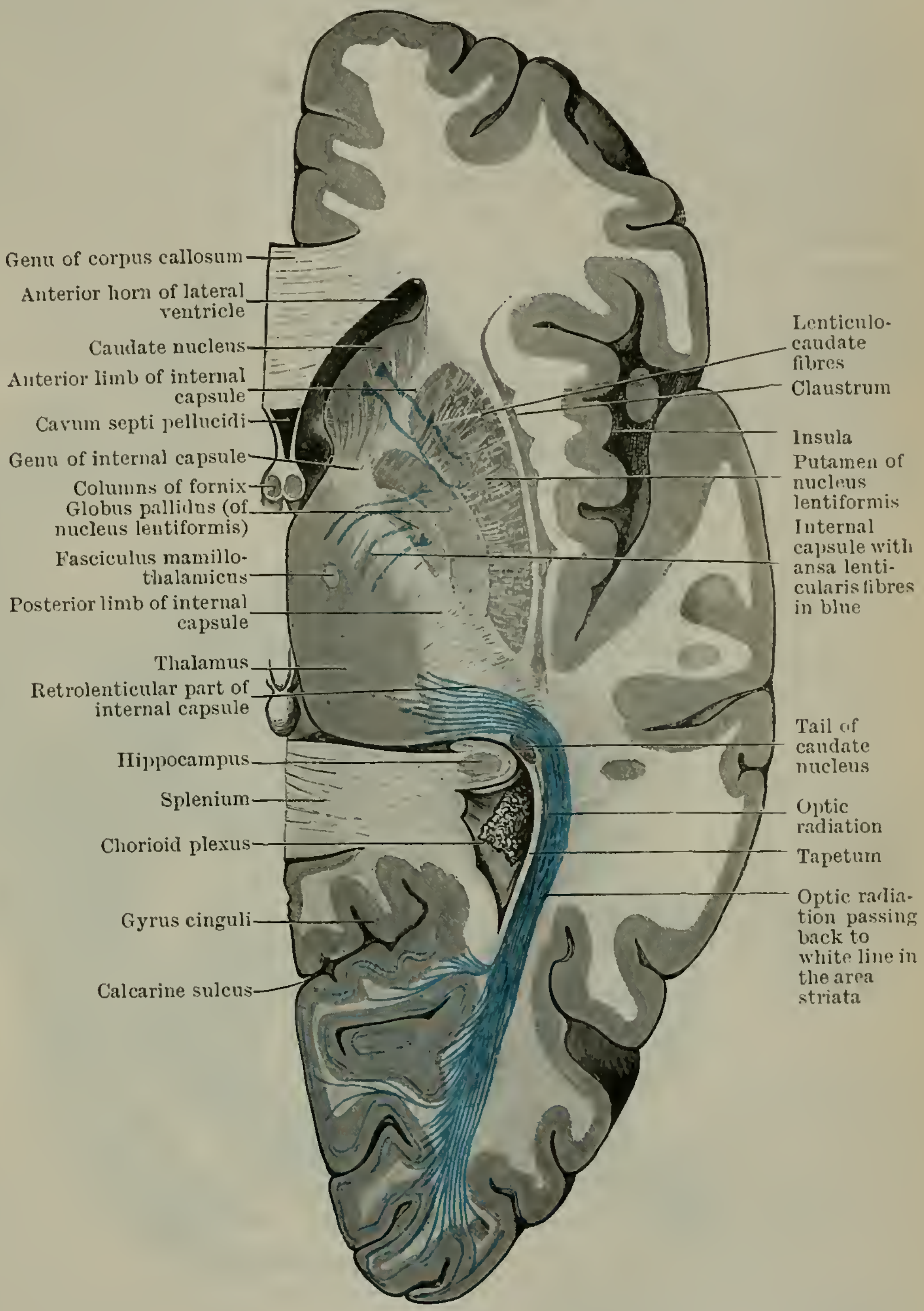
Genu of corpus callosum
Anterior horn of lateral ventricle
Caudate nucleus
Anterior limb of internal capsule
Cavum septi pellucidi
Genu of internal capsule
Columns of fornix
Globus pallidus (of nucleus lentiformis)
Fasciculus mamillo-thalamicus
Posterior limb of internal capsule
Thalamus
Retrolenticular part of internal capsule
Hippocampus
Splenium
Chorioid plexus
Gyrus cinguli
Calcarine sulcus
Lenticulo-caudate fibres
Claustrum
Insula
Putamen of nucleus lentiformis
Internal capsule with ansa lenticularis fibres in blue
Tail of caudate nucleus
Optic radiation
Tapetum
Optic radiation passing back to white line in the area striata

FIG. 534.—HORIZONTAL SECTION THROUGH THE RIGHT CEREBRAL HEMISPHERE AT THE LEVEL OF THE WIDEST PART OF THE LENTIFORM NUCLEUS.

The **nucleus lentiformis** lies on the lateral side of the caudate nucleus and thalamus, and is for the most part embedded within the white medullary substance of the cerebral hemisphere. It does not extend either so far forwards or so far backwards as the caudate nucleus. Indeed, it presents a very close correspondence in point of extent with the insula on the surface. When seen in horizontal section, it presents a shape similar to that of a biconvex lens. Its medial surface bulges more than the lateral surface, and its point of highest convexity is placed opposite the stria terminalis and the interval between the caudate nucleus and the thalamus. In frontal section the appearance presented by the lentiform nucleus differs very much in different planes of section. Fig. 535 represents a section through its anterior portion. Here it is semilunar or crescentic in outline and is directly continuous below with the head of the caudate nucleus; above, also, it is intimately connected with the caudate nucleus by bands of gray matter, which pass between the two nuclei and break up the white matter of the anterior part of the intervening internal capsule. It is due to the ribbed or barred appearance, which is presented by such a section as this, that the term **corpus striatum** is applied to the two nuclei. In the region of the substantia perforata anterior both nuclei reach the surface and become continuous with the cortex.

When a section is made in a plane further back (*e.g.* immediately posterior to the anterior commissure, as in Fig. 536) the divided lentiform nucleus assumes an altogether different shape, and is seen to be completely cut off from the caudate nucleus by the internal capsule. It is now triangular or wedge-shaped. Its *base* is turned towards the insula and is in direct relation to a thin lamina of white matter, termed the external capsule. Its *medial surface* is oblique and is applied to the internal capsule, whilst its *inferior surface* is horizontal and is directed downwards towards the base of the brain. But, further, two white laminæ, the **external** and **internal medullary laminæ**, are now evident, which traverse its substance in a vertical direction and divide it into three masses. The lateral, basal, and larger mass is termed the **putamen**; the two medial portions together constitute the **globus pallidus.**

The **putamen** forms much the largest part of the lentiform nucleus. It is darker in colour than the globus pallidus, and in this respect resembles the caudate nucleus. It is traversed by fine radiating bundles of fibres, which enter it from the external medullary lamina. Both in point of structure and in mode of development it is closely associated with the caudate nucleus, and it is the only part of the lentiform nucleus which is connected by intervening bands of gray matter with the caudate nucleus. The antero-posterior length, as well as the vertical depth of the putamen, is much greater than in the case of the globus pallidus; consequently, in both frontal and horizontal sections through the cerebrum it is encountered before the plane of the globus pallidus is reached.

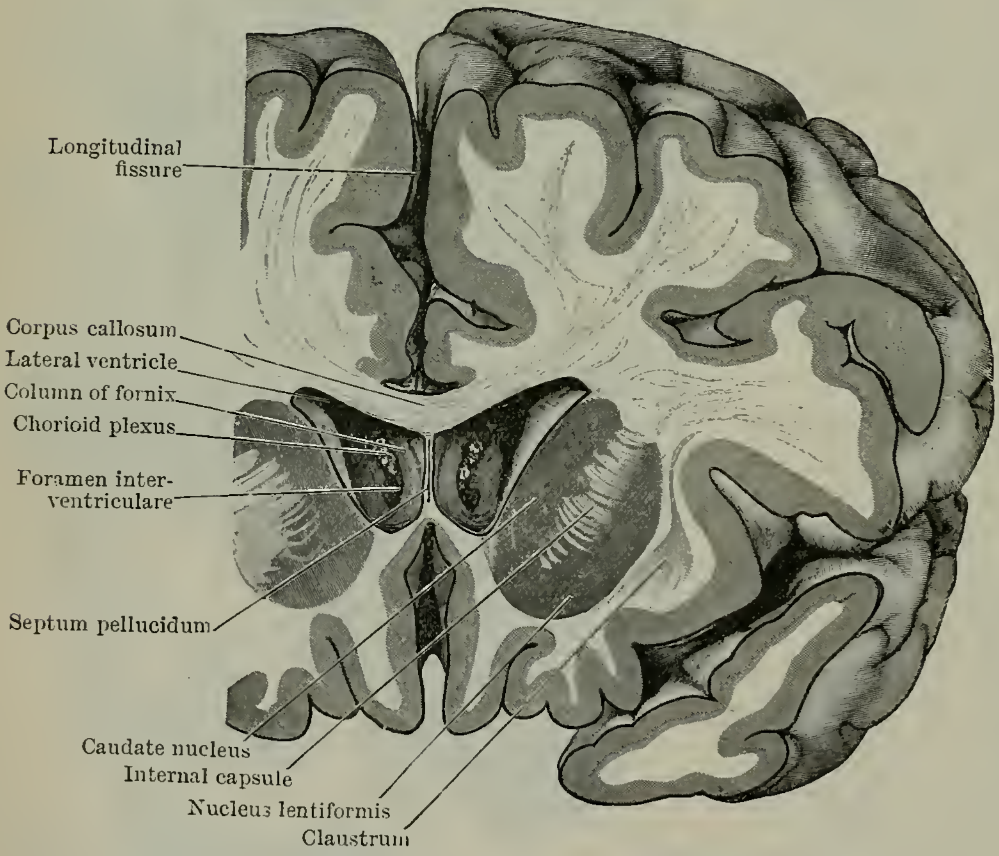

Fig. 535.—Frontal Section through the Cerebral Hemispheres so as to cut through the anterior part (putamen) of the lentiform nucleus in front of the globus pallidus. Viewed from in front; looking through the anterior horn into the central part of the ventricle.

The external capsule is loosely connected with the lateral surface of the putamen, and it can be readily stripped off. This accounts for the tendency, exhibited in hæmorrhages in this locality, for the effused blood to spread out in the interval between these structures.

The **globus pallidus** is composed of the two smaller and medial masses of the lentiform nucleus. They present a faint yellowish tint, and are paler and more abundantly traversed by fibres than the putamen. The mass next the putamen (*i.e.* the intermediate part) is much larger than the medial subdivision. It extends forwards to a point a little in front of the plane of the anterior commissure. When the lentiform nucleus is cut in a frontal direction, and in its widest part, the medial mass shows an indication of a separation into two parts, so that here the globus pallidus appears to consist of three subdivisions.

Connexions of the Corpus Striatum.—Recent clinical investigation has demonstrated the importance of the functions of the corpus striatum, which seems to exercise a "steadying influence" (Kinnier Wilson) upon the muscles which perform voluntary movements that call for delicate co-ordination. Hence it is desirable to study the connexions of these large masses of gray matter. Fibres of the internal capsule coming from the motor cortex (as well as from all other cortical areas) end in the corpus striatum (Fig. 537), so that when a voluntary movement is initiated this structure is called into activity. Fibres coming from the nucleus caudatus break through the anterior limb of the internal capsule (Fig. 538), some of them to reach the putamen, others to pass through the external medullary lamina to the globus pallidus. Other tracts pass from the lentiform nucleus into the caudate nucleus (**fibræ lenticulocaudatæ**). From the globus pallidus fibres arise which proceed into the internal capsule in the region of the genu and the neighbouring part of the posterior limb (Fig. 538). Many of these fibres become collected on the inferior aspect of the lentiform nucleus, where they form a transversely directed bundle (Fig. 538), known as the **ansa lenticularis**, which is distributed to the thalamus (Fig. 538, **fasciculus striothalamicus**) and hypothalamus, the red nucleus (**fasciculus striorubricus**) and substantia niger (**fasciculus strionigricus**). These connexions afford some explanation of the difficulties of articulation and swallowing and in the performance of delicate voluntary movements that result from damage to the corpus striatum or to this system of fibres.

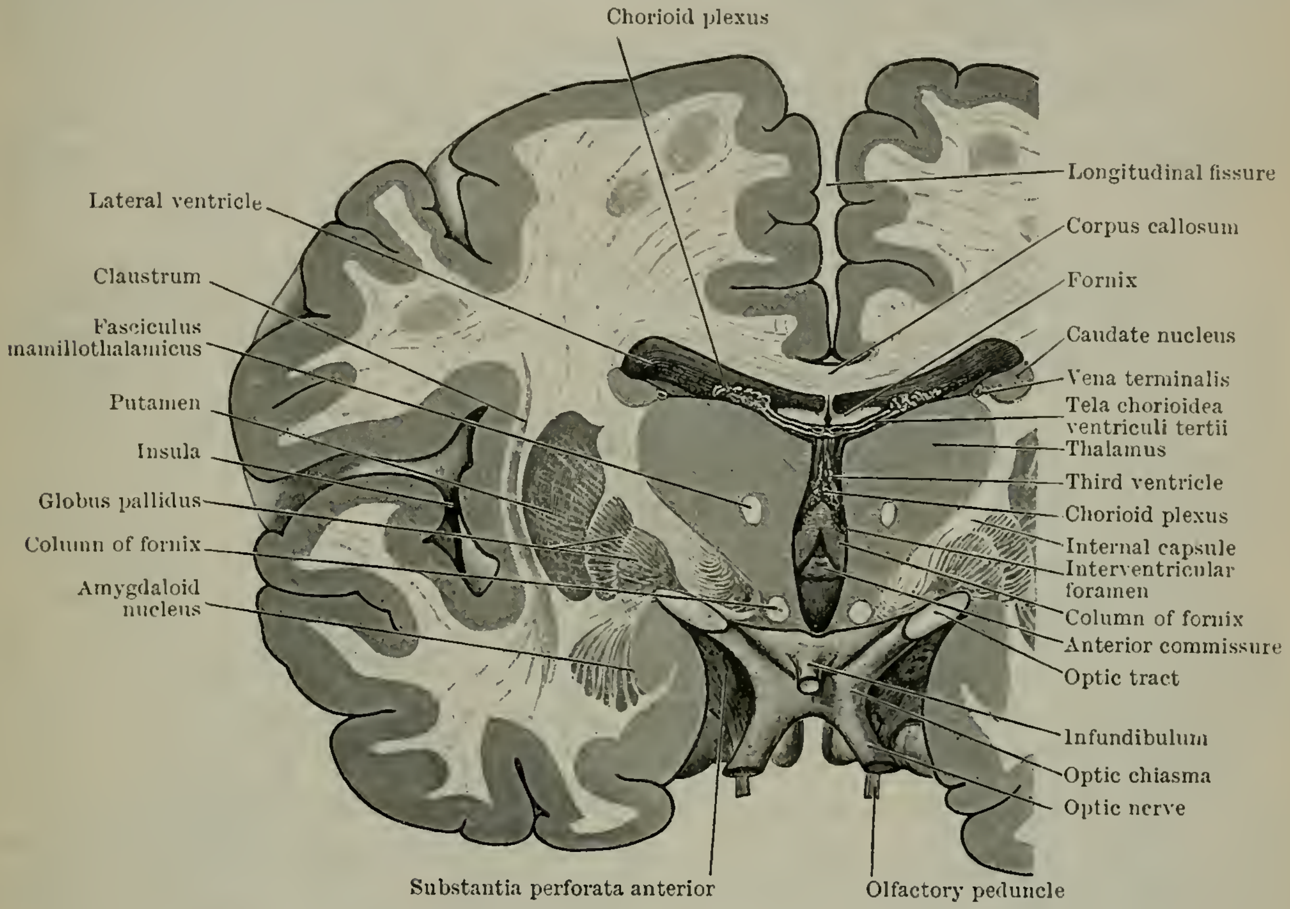

FIG. 536.—FRONTAL SECTION THROUGH THE CEREBRUM so as to cut through the three divisions of the lentiform nucleus ; posterior surface of the section shown here.

This system of fibres is phylo-genetically very old, being the most primitive efferent tract from the cerebral hemisphere.

Claustrum.—This is a thin plate of gray substance embedded in the white matter which intervenes between the lentiform nucleus and the gray cortex of the insula. Followed in an upward direction, it becomes gradually thinner and ultimately disappears. As it is traced downwards, however, it thickens considerably, and at the base of the brain it comes to the surface at the anterior perforated substance and becomes continuous with the gray matter of the cortex. Its extent corresponds very closely with the area occupied by the insula, and its surface towards this portion of the cerebral cortex shows ridges and depressions corresponding to the insular gyri and sulci.

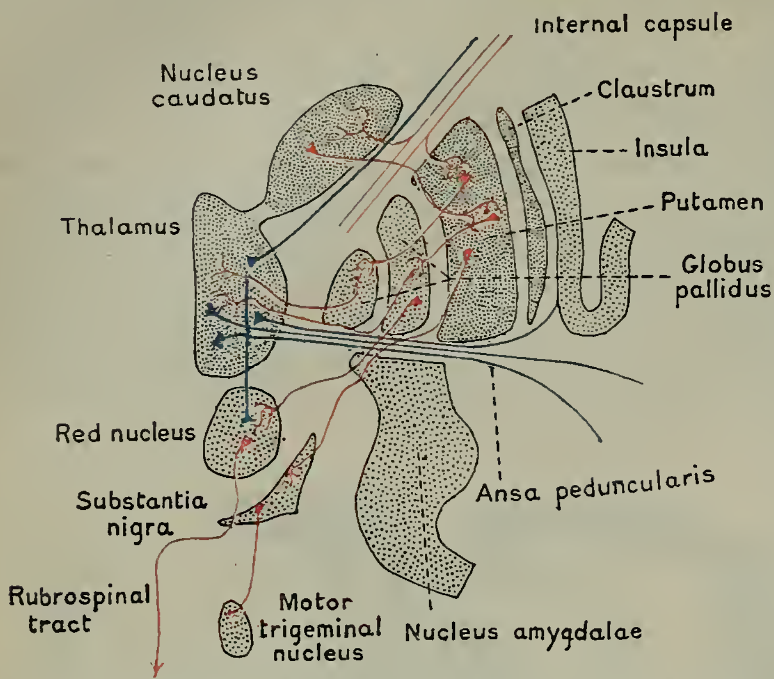

FIG. 537.—DIAGRAM OF A FRONTAL SECTION TO ILLUSTRATE THE FIBRE CONNEXIONS OF THE CORPUS STRIATUM.

Nucleus Amygdalæ.—In the anterior part of the temporal region, above the piriform area a fusiform mass of gray matter appears upon the surface (Fig. 522, p. 624), at the lateral extremity of the substantia perforata anterior (Fig. 520, p. 622). It is part of a large rounded mass, called the **amygdaloid nucleus**, which occupies a position in front of, and to some extent above the extremity of the inferior horn of the lateral ventricle. The tail of the caudate nucleus joins its inferior part (Fig. 539, p. 640), whilst above it is carried up into the putamen. Inferiorly it is continuous with the gray cortex of the piriform area, to which it is functionally related, probably in the same way that the major part of the corpus striatum is associated with the neopallium.

Stria Terminalis.—This is a band of fibres which, for the most part, arise in the amygdaloid nucleus. From this it runs backwards in the roof of the inferior horn of the lateral ventricle (Fig. 520, p. 622, and Fig. 539, p. 640), and then arches upwards and forwards, so as to gain the floor of the pars centralis of the lateral ventricle. In both situations it lies close to the medial side of the nucleus caudatus, and finally, at the interventricular foramen, it bends downwards towards the anterior commissure. Some of its fibres pass in front and others behind the commissure, and ultimately they end in the neighbourhood of the substantia perforata anterior (Kölliker).

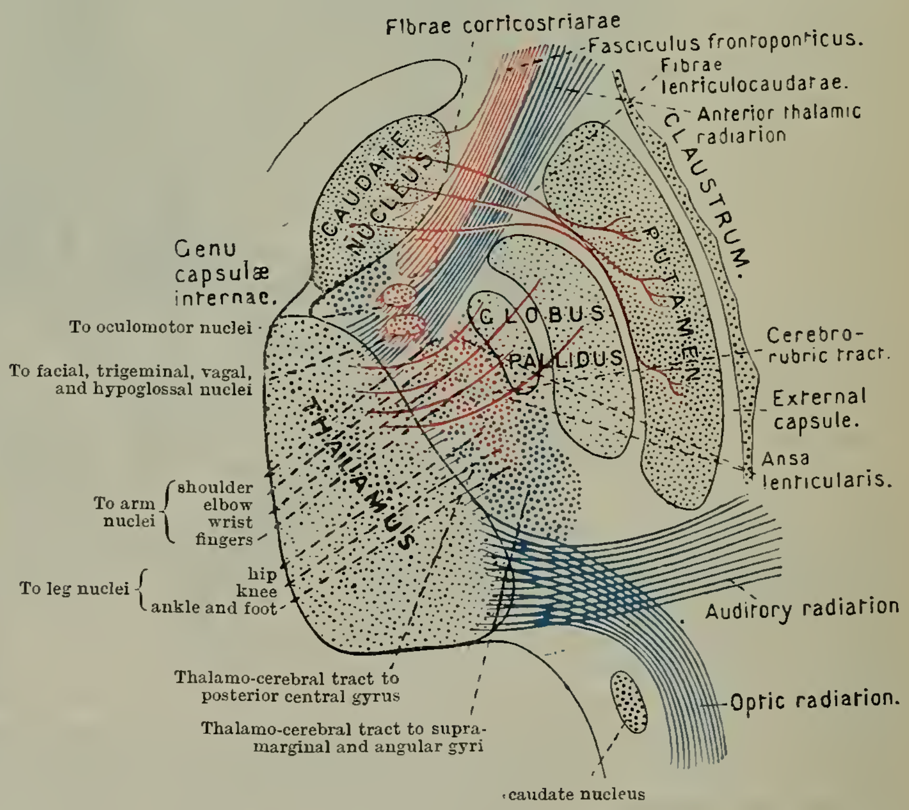

FIG. 538.—DIAGRAMMATIC REPRESENTATION OF THE INTERNAL CAPSULE (AS SEEN IN HORIZONTAL SECTION).

Internal Capsule.—This term is applied to the broad band of white matter which intervenes between the lentiform nucleus, on the lateral side, and the thalamus and caudate nucleus on the medial side. It presents many different appearances, according to the plane in which the brain is cut. A frontal section through the brain which passes through the cerebral peduncles shows that, in great part, the internal capsule is directly continuous with the basal part of the cerebral peduncle (Fig. 546, p. 649). Viewed from the lateral aspect after removing all else of the cerebral hemisphere excepting the corpus striatum (Fig. 539), the cut ends of the fasciculi of the internal capsule form three-fourths of an ellipse, the other fourth of which is occupied by the bridge of union between the lentiform and caudate nuclei, the substantia perforata anterior, the amygdaloid nucleus and the anterior commissure. It may be divided into an **anterior (lenticulo-caudate) part**, a **superior (lenticulo-thalamic) part**, a **retrolenticular part** (not labelled in the figure), and a **postero-inferior (sublenticular) part.** The last three parts are usually grouped together as the posterior limb. In horizontal section the internal capsule is observed to be bent upon itself opposite the stria terminalis, or the interval between the caudate nucleus and the thalamus. This bend, which points medially, is called the **genu.** About one-third of the internal capsule lies in front of the genu, and is termed the anterior limb; the remaining two-thirds, which lie behind the genu, constitute the posterior limb (Fig. 538).

The **anterior limb of the internal capsule** intervenes between the lentiform nucleus and the caudate nucleus. In its inferior and anterior part it is much broken up by the connecting bands of gray matter which pass between the anterior part of the putamen and the caudate nucleus.

The anterior limb of the internal capsule is composed largely of corticipetal fibres belonging to the anterior thalamic radiation. It contains corticifugal fibres also. The *corticipetal fibres* arise in the median and anterior part of the lateral nucleus of the thalamus, and go through the anterior limb of the internal capsule to reach the cortex of the frontal lobe.

The *corticifugal fibres* are represented by the fronto-pontine tract.

The **fronto-pontine tract** arises in the cortex of the frontal region, traverses the anterior limb of the internal capsule, forms the medial fifth of the basis of the cerebral peduncle, and finally ends in the nuclei pontis.

The **posterior limb of the internal capsule** is placed between the thalamus and the lentiform nucleus, and it extends backwards for a short distance beyond the posterior end of the putamen on the lateral side of the posterior part of the thalamus and of the tail of the caudate nucleus. The posterior limb, therefore, is spoken of as consisting of a lenticular, a retrolenticular, and a sublenticular part.

The **lenticular** or more properly **lenticulo-thalamic part** of the posterior limb is composed of both corticipetal and corticifugal fibres. The *corticipetal fibres* enter the internal capsule from the lateral aspect of the thalamus, and are composed of fibres which arise within the thalamus from the ventral (ventro-lateral) nucleus, and proceed upwards to the cerebral cortex.

The *corticifugal fibres* consist of the cerebro-spinal tract and the cortico-thalamic fibres.

The great **motor** or **cerebro-spinal tract,** descending from the cerebral cortex, occupies the anterior half of the lenticular part of the internal capsule. The fibres, that go to the nuclei of the oculomotor, trigeminal, and facial nerves, lie close to the genu, and behind these are the fibres which go to the hypoglossal nucleus; still further back are cerebro-spinal fibres which enter the spinal medulla and end around the motor cells of the anterior column of gray matter. This cerebro-spinal tract has been observed occupying the middle part of the pedunculus cerebri, into which it passes directly from the internal capsule.

According to Monakow the posterior limb contains also an important tract of fibres passing from the motor cortex to the red nucleus (**fasciculus cerebrorubricus**).

The **retrolenticular part** of the posterior limb contains: (1) the fibres of the optic radiation as they pass from the lateral geniculate body to establish their connexions with the occipital cerebral cortex; (2) the fibres of the acoustic radiation, or those which connect the medial geniculate body with the acoustic cortical field in the temporal lobe (Fig. 538, p. 638, and Fig. 544, p. 647); (3) the temporo-pontine tract, which is composed of fibres which take origin in the middle and inferior gyri of the temporal lobe and pass through the sublenticular section of the internal capsule to reach the lateral part of the pedunculus cerebri. Through this they reach the basilar part of the pons, in the gray matter of which they end. This tract is accompanied by the **fasciculus**

temporothalamicus, which has a widespread origin from the temporal and occipital regions and passes through the sublenticular part of the internal capsule.

If the fibres of the internal capsule are traced upwards they are found to spread out widely from each other in a radiating or fan-shaped manner, as they are followed to the various gyri of the cerebral hemisphere. This arrangement is termed the **corona radiata**. The callosal system of fibres, as they proceed into the hemisphere, also radiate, and they intersect the fibres of the corona radiata (Fig. 542, p. 645).

External Capsule.—The thin lamina of white matter between the lateral aspect of the putamen and the claustrum is called the external capsule. This joins with the internal capsule in front of and behind the putamen, and in this manner the nucleus lentiformis is encapsuled by white matter.

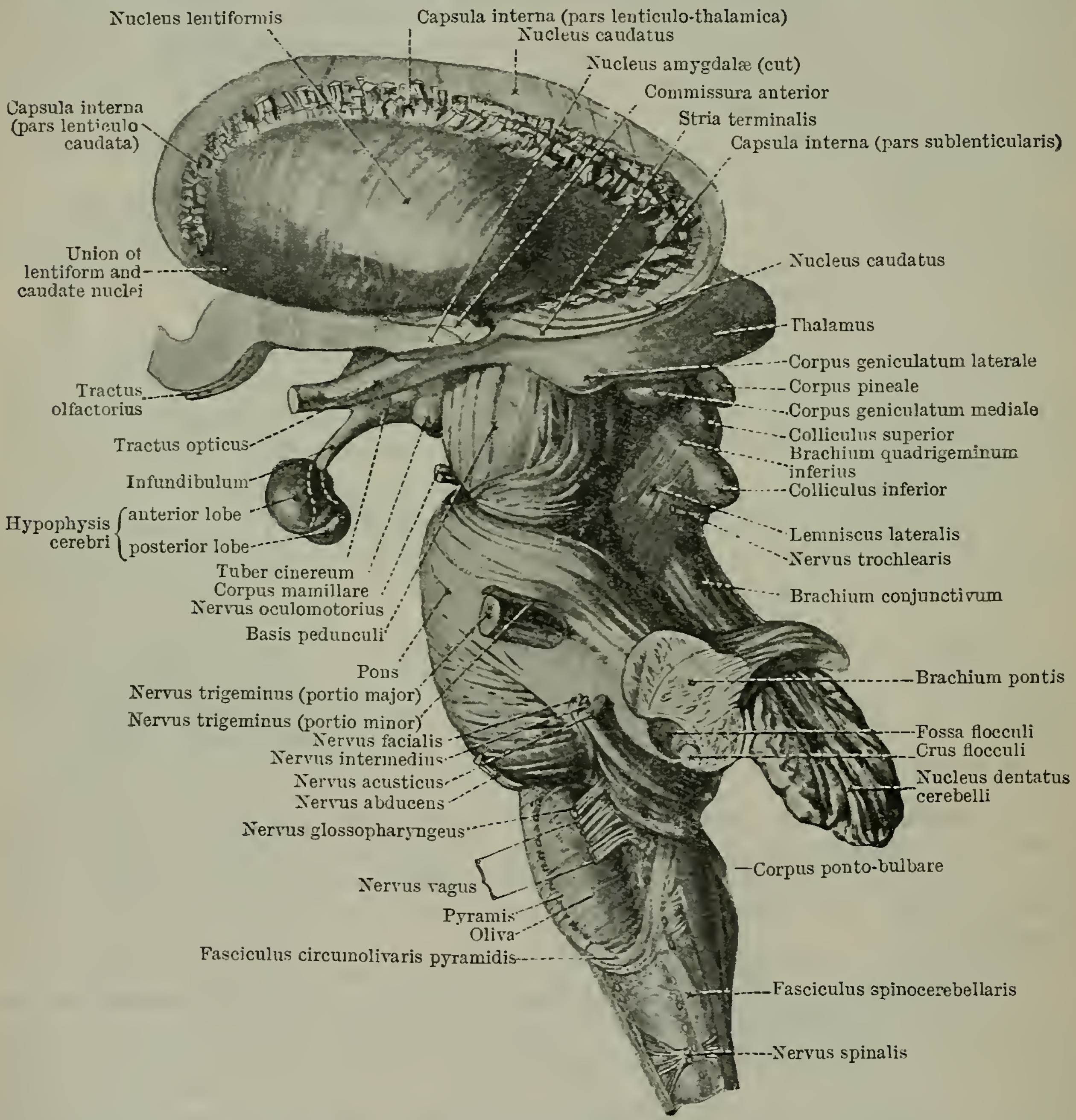

Fig. 539.—Dissection exposing the Lateral Aspect of the Lentiform Nucleus of the Left Hemisphere.

INTIMATE STRUCTURE OF THE CEREBRAL HEMISPHERE.

The cerebral hemisphere is composed of an external coating of gray matter, termed the **cortex**, spread over an internal mass of white matter, which is called the **medullary centre**. The cortex is of peculiar interest, seeing that there is good reason for believing that in it the higher functions of the brain, or those which may be classed under the general designation of the intellectual functions, take place. It is within the same layer of gray matter that the influence of those external impressions, which gain access to the cerebro-spinal axis through the senses, finally take shape as consciousness; and in it are placed also the centres which carry on the psycho-motor functions. The white medullary centre is composed of nerve-fibres which constitute the paths along which the influence of impressions is carried to and from the cortex, and from one part of the cortex to another.

THE CEREBRAL CORTEX.

The gray cortex is spread over the entire surface of the cerebral hemisphere, but it does not form a layer of equal thickness in all localities. At the summit of a gyrus it is apt to be thicker than at the bottom of a furrow. The maximum thickness of cortex (about 4 mm.) is attained in the superior parts of the motor area, whilst the minimum (about 1·25 mm.) may be observed in the region of the occipital pole. The amount of gray cortex differs considerably in different individuals, and appreciably diminishes in old age. It is also stated, but upon

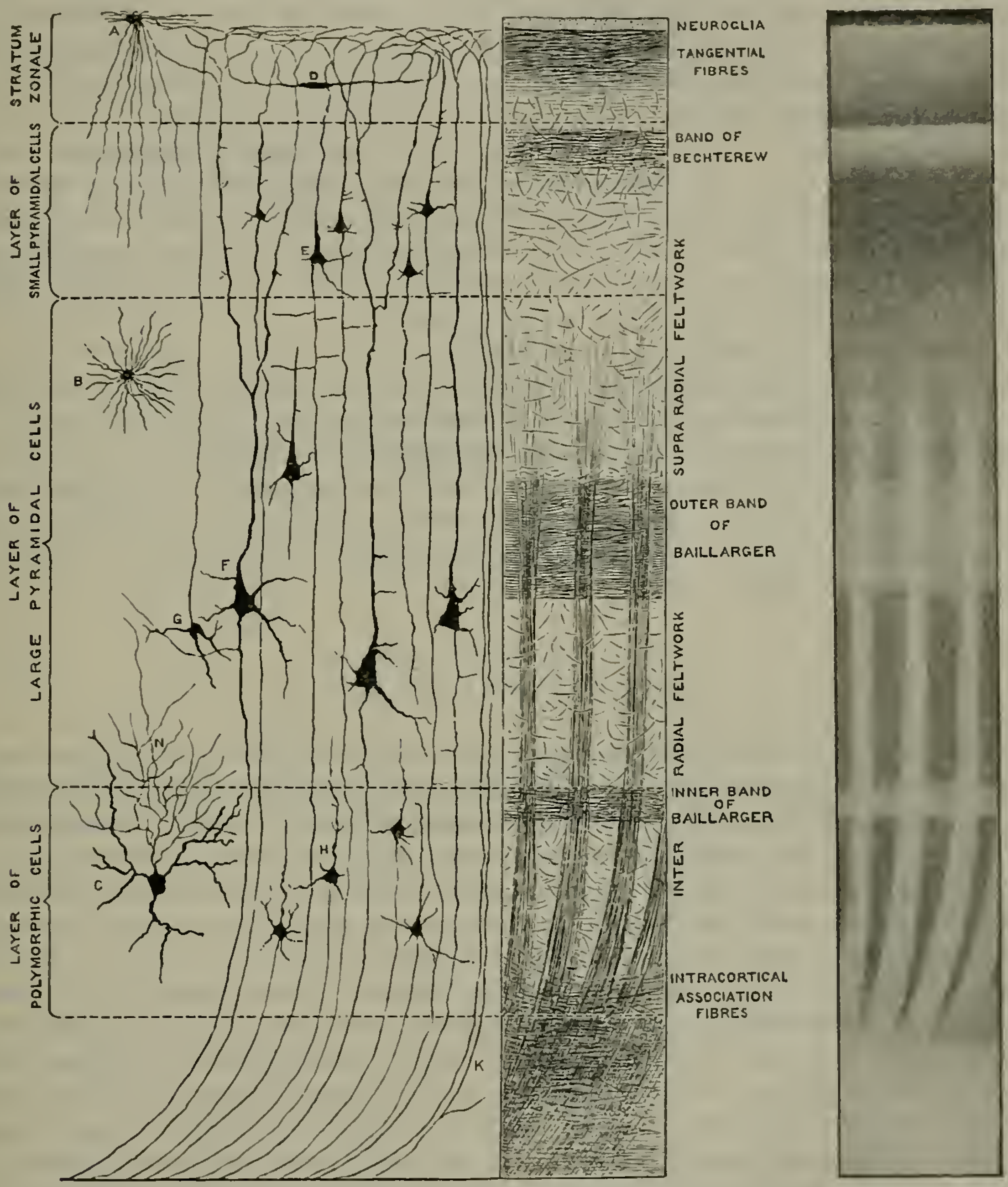

FIG. 540.—DIAGRAM TO ILLUSTRATE THE MINUTE STRUCTURE OF THE CEREBRAL CORTEX AND EXPLAIN HOW IT INFLUENCES THE MACROSCOPIC APPEARANCE.

A. B. } Neuroglia cells.
C. Cell with short axon (N) which breaks up in a free arborisation.
D. Spindle-shaped cell in stratum zonale.
E. Small pyramidal cell.
F. Large pyramidal cell.
G. Cell of Martinotti.
H. Polymorphic cell.
K. Corticipetal fibres.

imperfect evidence, that it is relatively more abundant in the male than in the female.

In structure, likewise, marked differences may be noted in the gray cortex of different regions, and much has been recently done in the direction of pointing out the connexion of these structural peculiarities with the functional characteristics of particular areas and applying them to the determination of the significance of the furrows that subdivide the cerebral cortex into a series of ridges or gyri. This structural difference is quite apparent to the naked eye when sections are made through the cortex in a fresh brain, and sharp transitions in structure occur at the place where one area joins another. It is only to those general structural features which more or less characterise the entire cortical layer that we shall be able to refer.

When sections are made through the fresh brain, and the cut surface is closely inspected. it will usually be apparent that the cortex is distinctly stratified. On the outside there is a thin, whitish layer, and beneath this the gray matter presents two strata of very nearly equal thickness, viz., a middle, gray-coloured stratum and an inner, yellowish-red stratum. Between the two latter layers a narrow white band is, in many places, visible. This is termed the **outer band of Baillarger.** When the layers indicated above are present, four strata, superimposed one upon the other, are recognised; but in certain regions a second white streak traverses the deep or inner gray layer and divides it into further stratifications. This is termed the **inner white band of Baillarger**, and, when it is present, the gray cortex becomes divided obscurely into six alternating white and gray layers.

The outer band of Baillarger is strongly marked in the region behind the calcarine sulcus and gives a characteristic appearance to this portion of the cortex. In this locality it receives the name of the **stria of Gennari** (Fig. 530, p. 632).

White Medullary Centre of the Cerebral Hemisphere.—The white matter of the hemisphere which lies subjacent to the gray cortex is composed of medullated nerve-fibres, arranged in a very intricate manner. But the arrangement of these fibres cannot be properly understood until the configuration of the surface of the hemisphere has been considered.

THE NEOPALLIUM.

Fibre-tracts proceed into different districts of the neopallium from the various nuclei of the thalamus to serve as the channels through which tactile, visual, acoustic, and other kinds of sensory impressions are poured into it. These districts may be regarded as the receptive sensory areas, tactile, visual, acoustic, etc.; but around each sensory area there is differentiated a series of more or less concentric bands of neopallium, which are related to an incoming sensory path only through the intermediation of the sensory area which it fringes.. Finally, there are interposed between the sensory area and its fringing bands of one sense and those of another, certain **association areas**, which cannot be regarded as the territory of any one sense, but as the place of meeting (and the physical counterpart of the blending in consciousness) of the impressions of different senses. In the human brain the neopallium becomes mapped out into a large series (more than forty) of areas, which differ one from the other in structure and in their connexions, and presumably therefore in their functions; and many of these areas may be further subdivided into a series of less obtrusively differentiated territories (Figs. 486 and 580).

The gray matter of the neopallium is spread over the surface of the white matter as a thin film (**cortex cerebri**), which is nowhere more than 4 millimetres, and may be only 1·25 millimetres thick. In different regions it presents every gradation of thickness between these two extremes. As the cortex increases in volume it does so not by any addition to its depth, but solely by an expansion of its superficial area. Thus it happens that in all larger mammalian brains, as the cerebral hemisphere expands and there is an increasing disproportion between the bulk of the hemisphere and the area of its surface, the cortex must become folded to accommodate itself to the limited area of surface upon which it has to be packed.

But this process of folding does not take place in any haphazard or purely mechanical way. The situations of the furrows or **sulci** which make their appearance are determined, for the most part, by the arrangement and the relative rates of expansion of the various areas into which the neopallium becomes differentiated.

The great majority of the furrows belong to a group, which we may call (1) **sulci terminales**, *i.e.* they make their appearance along the boundary lines between areas of different structure. The fissura rhinalis and sulcus centralis are examples of this group. Another group, which may be called (2) **sulci axiales**, develop by the folding of areas of uniform structure, *i.e.* along the axis of certain territories. The retro-calcarine sulcus and the sulcus occipitalis lateralis belong to this group. There is a third group of (3) **sulci operculati**, where the edge of one area becomes pushed over an adjoining territory, so that a trough is formed (Fig. 541, C), which is neither a limiting nor an axial sulcus. The sulcus lunatus is an example. And finally there is a fourth group, in which some more definitely mechanical factor comes into play to complicate the operation of these other factors, or even to determine the development of a furrow. The sulcus parieto-occipitalis and the fissura lateralis are examples of the fourth group.

[It is the custom to call certain furrows *sulci* and others *fissures*, and to call some of them *complete*, because they indent the whole thickness of the wall of the ventricle, and to call the rest *incomplete*. There is no justification whatever for any such distinctions.

It is usual also to subdivide the surface of the hemisphere in a purely arbitrary manner into "*lobes*" and to speak of *interlobar fissures*, but this is an artificial and misleading terminology which we shall avoid as far as possible.]

Fissura Longitudinalis Cerebri.—The longitudinal fissure is not a fissure of the cortex but is the great cleft between the two cerebral hemispheres. In front and behind it separates the cerebral hemispheres completely the one from the other. In its middle part, however, the fissure is interrupted and floored by the corpus callosum, a white commissural band, which passes between the hemispheres and connects them together. The superior surface of the corpus callosum is displayed when the contiguous medial surfaces of the cerebral hemispheres are drawn asunder. The longitudinal fissure is occupied by a median fold of dura mater, termed the falx cerebri, which partially subdivides the part of the cranial cavity allotted to the cerebrum into a right and left chamber.

External Configuration of each Cerebral Hemisphere.—Each cerebral hemisphere presents a lateral, a medial, and an inferior surface. The *lateral surface* is convex and is adapted accurately to the internal surface of the cranial vault. The *medial surface* is flat and perpendicular, and bounds the longitudinal fissure. In great part it is separated from the corresponding surface of the opposite hemisphere by the falx cerebri. The *inferior surface* is irregular and is adapted to the anterior and middle cranial fossæ of the cranial floor and, behind these, to the superior surface of the tentorium cerebelli. Traversing this surface in a transverse direction, nearer the anterior end of the hemisphere than the posterior end, is the stem of the lateral fissure. This deep cleft divides the inferior surface into an anterior or *orbital area*, which rests on the orbital part of the frontal bone and is consequently concave from side to side, and a more extensive posterior or *tentorial area*, which lies on the floor of the lateral part of the middle cranial fossa and upon the superior surface of the tentorium cerebelli. This surface is arched from before backwards, and looks medially as well as downwards. In its posterior two-thirds it lies above the cerebellum, from which it is separated by the tentorium cerebelli.

The borders which intervene between these surfaces are the supero-medial, the superciliary, the infero-lateral, the medial occipital and medial orbital. The *supero-medial border*, convex from before backwards, intervenes between the convex lateral surface and the flat medial surface of the hemisphere. The *superciliary border* is highly arched and separates the orbital surface from the lateral surface. The *infero-lateral border* marks off the tentorial surface from the lateral surface. The *medial occipital border* can be seen only in cases where the brain has been hardened *in situ* and faithfully retains the natural form. It extends from the posterior end of the hemisphere towards the posterior extremity of the corpus callosum, and intervenes between the medial and tentorial surfaces. It is the border which lies along the straight blood sinus, and it therefore occupies the angle which is formed by the attachment of the posterior part of the falx cerebri to the superior surface of the tentorium cerebelli. The *medial orbital* border separates the medial surface from the orbital surface.

The most projecting part of the anterior end of the cerebral hemisphere is called the **frontal pole**, whilst the most projecting part of the posterior end is termed the **occipital pole**. On the inferior surface of the hemisphere the prominent point of cerebral substance which extends forwards below the lateral fissure receives the name of the **temporal pole**. In a well-hardened brain a broad groove is usually present on the medial and inferior aspect of the occipital pole of the right hemisphere. This corresponds to the commencement of the right transverse venous sinus. A less distinct groove on the occipital pole of the left hemisphere frequently indicates the commencement of the left transverse sinus. On the tentorial surface, a short distance behind the temporal pole, a well-marked depression, **impressio petrosa**, is always visible. This corresponds to the elevation on the anterior surface of the petrous portion of the temporal bone over the superior semicircular canal.

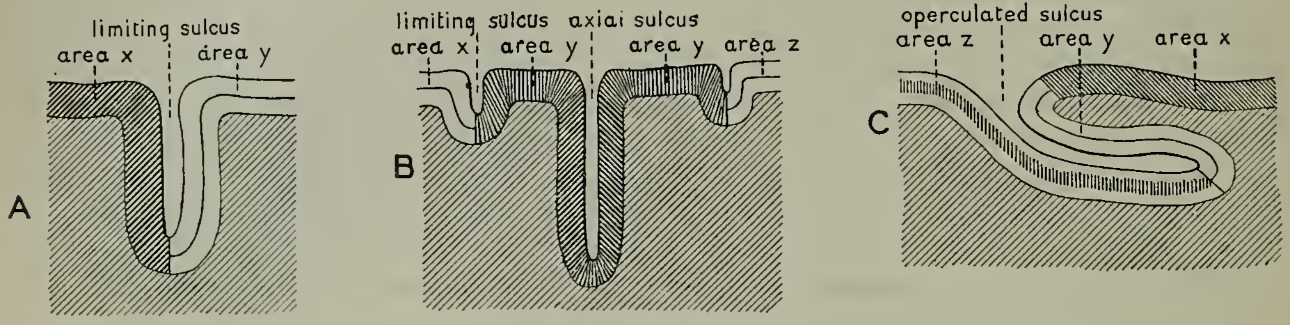

FIG. 541.—DIAGRAMS TO EXPLAIN THREE TYPES OF CEREBRAL FURROWS.

THE WHITE MATTER OF THE CEREBRAL HEMISPHERES.

According to the connexions which they establish the fibres forming the white medullary matter of the hemispheres may be classified into three distinct groups, viz., (1) commissural fibres; (2) association fibres; and (3) projection fibres.

Commissural Fibres.—These are fibres which link together portions of the gray cortex of opposite cerebral hemispheres. They are arranged in three groups forming three definite structures, viz., the corpus callosum, the anterior commissure, and the hippocampal commissure.

The **corpus callosum** has in a great measure been already studied (p. 626). As it enters each hemisphere, its fibres spread out in an extensive radiation (the radiation of the corpus callosum). It thus comes about that every part of the cerebral cortex, with the exception of the bulbi olfactorii, the olfactory parts of the hemisphere, and the inferior and anterior part of the temporal lobe, is reached by the callosal fibres. But it should be clearly understood that all the regions of the cortex do not receive an equal proportion of fibres; in other words, some cortical areas would appear to be more plentifully supplied than others. Another point of some importance consists in the fact that the callosal fibres do not, as a rule, connect together symmetrical portions of the gray cortex. As the fibres cross the median plane they become greatly scattered, so that dissimilar parts of the cortex of opposite hemispheres come to be associated with each other.

The **commissura anterior** is a structure supplemental to the corpus callosum, although originally it was the principal cerebral commissure long before the corpus callosum was evolved. It connects together the two olfactory bulbs, and also portions of the opposite temporal lobes. It presents a cord-like appearance and in median section appears as a small oval bundle in the lamina terminalis (Fig. 512, p. 615). The middle free portion is placed immediately in front of the columns of the fornix as they curve downwards, and also in intimate relation to the anterior end of the third ventricle. Posteriorly, the small portion of the anterior commissure which appears in the ventricle between the two columns of the fornix is clothed with the ventricular ependyma; anteriorly, the commissure is connected with the lamina terminalis as it stretches from the optic chiasma upwards towards the inferior (anterior) end of the hippocampal commissure.

The lateral part of the anterior commissure penetrates the cerebral hemisphere, and, gaining the inferior part of the anterior end of the internal capsule, divides into two portions, viz., a small inferior olfactory part and a much larger temporal part.

The **olfactory portion** of the anterior commissure is an exceedingly small fasciculus. It passes downwards and forwards, and finally enters the olfactory tract. It is composed (1) of true commissural fibres, which bind one olfactory bulb to the other; and (2) of other fibres, which connect the olfactory bulb of one side with the piriform area of the other side.

The **temporal portion** is formed of almost the whole of the fibres of the commissure. It is carried laterally under the lentiform nucleus, until it gains the interval between the globus pallidus and the putamen. At this point it changes its direction and sweeps backwards. In frontal sections through the brain, posterior to this bend, the temporal portion of the anterior commissure appears as an oval bundle of fibres cut transversely and placed in close contact with the inferior surface of the lentiform nucleus (Fig. 542). Finally, it turns sharply downwards on the lateral aspect of the amygdaloid nucleus, and its fibres are lost in the white medullary centre of the temporal lobe. When the lateral part of the anterior commissure is displayed by dissection, it is seen to be twisted like a rope.

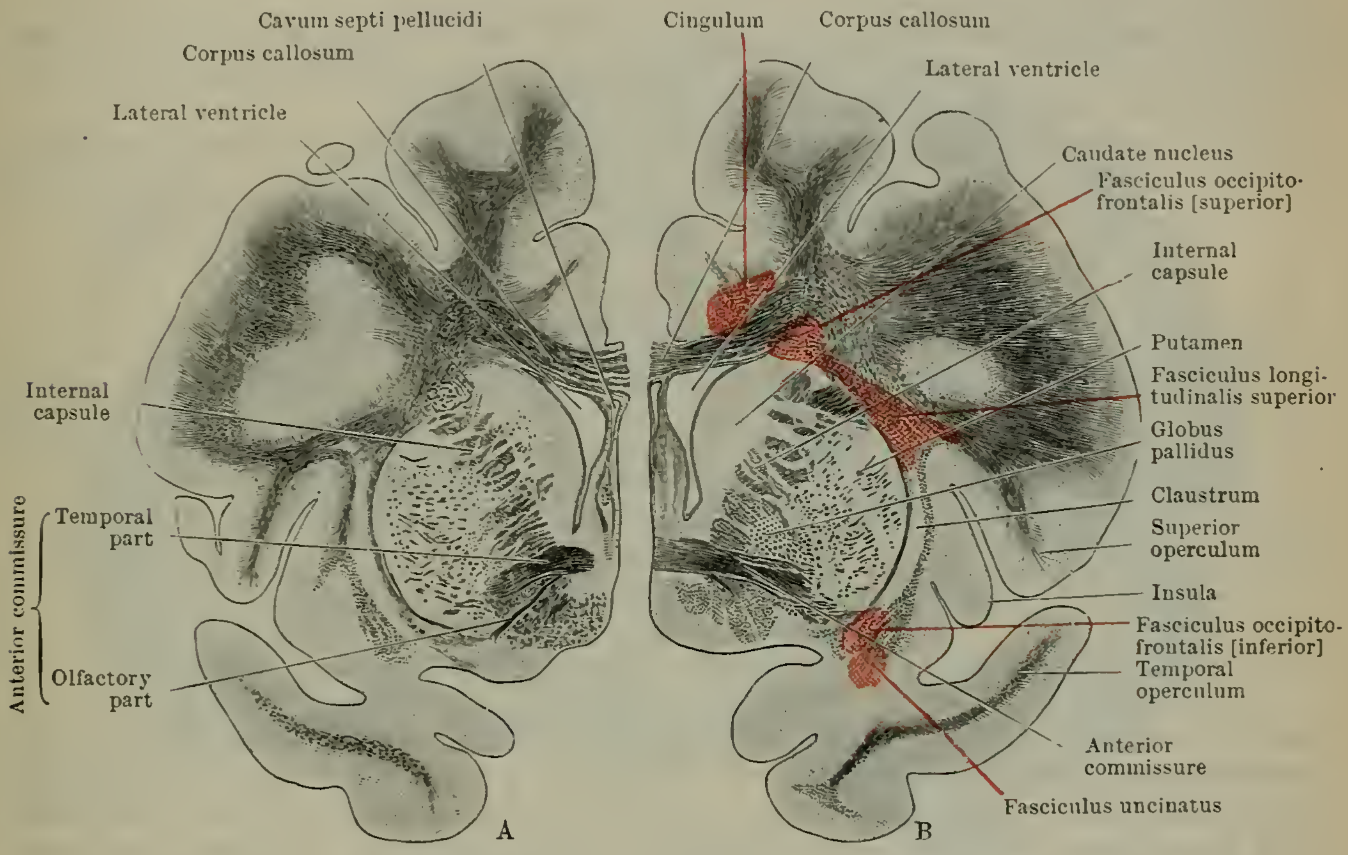

FIG. 542.—TWO FRONTAL SECTIONS THROUGH THE CEREBRAL HEMISPHERES OF AN ORANG, IN THE PLANE OF THE ANTERIOR COMMISSURE.

A, Section through the left hemisphere in a plane a short distance behind B, which is a section through the right hemisphere. The positions of the great longitudinal association tracts are indicated in red.

The **hippocampal commissure** is composed of fibres which connect the hippocampus of one side with the corresponding structure of the opposite side. It is described on p. 626.

Association Fibres.—The association fibres bind together different portions of the cortex of the same hemisphere. They are grouped into long and short association bundles.

The greater number of the **short association fibres** pass between adjacent gyri. They curve round the bottoms of the sulci in U-shaped loops. Some of these occupy the deepest part of the gray cortex itself, and are termed *intracortical association fibres* (Figs. 543 and 544); others lie immediately subjacent to the gray matter—between it and the general mass of the white matter—and receive the name of *subcortical fibres.* Many groups of short association fibres, instead of linking together contiguous gyri, pass between gyri more or less remote. It is only after birth, when intellectual effort and education have stimulated different portions of the cortex to act in harmony and in conjunction with each other, that these association fibres assume their sheaths of myelin and become functional.

The **long association fibres** are arranged in bundles which run for considerable distances within the white medullary centre of the cerebral hemisphere, and unite districts of gray cortex which may be far removed from each other. The better known of these fasciculi are the following: (1) the uncinate bundle; (2) the cingulum; (3) the superior longitudinal bundle; (4) the inferior longitudinal; and (5) the occipito-frontal.

The **fasciculus uncinatus** is composed of fibres which arch over the stem of the lateral cerebral fissure and connect the frontal pole, and the orbital gyri of the frontal lobe, with the anterior portion of the temporal lobe.

The **cingulum** is a very well-marked and distinct band, which is closely associated with the medial edge of the neopallium. Beginning in front, in the region of the anterior perforated substance, it arches round the genu of the corpus callosum and is carried backwards on the superior surface of this structure at the place where its fibres pass into the callosal radiation. The cingulum, therefore, lies under cover of the gyrus cinguli and stands in intimate relation to the white centre of this gyrus (Fig. 526, p. 628). At the posterior end of the corpus callosum the cingulum turns round the splenium and is carried forwards, in relation to the hippocampal gyrus, to the uncus and the temporal pole. The cingulum is composed of several systems of fibres which run only for short distances within it.

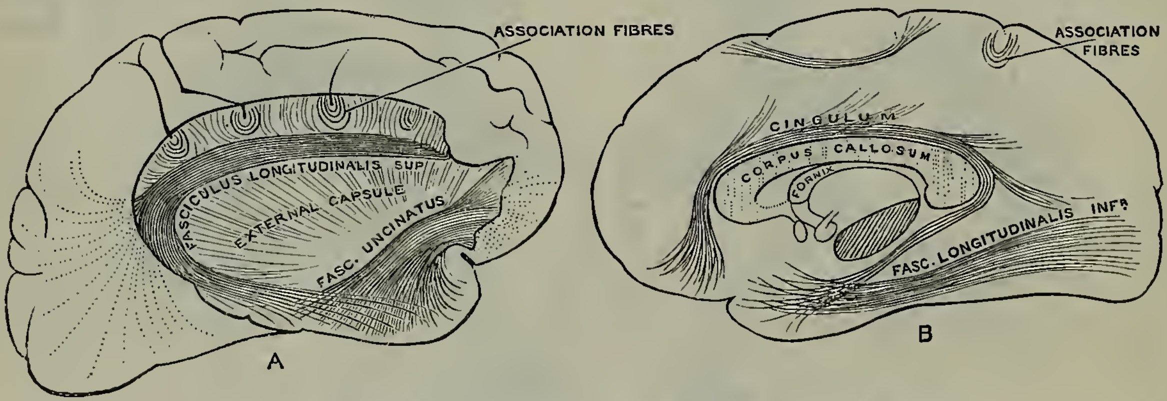

FIG. 543.—DIAGRAMS OF THE LEADING ASSOCIATION BUNDLES OF THE CEREBRAL HEMISPHERE. (Founded on the drawings of Déjerine.)

A, Lateral aspect of hemisphere. B, Medial aspect of hemisphere.

The **fasciculus longitudinalis superior** is an arcuate bundle which is placed on the lateral aspect of the foot or basal part of the corona radiata and connects the frontal, occipital, and temporal regions of the hemisphere. It lies in the base of the superior operculum and sweeps backwards over the insular region to the posterior end of the lateral cerebral fissure. Here it bends downwards round the posterior end of the putamen and proceeds forwards in the temporal lobe, to reach its anterior extremity. As it turns downwards to reach the temporal lobe numerous fibres radiate from it into the occipital lobe.

The **fasciculus longitudinalis inferior** is a very conspicuous bundle which extends along the whole length of the occipital and temporal regions (Fig. 543, B). Curran has recently demonstrated that the fasciculus uncinatus and the inferior longitudinal bundle are merely the shorter inferior fibres of a much bigger and longer tract (Fig. 544), to which he has applied the name **occipito-frontalis inferior.** The arrangement of these longitudinal tracts may be put concisely by saying that fibre connexions of differing lengths link together the various cortical areas in the longitudinal direction, the deeper fibres (*i.e.* those furthest removed from the cortex, medial, lateral, superior or inferior) being progressively longer than the superficial. The deepest fibres extend the whole length of the hemisphere and are pushed aside by the insula (Fig. 544) and collected into two great bundles, a superior longitudinal and an inferior occipito-frontal bundle. In the occipital lobe the inferior occipito-frontal bundle is placed on the lateral aspect of the optic radiation, which takes a similar direction and from which it is distinguished by the greater coarseness of its fibres (Figs. 542, p. 645; 544; 526, p. 628). It is not present in the macaque monkey (Ferrier and Turner), but is well developed in the orang and the chimpanzee.

The **fasciculus occipito-frontalis superior** is a bundle of fibres which runs in a sagittal direction in intimate relation to the lateral ventricle (Fig. 542, p. 645). It may be regarded as the medial edge of the superior longitudinal bundle. It has been pointed out (Forel, Onufrowicz, and others) that, in cases where the corpus callosum fails to develop, the tapetum remains apparently unaffected, and Déjerine has endeavoured to prove that the fibres of this layer really belong to the fasciculus occipito-frontalis. The fasciculus occipito-frontalis lies on the medial aspect of the corona radiata in intimate relation to the caudate nucleus, and posteriorly it spreads out over the superior and lateral aspect of the lateral ventricle, immediately outside the ependyma, where, according to Déjerine, it constitutes the tapetum (see p. 629).

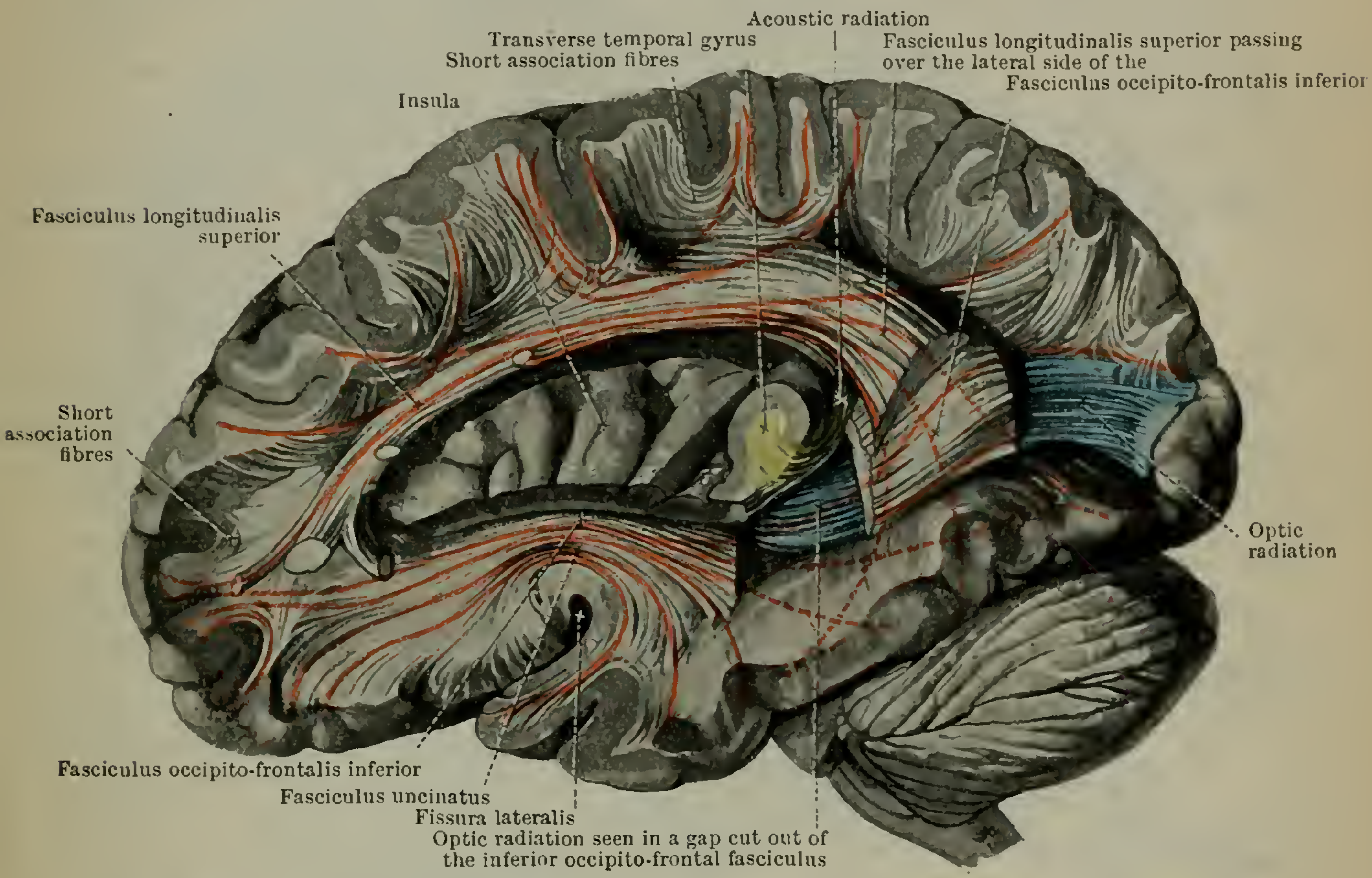
Acoustic radiation
Transverse temporal gyrus
Short association fibres
Fasciculus longitudinalis superior passing over the lateral side of the Fasciculus occipito-frontalis inferior
Insula
Fasciculus longitudinalis superior
Short association fibres
Optic radiation
Fasciculus occipito-frontalis inferior
Fasciculus uncinatus
Fissura lateralis
Optic radiation seen in a gap cut out of the inferior occipito-frontal fasciculus

FIG. 544.—DISSECTION TO DISPLAY SOME OF THE PRINCIPAL ASSOCIATION BUNDLES OF THE CEREBRAL HEMISPHERE.

The occipito-temporal extremity of the superior longitudinal bundle has been cut away in order to expose the subjacent inferior occipito-frontal bundle, parts of which in turn have been removed to expose the origin and termination of the still deeper optic radiation (coloured blue); (acoustic fibres, yellow).

Projection Fibres.—We have already seen that every part of the cerebral cortex is linked to other cortical areas, not only in its own neighbourhood (short association fibres) (Fig. 544), but also in the most distant parts of the hemisphere (long association fibres), as well as to the cortex of the other hemisphere (commissural fibres). In addition there are two large series of fibres: (i.) an ascending group which conveys to the cerebral cortex impulses coming from the thalamus and metathalamus, the corpora quadrigemina and the red nucleus, and the various other sensory nuclei scattered throughout the brain stem and spinal medulla; and (ii.) a descending group connecting the cerebral hemisphere with the corpus striatum, various parts of the diencephalon, mesencephalon and cerebellum, as well as with all the motor nuclei scattered throughout the central nervous system. These two groups of tracts, respectively passing to and from the cerebral cortex, are known collectively as its **projection fibres.**

While examining the general arrangement of these projection fibres of the cerebral hemisphere it is convenient to refer incidentally to certain other fibre-tracts which do not fall strictly within this group.

The Sensory Tracts.—A certain proportion of the fibres that enter the spinal medulla by its posterior root, which are supposed to be the sensory nerves of muscles, tendons, and joints, pass upwards without interruption in the posterior funiculi throughout the whole length of the spinal medulla until they reach the medulla oblongata, where they end in the nucleus gracilis and nucleus cuneatus. From these nuclei, arcuate fibres (**fasciculus bulbothalamicus**) arise, and, after crossing the median plane, proceed upwards in the medial lemniscus of the other side to end in the ventro-lateral nucleus of the thalamus, from which a third group of neurones arises and proceeds upwards through the internal capsule to the cerebral cortex, where the impulses conveyed by it excite a consciousness of position and movement. But other sensory fibres end in the spinal medulla near their place of entry into it, and from the cells related to the endings of these fibres a new tract (**fasciculus spino-thalamicus**) arises, crosses the median plane to reach the antero-lateral funiculus of the opposite side, in which it proceeds upwards throughout the whole length of the spinal medulla (that lies above its origin), the rhombencephalon and mesencephalon to the thalamus, where it ends alongside the bulbo-thalamic tract in relationship with cells of the ventro-lateral nucleus. The fibres arising from this nucleus proceed to the gyrus centralis posterior, and convey impulses to it, which may excite a consciousness of touch, pressure, pain, heat, or cold. Some of these spino-thalamic fibres enter the medial lemniscus in the medulla oblongata, but others remain separate from it (Fig. 546) until they reach the level of the pons, where they become added to the lateral margin of the bulbo-thalamic tract.

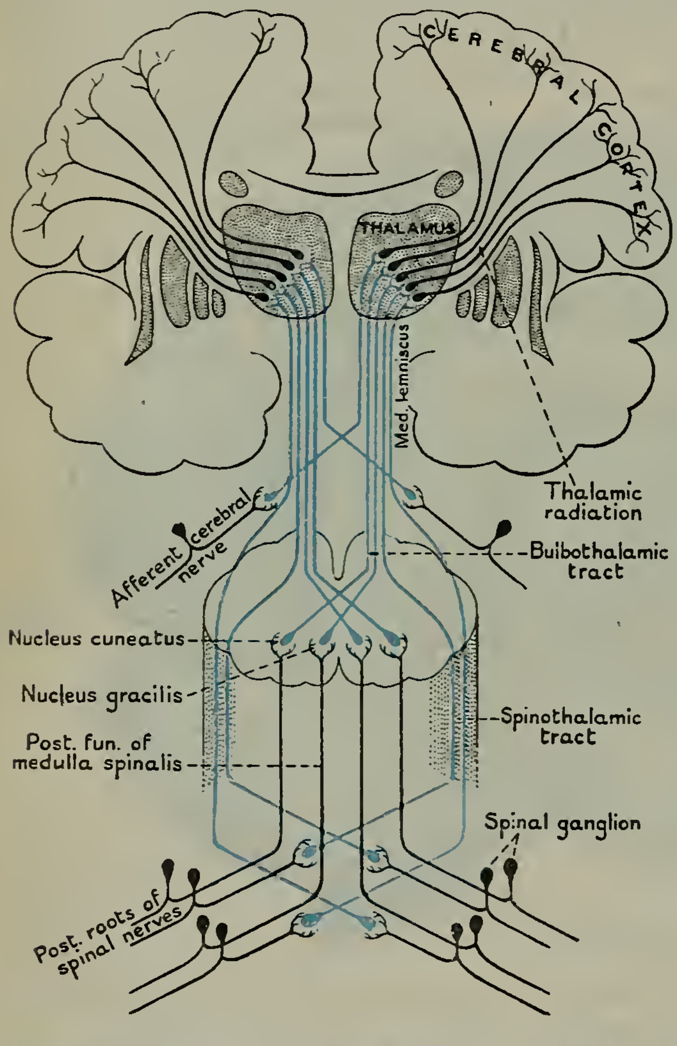

FIG. 545.—DIAGRAM OF THE SENSORY TRACTS FROM THE SPINAL MEDULLA TO THE CEREBRAL CORTEX.

[In Fig. 546 the line from the label "lemniscus medialis" points to the place of junction of the spino- and bulbo-thalamic tracts.]

Other groups of fibres, serially homologous to both the spino-thalamic and the bulbo-thalamic tracts, come from the various sensory cerebral nerves—trigeminal, facial, glossopharyngeal, and vagus—and become added to the great strands that are proceeding upwards to the thalamus (Figs. 545 and 465, p. 561).

Of the other great ascending tracts in the spinal medulla, such as the two pairs of fasciculi spinocerebellares, nothing further need be said; nor is it necessary to do more than remind the reader that from the nucleus dentatus of the cerebellum a great tract (brachium conjunctivum) ascends to the opposite red nucleus and thalamus, and through them establishes an indirect connexion with the cerebral cortex in the precentral and frontal regions.

The other sensory pathways to the cerebrum, auditory, vestibular, visual, gustatory, and olfactory, are described elsewhere.

The Corticifugal Projection Strands.—The **fasciculus cerebrospinalis**, the great motor or pyramidal tract, is composed of fibres which arise from giant pyramidal cells of Betz in the posterior part of the precentral cortex (p. 661) in the district immediately in front of the sulcus centralis. The fibres descend through the corona radiata into the posterior limb of the internal capsule. From this point the further course of the pyramidal tract has been traced, viz., through the central part of the basal region of the cerebral peduncle and pons, and the pyramid of the medulla oblongata. At the level of the foramen magnum it decussates in the manner already described, and enters the spinal medulla as the lateral cerebro-spinal and anterior cerebro-spinal tracts. The fibres composing these end in connexion with the ventral or motor column of cells, from which the fibres of the anterior roots of the spinal nerves arise.

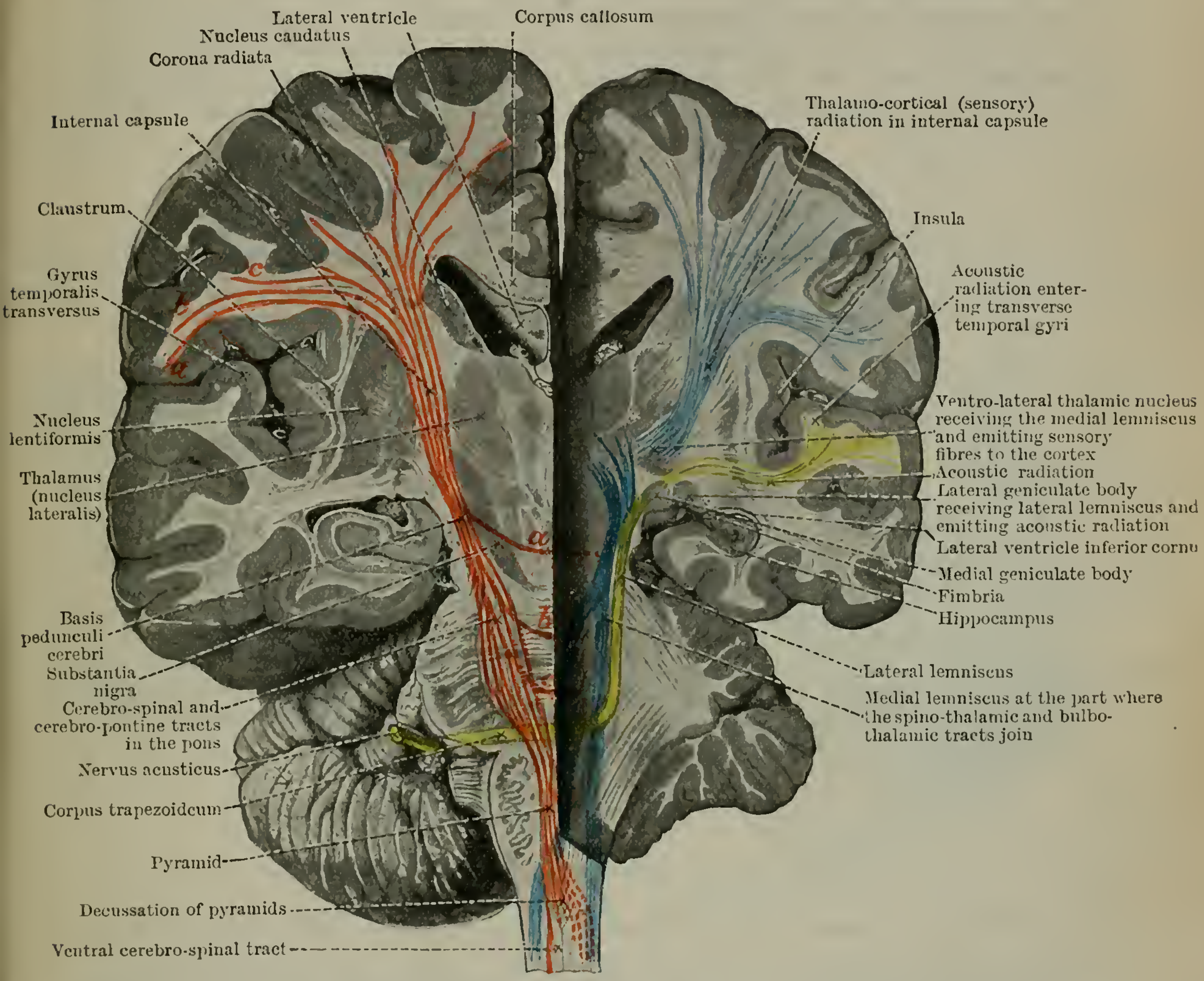
Lateral ventricle
Nucleus caudatus
Corona radiata
Corpus callosum
Internal capsule
Claustrum
Gyrus temporalis transversus
Nucleus lentiformis
Thalamus (nucleus lateralis)
Basis pedunculi cerebri
Substantia nigra
Cerebro-spinal and cerebro-pontine tracts in the pons
Nervus acusticus
Corpus trapezoideum
Pyramid
Decussation of pyramids
Ventral cerebro-spinal tract
Thalamo-cortical (sensory) radiation in internal capsule
Insula
Acoustic radiation entering transverse temporal gyri
Ventro-lateral thalamic nucleus receiving the medial lemniscus and emitting sensory fibres to the cortex
Acoustic radiation
Lateral geniculate body receiving lateral lemniscus and emitting acoustic radiation
Lateral ventricle inferior cornu
Medial geniculate body
Fimbria
Hippocampus
Lateral lemniscus
Medial lemniscus at the part where the spino-thalamic and bulbo-thalamic tracts join
c
b
a
a
b

FIG. 546.—FRONTAL SECTION OF BRAIN, PASSING IN THE LINE OF THE CEREBRO-SPINAL TRACT (*marked in red*) IN THE RIGHT HEMISPHERE (left side of Fig.), and on a more posterior plane in the left hemisphere, where the sensory paths (tactile in blue, and acoustic in yellow) have been represented.

Similar fibres arise from the inferior part of the precentral area and proceed through the internal capsule and cerebral peduncle to all the motor nuclei upon the opposite side of the brain stem (**fasciculi cerebronucleares**). Hence the cerebral cortex of one hemisphere can control all the muscles of the opposite side of the body.

The **fronto-pontine strand** is composed of fibres which arise as the axons of the cells in the cortex which covers the frontal region that lies in front of the precentral furrows. It descends in the anterior limb of the internal capsule, enters the medial part of the base of the cerebral peduncle, through which it gains the basilar part of the pons. In this its fibres end amongst the cells of the nuclei pontis, from which axons arise and establish relations with the cortex of the opposite cerebellar hemisphere.

The **temporo-pontine tract** consists of fibres which spring from the cells of that part of the cortex which covers the middle portions of the lower two temporal gyri. The temporo-pontine tract passes medially under the nucleus lentiformis, enters the retrolenticular part of the posterior limb of the internal capsule, and thus gains the lateral part of the cerebral peduncle. From this it descends into the basilar part of the pons, in which it ends in the nuclei pontis.

Cortico-striate and other Descending Fibres.—From the fibres of the internal capsule numerous collateral branches are given off to the nucleus caudatus and nucleus lentiformis, and from these basal ganglia fibres arise which enter the cerebral peduncle as constituent elements of the great cerebro-spinal tract.

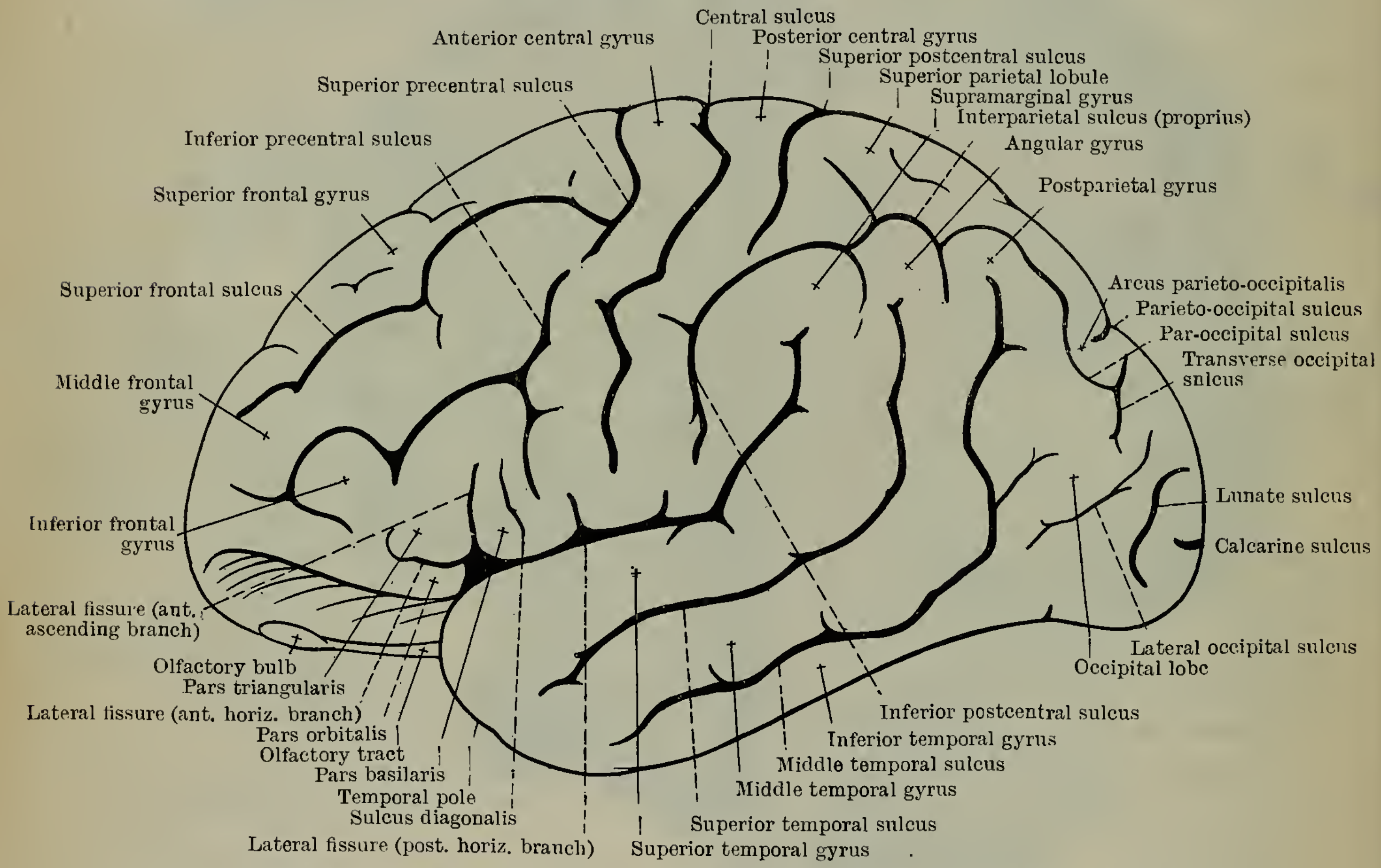

FIG. 547.—DIAGRAM OF THE SULCI AND GYRI ON THE SUPERO-LATERAL SURFACE OF THE HEMISPHERE. The middle frontal sulcus, which sometimes lies between the superior and inferior frontal sulci, is not shown.

Some of the fibres from the corpus striatum, especially the nucleus lentiformis, as well as others descending from the frontal cortex, pass into the red nucleus (Fig. 537), which also receives afferent tracts from the tectum mesencephali and from the cerebellum: it emits an important efferent tract (**fasciculus rubrospinalis**), which crosses the median plane and descends in the brain stem and spinal medulla to the various motor nuclei (see Fig. 429).

THE SULCI AND GYRI OF THE CEREBRAL HEMISPHERES.

Fissura Cerebri Lateralis (O.T. **Fissure of Sylvius**).—This is the most conspicuous furrow on the surface of the cerebral hemisphere. In reality it is formed, not as a furrow upon the surface of the hemisphere, but as a great fossa, the margins of which develop into large lip-like folds that bulge over the fossa and meet to form the superficial pattern of the lateral fissure. It is composed of a short main stem, from the lateral extremity of which two or three branches or limbs radiate. The **stem** of the lateral fissure is placed on the inferior surface of the hemisphere. It begins at the substantia perforata anterior and passes laterally, forming a deep cleft between the temporal pole and the orbital surface of the frontal region. Appearing on the lateral surface of the hemisphere, the fissure immediately divides into two or three radiating rami. These are: (1) the ramus posterior; (2) the ramus anterior horizontalis; (3) the ramus anterior ascendens, of which the last is inconstant.

The **posterior ramus** is the longest and most constant of the three limbs. It extends backwards, with a slight inclination upwards, on the lateral surface of the hemisphere for a distance which may vary from about two to three inches. It intervenes between the frontal and parietal regions, which lie above it, and the temporal region which lies below it; and it finally ends in the region subjacent to the parietal tuberosity of the cranial wall by turning upwards into the parietal region in the form of an *ascending terminal piece.*

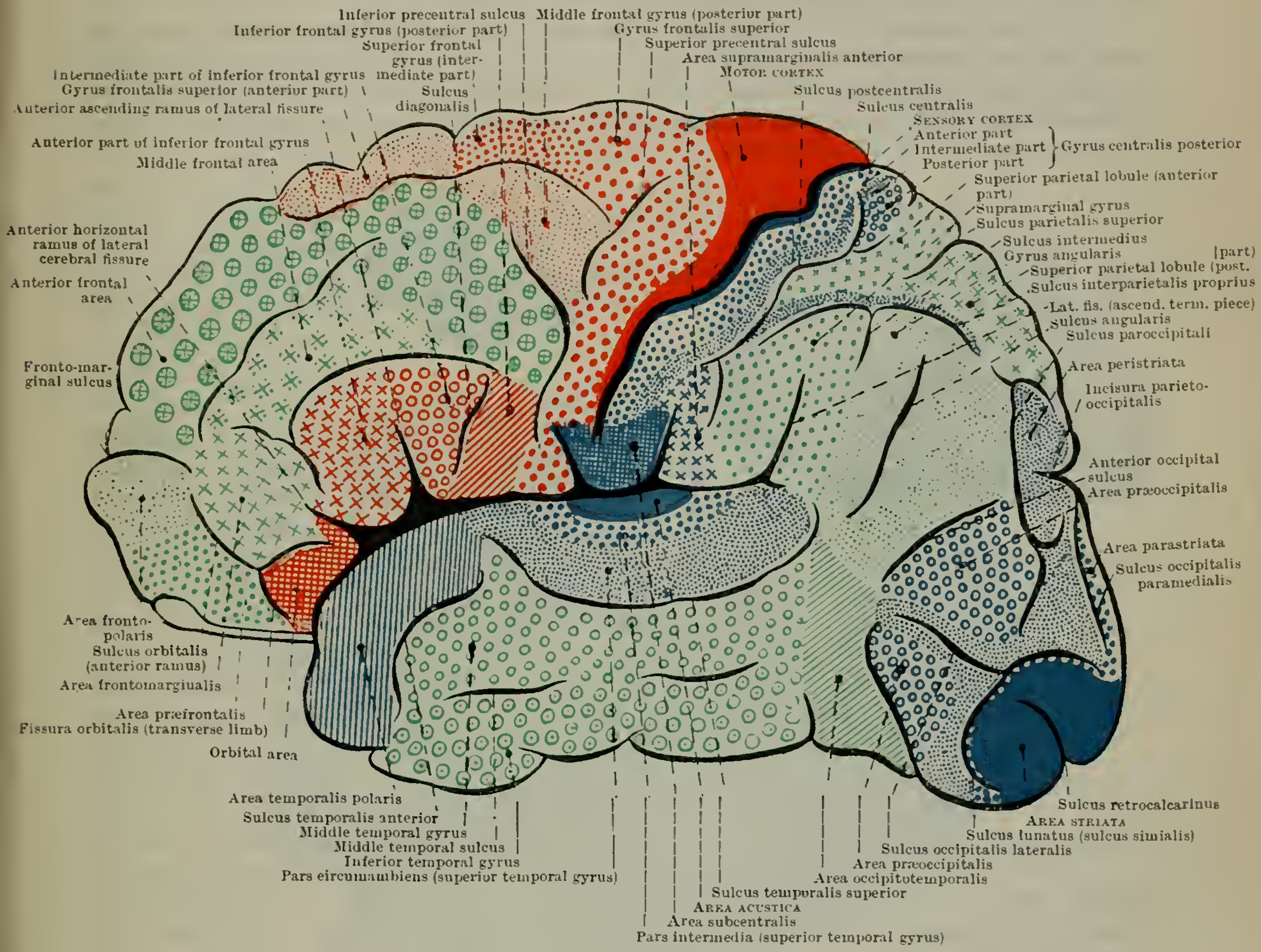
Inferior precentral sulcus
Middle frontal gyrus (posterior part)
Inferior frontal gyrus (posterior part)
Gyrus frontalis superior
Superior frontal gyrus (intermediate part)
Superior precentral sulcus
Area supramarginalis anterior
Intermediate part of inferior frontal gyrus
MOTOR CORTEX
Gyrus frontalis superior (anterior part)
Sulcus diagonalis
Sulcus postcentralis
Anterior ascending ramus of lateral fissure
Sulcus centralis
SENSORY CORTEX
Anterior part
Intermediate part
Posterior part
Gyrus centralis posterior
Anterior part of inferior frontal gyrus
Middle frontal area
Superior parietal lobule (anterior part)
Supramarginal gyrus
Sulcus parietalis superior
Anterior horizontal ramus of lateral cerebral fissure
Sulcus intermedius
Gyrus angularis
Superior parietal lobule (post. part)
Anterior frontal area
Sulcus interparietalis proprius
Lat. fis. (ascend. term. piece)
sulcus angularis
Sulcus paroccipitali
Fronto-marginal sulcus
Area peristriata
Incisura parieto-occipitalis
Anterior occipital sulcus
Area præoccipitalis
Area parastriata
Sulcus occipitalis paramedialis
Area fronto-polaris
Sulcus orbitalis (anterior ramus)
Area frontomarginalis
Area præfrontalis
Fissura orbitalis (transverse limb)
Orbital area
Area temporalis polaris
Sulcus temporalis anterior
Middle temporal gyrus
Middle temporal sulcus
Inferior temporal gyrus
Pars circumambiens (superior temporal gyrus)
Sulcus retrocalcarinus
AREA STRIATA
Sulcus lunatus (sulcus simialis)
Sulcus occipitalis lateralis
Area præoccipitalis
Area occipitotemporalis
Sulcus temporalis superior
AREA ACUSTICA
Area subcentralis
Pars intermedia (superior temporal gyrus)

FIG. 548.—A DIAGRAM OF THE LATERAL ASPECT OF THE LEFT CEREBRAL HEMISPHERE.

The *inferior frontal sulcus* (the superior boundary of the inferior frontal gyrus), the *middle frontal sulcus* (separating the anterior and middle frontal areas), and the *superior frontal sulcus* (bounding the superior frontal gyrus) are not labelled.

The **anterior horizontal ramus** extends horizontally forwards in the frontal region for a distance of not more, as a rule, than three-quarters of an inch, immediately above and parallel to the posterior part of the superciliary margin of the hemisphere.

The **anterior ascending ramus** proceeds upwards and slightly forwards, into the inferior part of the lateral surface of the frontal region for a variable distance (an inch or less). In many cases the two anterior limbs spring from a common stem of greater or less length, and not infrequently there is only a single anterior limb.

Sulcus Circularis.—If the lips of the posterior ramus of the lateral fissure are pulled widely asunder from each other, the **insula** (island of Reil) will be seen at the bottom. The insular district of the cortex is completely hidden from view, when the lateral fissure is closed, by overlapping portions of the cerebral hemisphere, and, when brought into view in the manner indicated, it is observed to present a triangular outline and to be surrounded by a limiting sulcus, of which three parts may be recognised, viz., a *superior part,* bounding it above and separating it from the parietal and frontal regions; an *inferior part,* marking it off below from the temporal region; and an *anterior part,* separating it in front from the frontal region.

The insula consists of three areas of different structure. At the antero-inferior corner (where the sulcus circularis is deficient) the knee-like bend of the area piriformis (see Figs. 550 and 520) appears at the **limen insulæ**. The rest is subdivided by an oblique furrow (**sulcus centralis insulæ**) into a posterior part divided into **gyri longi** and an anterior part divided into **gyri breves**.

Opercula Insulæ.—The overlapping portions of the cerebral substance which cover over the insula are termed the insular opercula, and they form, by the apposition of their margins, the three rami of the lateral fissure. The rami of the fissure extend from the exposed surface of the hemisphere to the submerged surface of the insula, and, in this manner, separate the opercula from each other.

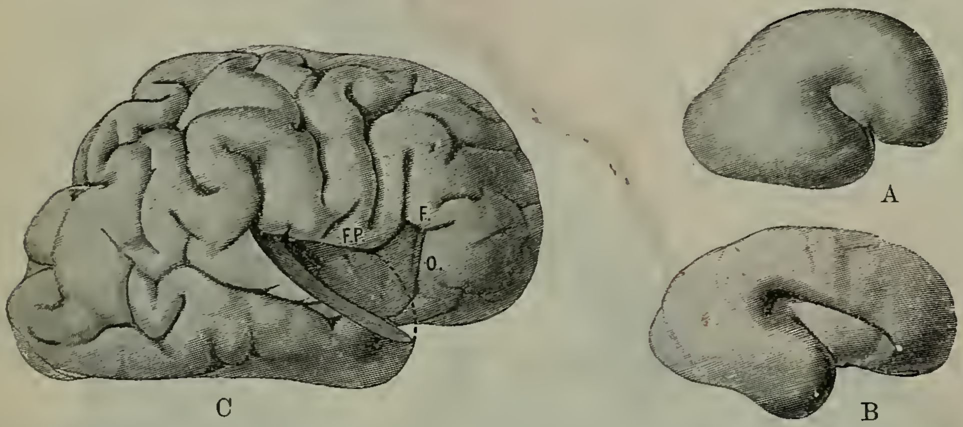

Fig. 549.—Right Hemispheres of Human Fœtuses showing Three Stages in the Development of the Insula and the Insular Opercula.

A, Right cerebral hemisphere from a fœtus in the latter part of the fourth month of development; B, Right cerebral hemisphere from a fœtus in the fifth month of development; C, Right cerebral hemisphere from a fœtus in the latter part of the eighth month of development.

In C the temporal operculum has been removed, and thus a large part of the insula is exposed. The outline of the temporal operculum is indicated by a dotted line.

F.P, Superior operculum. F, Frontal operculum. O, Orbital operculum.

The **temporal operculum** (**pars temporalis**) extends upwards over the insula from the temporal region, and its superior margin forms the inferior lip of the posterior ramus of the lateral fissure.

The **superior operculum** is carried downwards from the parietal (**pars parietalis**) and frontal (**pars frontalis**) regions over the insula, and its inferior margin, meeting the temporal operculum, forms the superior lip of the posterior ramus of the lateral fissure.

The small triangular piece of cerebral substance which sometimes intervenes between the ascending and horizontal anterior rami of the lateral fissure is formed by the bending downwards of the front part of the upper operculum. It covers over a small part of the anterior portion of the insula, and is sometimes termed the **pars triangularis**.

The **orbital operculum** is, for the most part, on the inferior surface of the hemisphere. It lies below and to the medial side of the horizontal anterior ramus of the lateral fissure, and proceeds backwards from the orbital aspect of the frontal lobe over the anterior part of the insula.

Development of the Lateral Fissure and of the Insular District of the Cerebral Hemisphere.—It is only during the latter half of the intra-uterine period of development that the opercula take shape and grow over the insula, so as to shut it out from the surface. In its early condition the insula presents the form of a depressed area on the side of the cerebral hemisphere, surrounded by a distinct boundary wall formed by the surrounding more elevated surface of the hemisphere (Fig. 549, A). After a time this depressed area, which is called the fossa lateralis, assumes a triangular outline, and then the bounding wall is observed to be composed of three distinct parts, viz., a superior or fronto-parietal, an inferior or temporal, and an anterior or orbital part (Fig. 549, B). The angle formed by the meeting of the superior and anterior portions of the boundary may become flattened, and a short oblique part of the limiting wall develop into a small triangular frontal operculum (Fig. 549, F). Each of these portions of the bounding wall of the fossa becomes a line of growth, from which an operculum takes origin, and by the approximation of these opercula, as they grow over the surface of the fossa, the insula becomes closed in and the rami of the lateral fissure are formed (Fig. 549, C).

The lateral fissure is an example of the fourth category of furrows enumerated above. It is largely the result of the operation of the mechanical factors incidental to the bending downwards of the pallium in front of and behind the place where the hemisphere-wall is supported and held in position by the corpus striatum. The cortical area roughly corresponding to the surface of the corpus striatum is the insula; the temporal region extends downwards behind it, and to a less extent the frontal region in front of it (Fig. 549, A). Then towards the end of the fifth month of fœtal life the exuberant growth of the free fronto-parietal pallium above the insula (Fig. 549, B) and the temporal pallium below and behind it leads to the development of lip-like folds of neopallium—the opercula—which gradually approach one another (Fig. 549, C) and eventually cover up the insula. Other factors come into play in determining the form and topographical relations of the fissura lateralis. For example, the posterior part of the fissure is the morphological boundary between the acoustic and tactile territories of the neopallium.

THE ACOUSTIC AREA AND FIBRE-TRACTS.

In the embryo of the fifth month (Fig. 549, B), as well as in every later stage, even up to the adult condition (Fig. 550), an area upon the superior surface of the temporal operculum can be seen to slope medially towards the upper limb of the sulcus circularis, behind the insula. This area constitutes the receptive centre for acoustic impressions—the **gyrus temporalis transversus** or **Heschl's convolution**—although the extent of this acoustico-sensory area does not coincide exactly with that of the transverse temporal gyrus. The area formed by the upper surface of the temporal operculum immediately behind this prominent transverse gyrus is also called by the same name, so that there are anterior and posterior transverse temporal gyri (Fig. 550; the posterior transverse temporal gyrus is not labelled in the figure).

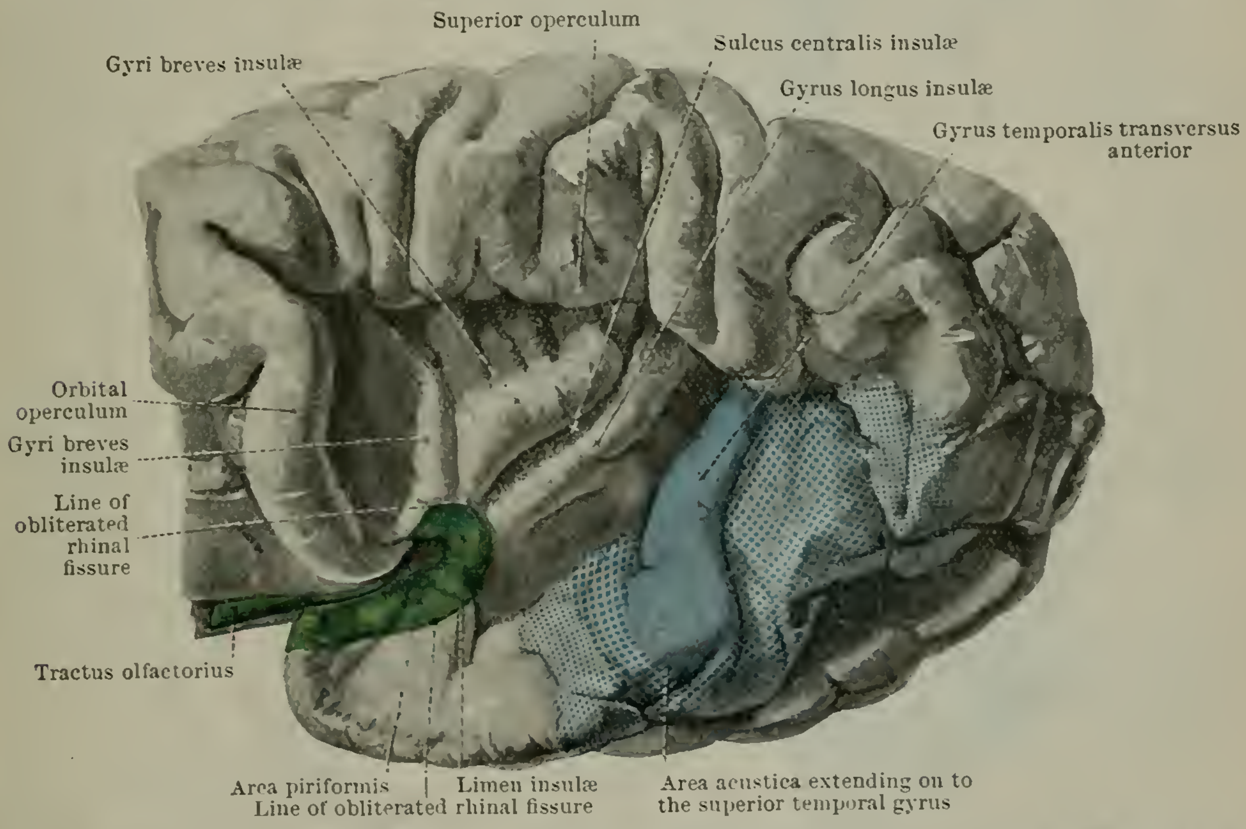
Superior operculum
Gyri breves insulæ
Sulcus centralis insulæ
Gyrus longus insulæ
Gyrus temporalis transversus anterior
Orbital operculum
Gyri breves insulæ
Line of obliterated rhinal fissure
Tractus olfactorius
Area piriformis
Limen insulæ
Line of obliterated rhinal fissure
Area acustica extending on to the superior temporal gyrus

Fig. 550.—Part of a Left Cerebral Hemisphere with the Opercula of the Insula widely separated to expose the Insula and the Superior Surface of the Temporal Operculum.

The *area acustica* is coloured a uniform blue, the *area intermedia* with large blue spots and the *area circumambiens* with fine blue dots.

In studying the brain-stem we have seen that a tract of fibres originating in the cochlear terminal nuclei (in the medulla oblongata) crosses the median plane (corpus trapezoideum) and bends upwards in the lateral lemniscus of the other side (Fig. 546) to end in the medial geniculate body of the metathalamus. From the medial geniculate body a new tract arises (composed of tertiary acoustic neurones), which passes laterally (Figs. 546 and 520) to end in the transverse temporal gyri. This tract may be called the **radiatio thalamotemporalis.**

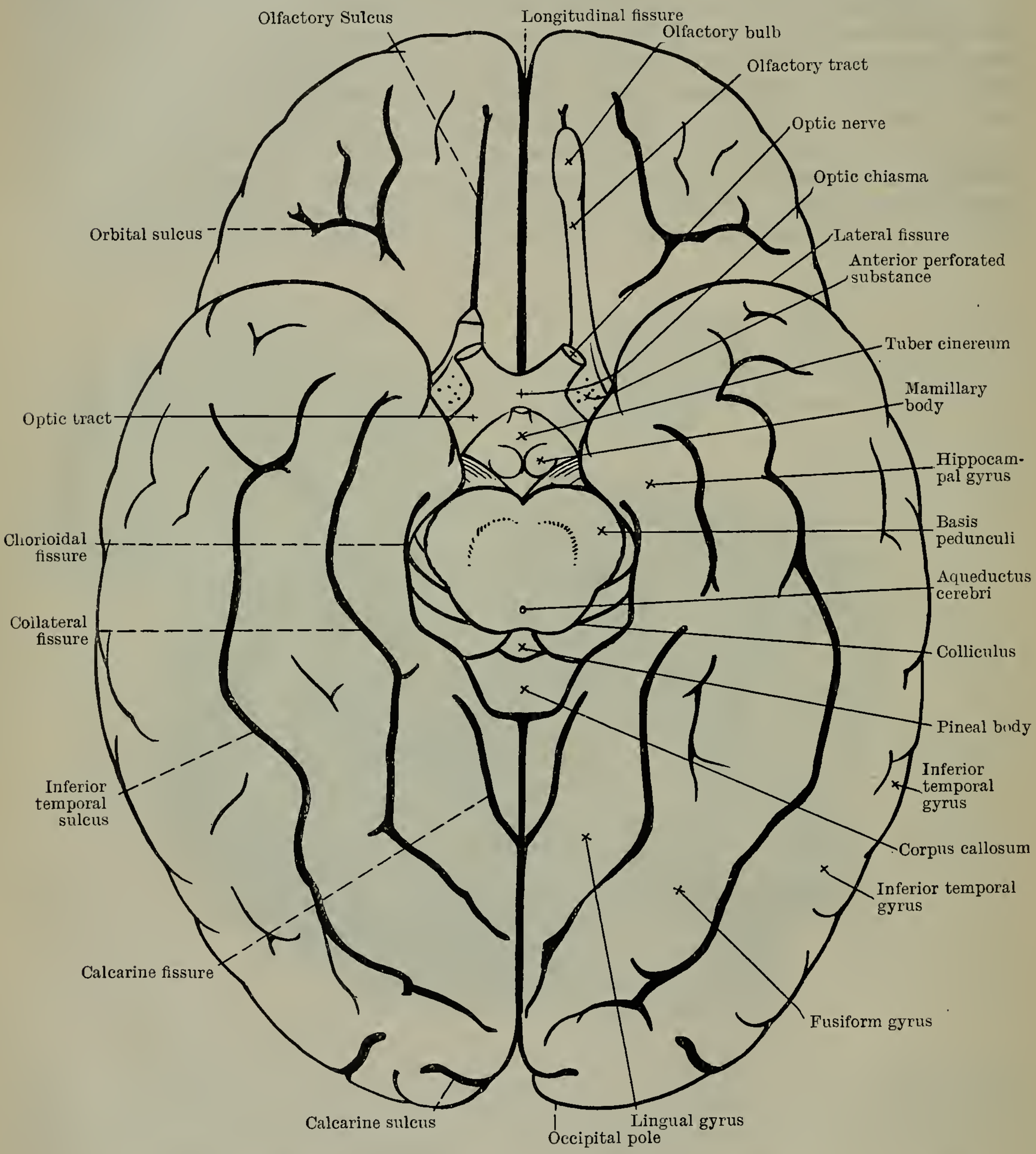

FIG. 551.—DIAGRAM OF THE GYRI AND SULCI OF THE INFERIOR SURFACES OF THE HEMISPHERES.

The area into which this acoustic radiation is inserted occupies not only the region of the anterior transverse temporal gyrus (Fig. 550) hidden within the lateral fissure, but also extends over its inferior lip, on to the exposed surface of the superior temporal gyrus (Fig. 548). Surrounding this area there are two concentric bands, which are also concerned with acoustic functions, but are related to the acoustic radiation only through the intermediation of the **area acustica** of the transverse gyrus (Figs. 548 and 550).

These areas may be distinguished as the **pars intermedia** and **pars circumambiens,** respectively, of the **gyrus temporalis superior.** During the sixth month of fœtal life a furrow makes its appearance along the line of the inferior boundary of the superior temporal area (Fig. 558). It is called the **sulcus temporalis superior.**

At a much later stage of development another furrow (**sulcus temporalis anterior**) makes its appearance further forwards in the temporal region, as the posterior boundary of the **area temporalis polaris**; it often becomes confluent with the real sulcus temporalis superior, and is usually described as part of it. But it is genetically quite distinct from it (Fig. 548).

If the area acustica is cut across in a perfectly fresh brain it will be found to be composed of a thin layer (1·75 mm.) of cortical gray matter, in which two very dense and fairly broad bands of white matter are visible (Fig. 520). These bands are composed largely of fibres of the acoustic radiation, which have entered the cortex to terminate in it. The superior temporal area is composed of somewhat thicker cortex with two bands which are not so densely white as those of the area acustica. The cortex of the temporal polar area is composed of moderately thick, clear, gray matter in which there is a single, narrow, sharply defined white line.

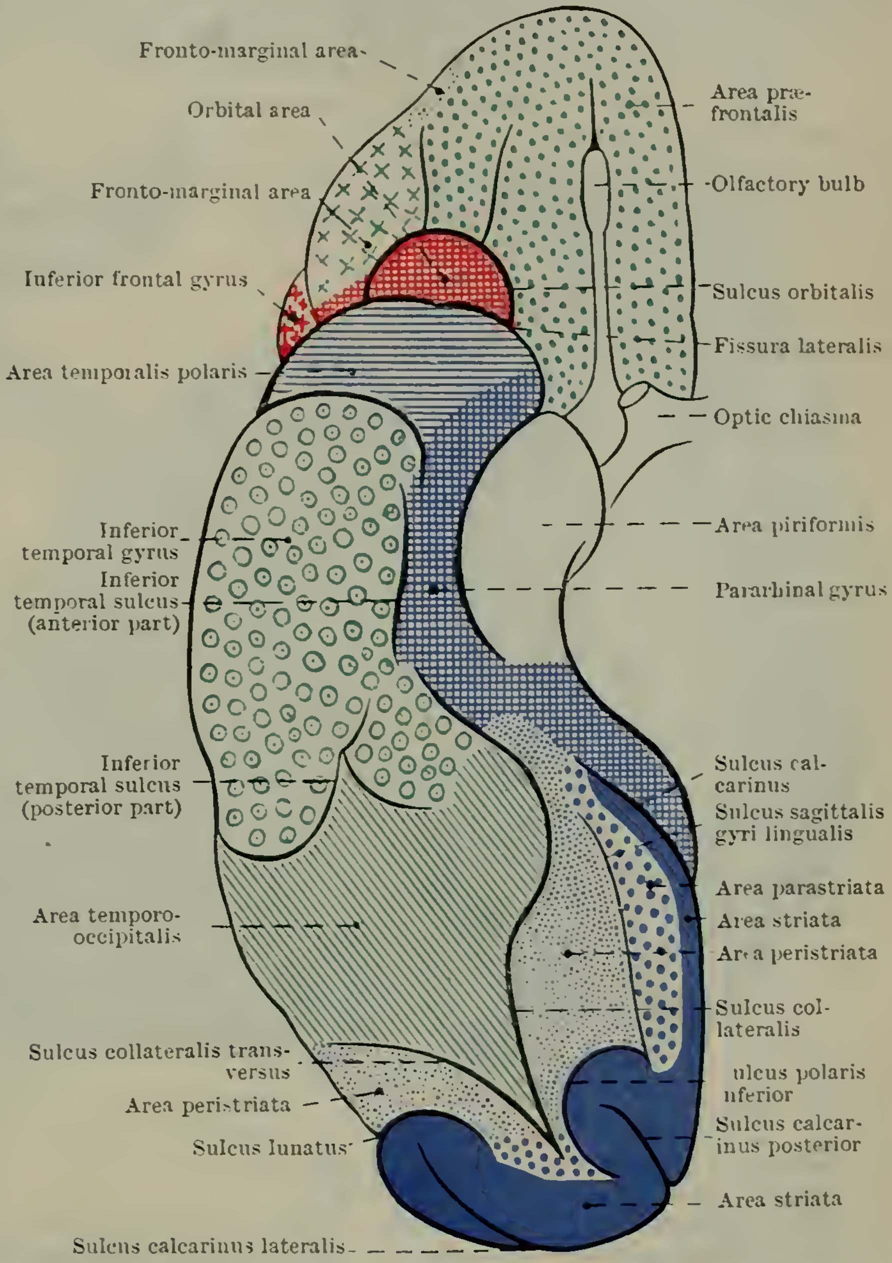

FIG. 552.—CORTICAL AREAS on the tentorial and orbital aspects of the cerebral hemispheres.

The remainder of the true temporal region is composed of an extensive district below the superior temporal sulcus. It is composed of thicker cortex than the superior temporal area, ranging from 3 mm. just below the superior temporal sulcus to 2·5 mm. at the inferior border of the hemisphere. It is composed of three bands of different texture, the **middle temporal gyrus,** the **inferior temporal gyrus,** and the **pararhinal gyrus,** which fringes the area piriformis on the tentorial surface. Upon the lateral aspect of the temporal region a series of irregular furrows are situated along the line of demarcation between the **gyrus temporalis medius** and the **gyrus temporalis inferior**; they are considered to represent a **sulcus temporalis medius,** but they are subject to much irregularity, especially in highly developed brains. The **sulcus temporalis inferior,** which forms the line of demarcation between the gyrus temporalis inferior and the gyrus fusiformis, is placed upon the inferior aspect of the temporal region.

The great extent of the middle and inferior temporal gyri constitutes one of the outstanding features distinctive of the human brain. Flechsig has shown that the fibres passing to and from these two gyri are the last to become medullated, later even than the important parietal and frontal areas.

THE VISUAL AREAS AND FIBRE-TRACTS.

We have already seen (Fig. 520) that each optic tract ends in the lateral geniculate body, the pulvinar of the thalamus, and the superior colliculus. From the lateral geniculate body (and according to most writers the thalamus also, though this is not admitted by all) a tract arises which conveys visual impulses back to the occipital pole of the hemisphere. This **radiatio thalamo-occipitalis (Gratiolet's optic radiation)** is seen from various points of view in the figures mentioned, but it is possible (see Fig. 553) to expose it in a section which will display it in its relationship to the rest of the visual path (Fig. 554).

From this it will be seen that the fibres of the optic radiation, after emerging from the lateral geniculate body, bend backwards in the lateral wall of the ventricle and proceed to an extensive district of thin cortex (1·5 mm. or less in thickness), occupying an area of about 3000 sq. mm. of the medial surface and pole of the occipital area. The cortex in this area is distinguished by the presence of a very distinct white line or stria, which was first noticed by Gennari in the year 1776.

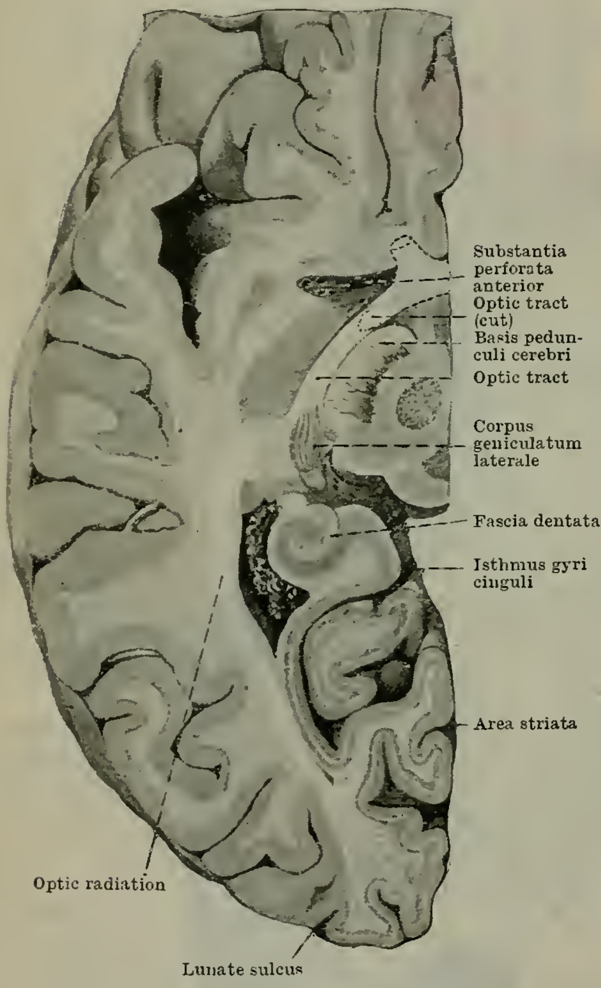

FIG. 553.—A SLIGHTLY OBLIQUE (ALMOST HORIZONTAL) SECTION THROUGH A CEREBRAL HEMISPHERE IN THE PLANE OF THE OPTIC TRACT AND RADIATION. The area striata contains the white line of Gennari.

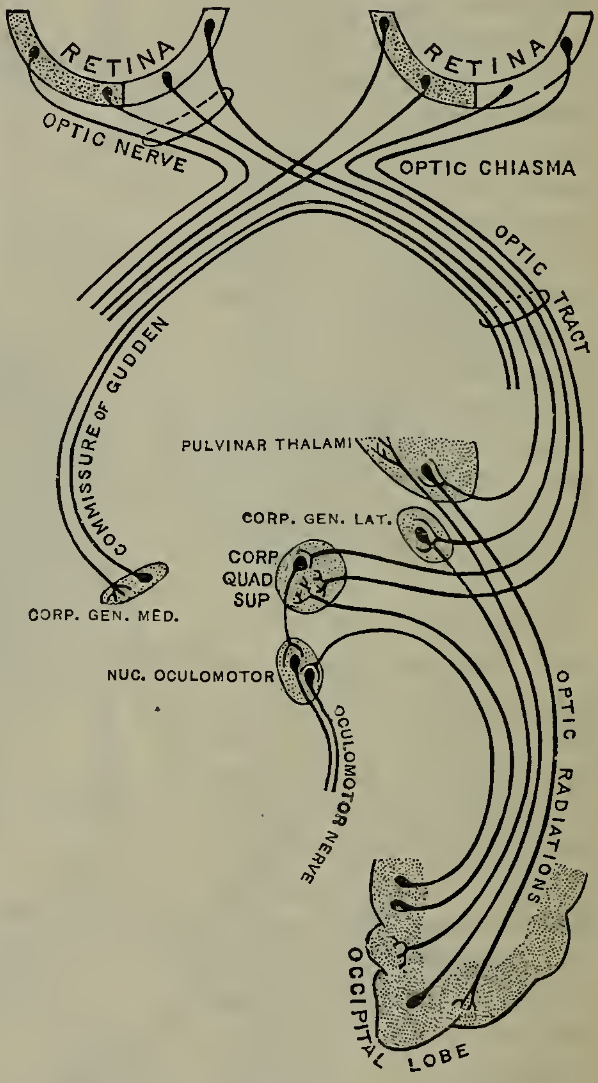

FIG. 554.—DIAGRAM OF THE CENTRAL CONNEXIONS OF THE OPTIC NERVE AND OPTIC TRACT.

If this visual receptive **area striata** of the occipital cortex is excised and spread out in one plane, it will be found to present an elongated ovoid form and a superficial extent of about 3000 sq. mm. (varying in different brains from about 2700 to 4000). The narrow extremity of the oval is placed a short distance behind and below the splenium of the corpus callosum; and from this point the area extends horizontally backwards to the occipital pole, or even beyond it on to the lateral aspect of the hemisphere. In the course of development this area striata becomes folded along its axis during the sixth month, and the furrow thus formed is usually called the **sulcus calcarinus.** This name was applied to the furrow by Huxley because its deep anterior part indents the whole thickness of the medial wall of the hemisphere, and the swelling so produced in the posterior cornu of the lateral ventricle was supposed by the older anatomists to resemble a cock's spur and was hence called **calcar avis** (see Fig. 533, p. 634).

The anterior part of this furrow is much deeper, more constant in form and position, more precocious in development, and phylogenetically much older than the posterior part. As it is the part of the sulcus which gives rise to the calcar avis, it is the true calcarine; while the newer, shallower posterior part is wholly on the caudal side of the calcar avis, and is called **sulcus calcarinus posterior.** If the area striata is prolonged on to the lateral surface, it also may become folded in the line of its axis, and so give rise to a **sulcus calcarinus lateralis.**

There is a fundamental distinction between the calcarine sulcus and the posterior calcarine in their relations to the area striata. For the stria of Gennari is found only in the inferior wall of the sulcus calcarinus, which is therefore a sulcus limitans; whereas the stria extends throughout both walls of the posterior calcarine sulcus, and in most cases beyond its lips on to the surface of the **cuneus** and the **gyrus lingualis** (Figs. 555 and 557), *i.e.* the exposed cortical areas placed upon the superior and inferior aspects respectively of the sulcus calcarinus posterior.

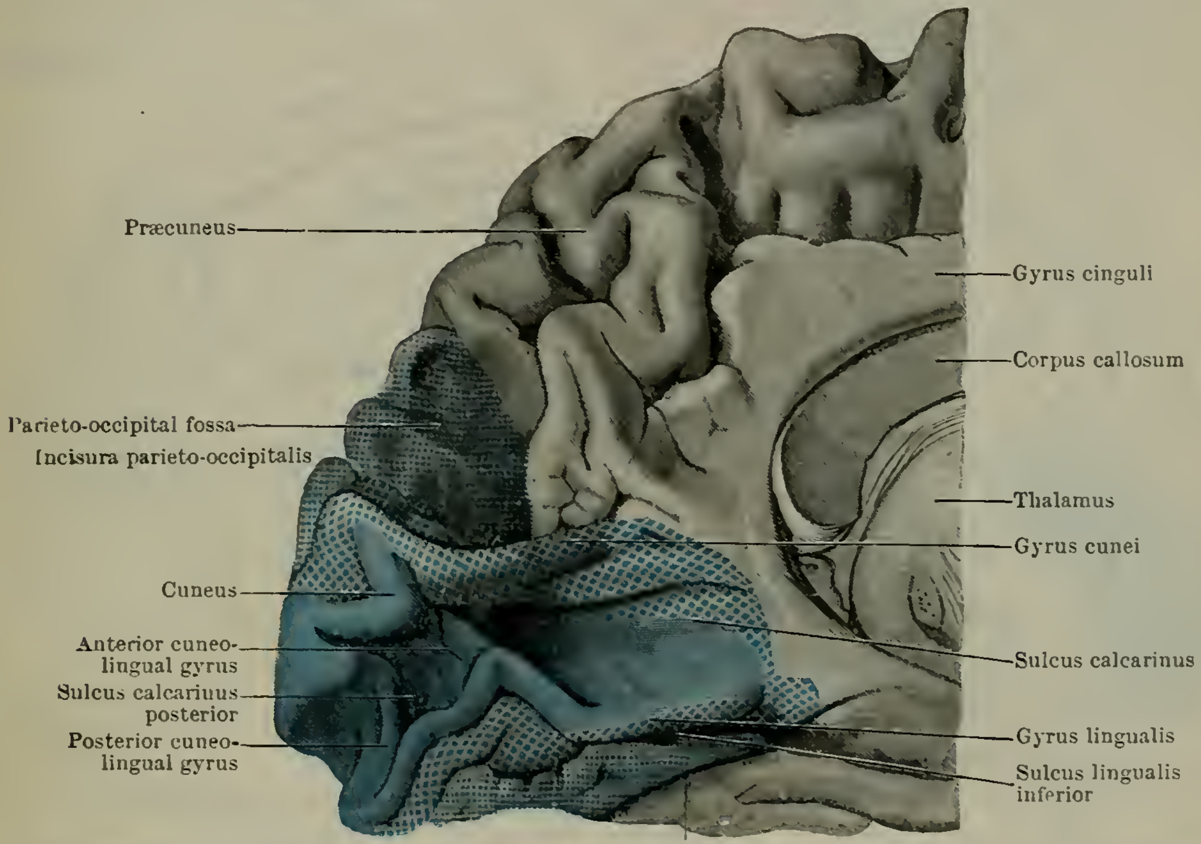
Præcuneus
Parieto-occipital fossa
Incisura parieto-occipitalis
Cuneus
Anterior cuneo-lingual gyrus
Sulcus calcarinus posterior
Posterior cuneo-lingual gyrus
Gyrus cinguli
Corpus callosum
Thalamus
Gyrus cunei
Sulcus calcarinus
Gyrus lingualis
Sulcus lingualis inferior

Fig. 555.—The Parieto-occipital and the Calcarine Sulci fully opened up, so as to show the deep transitional gyri marking off the several elements of the ≺-shaped system.

Area striata, uniform blue ; *area parastriata*, large blue spots ; *area peristriata*, fine blue dots.

Along the superior and inferior boundary lines of this area shallow limiting sulci usually develop (Fig. 557), and these furrows often pass backwards into little arched *sulci polares*, which are furrows of the operculated variety (see p. 642), called into existence by the broadening out of the area striata (not an actual broadening, but an unfolding) as it passes round the edge of the hemisphere.

At the point of transition from the deep sulcus calcarinus into the shallower sulcus calcarinus posterior (Fig. 555) a submerged ridge is usually found—the **gyrus cuneolingualis anterior**; and other similar ridges, which may be exposed on the surface or may be submerged, are often found interrupting the posterior and lateral calcarine sulci themselves (Fig. 555).

The posterior and lateral calcarine sulci are subject to a very wide range of variation in form, but they are always axial foldings of the area striata.

When the area striata crosses on to the lateral surface of the hemisphere a small semilunar furrow develops a short distance in front of its anterior edge. This is the **sulcus lunatus.** The larger the lateral extension the closer does the edge of the area striata approximate to the caudal lip of the sulcus, which under such circumstances assumes a definitely operculated form. Such cases occur most often in the left hemisphere and in the brains of primitive people; and they represent a perfect realisation of a furrow once supposed not to occur in the human brain, but to be distinctive of the ape. Hence it used to be called the "**Affenspalte**" or **sulcus simialis.**

The area striata is surrounded by two peripheral concentric bands—an inner, which may be called **area parastriata,** and an outer, the **area peristriata.** Sulci develop along the boundary lines of each of these areas; and those which indicate the superior and inferior limits of the peripheral band (*i.e.* peristriate area) make their appearance relatively early in development and become very deep furrows.

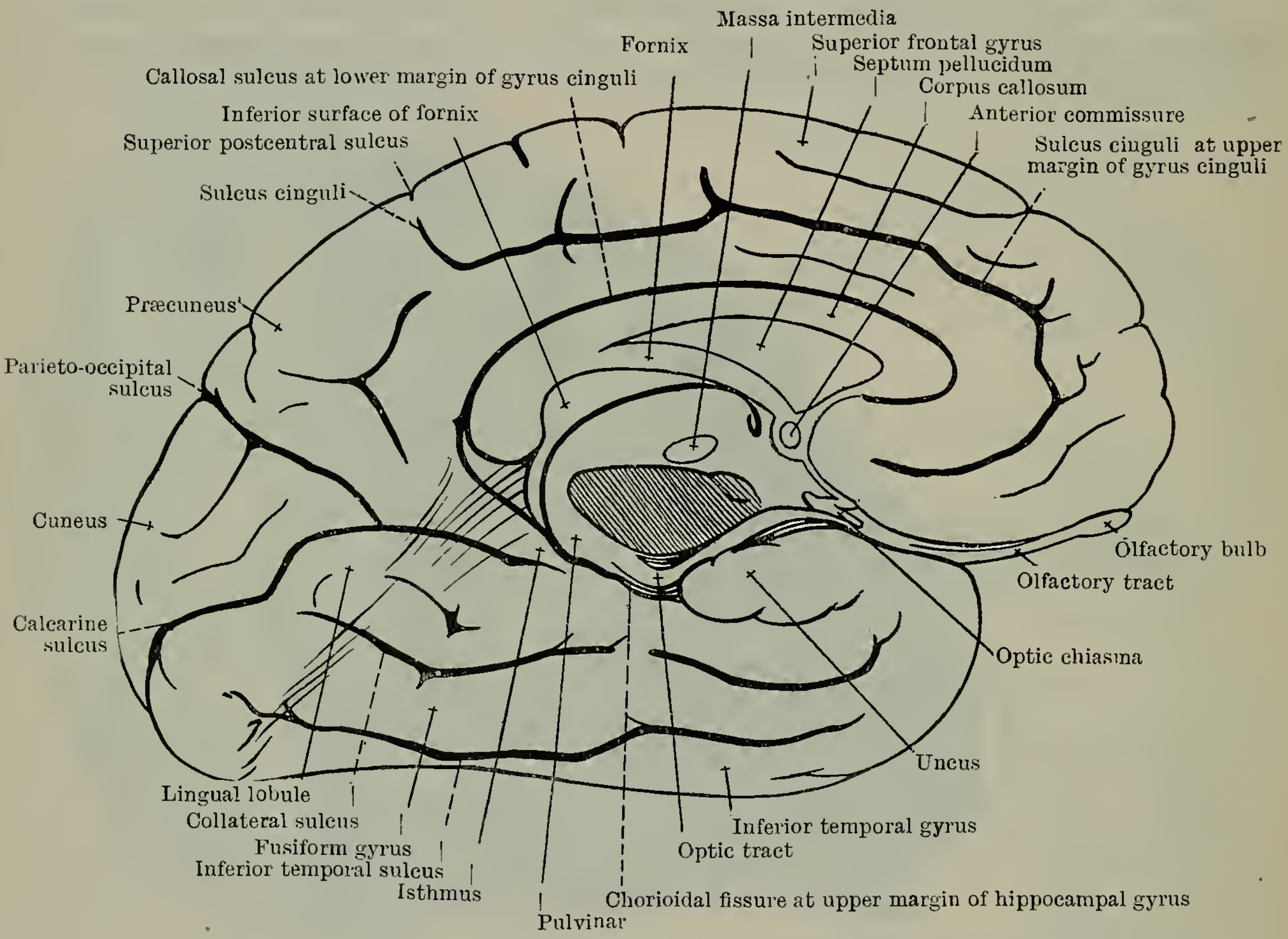

FIG. 556.—DIAGRAM OF SULCI AND GYRI OF MEDIAL AND INFERIOR SURFACES OF HEMISPHERE.

The inferior of these is placed upon the tentorial surface, and is known as the **sulcus collateralis**; the superior limiting furrow of the visual territory (its peristriate part) is upon the superior surface of the hemisphere, and is usually regarded as the **ramus occipitalis** of the **sulcus interparietalis.** But it is genetically independent of the latter furrow, and may be distinguished as the **sulcus paroccipitalis.**

Near the supero-medial margin of the hemisphere there is a furrow, which indicates the line of demarcation between the para- and the peristriate areas—the **sulcus occipitalis paramedialis.** It may be situated upon either the medial or the superior surface of the hemisphere. In some cases it belongs to the category of limiting sulci, in others to the group of operculated sulci (see p. 643).

Passing horizontally forwards upon the lateral surface of the hemisphere there is a constant furrow formed by the axial folding of part of the peristriate area, approximately in line with the axial folding of the striate area (sulcus calcarinus lateralis); it is the **sulcus occipitalis lateralis.** When there is a fully developed sulcus lunatus the lateral occipital sulcus joins it near its midpoint (Fig. 548, p. 651).

The **sulcus** (or **fossa**) **parieto occipitalis** (Fig. 522) is usually a deep furrow upon the medial aspect of the hemisphere which passes vertically downwards from the supero-medial border and appears to join the calcarine sulcus near its union with the posterior calcarine, forming upon the surface a Y-shaped pattern, the stem of which is calcarine, the limbs posterior calcarine and parieto-occipital respectively, and the wedge-shaped area between the limbs the **cuneus** (Fig. 555; compare with the pattern shown in Fig. 557, where the parieto-occipital sulcus is not labelled).

If, however, the lips of these three furrows are divaricated (Fig. 555), the parieto-occipital depression will be found to be separated from the calcarine by a prominent submerged cortical ridge, the **gyrus cunei**; and the parieto-occipital will be found to be something more than a mere sulcus. It is, in fact, a great fossa in which are submerged the anterior parts of the area parastriata and area peristriata, and the posterior part of the parietal area known as the **præcuneus**, as well as the sulci which separate these territories one from the other. It is a great trough formed by the splenium of the corpus callosum as in the course of its development it thrusts itself backwards and crumples up the cortex. When the corpus callosum fails to develop, no parieto-occipital fossa makes its appearance. The part of the sulcus that notches the supero-medial border (Fig. 557) forms a distinct element, which Retzius has called the *incisura parieto-occipitalis*.

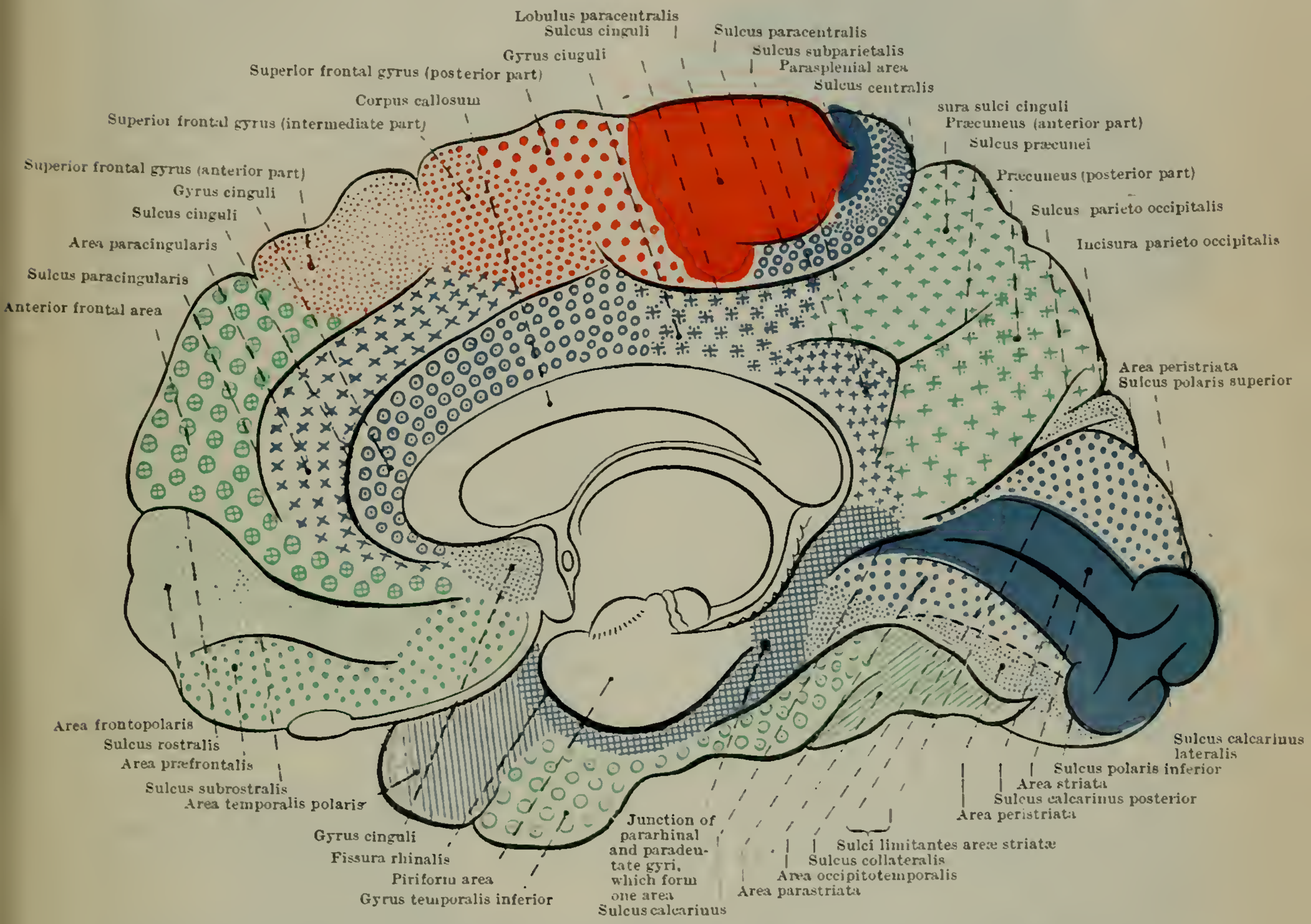

FIG. 557.—THE CORTICAL AREAS ON THE MEDIAL ASPECT OF THE CEREBRAL HEMISPHERE.

Sulcus Collateralis.—The collateral sulcus is a strongly marked furrow on the tentorial face of the cerebral hemisphere. It begins near the occipital pole and extends forwards towards the posterior end of the rhinal fissure, with which it sometimes becomes confluent. In its posterior part it is placed below, and parallel to, the calcarine fissure, from which it is separated by the lingual gyrus. From the posterior extremity a sulcus proceeds forwards and then laterally across the inferior surface of the occipital region, forming a V-shaped pattern with the collateral sulcus (Fig. 552). As it is serially homologous with the latter, being, like it, an inferior boundary of the area peristriata, it may be called the **sulcus collateralis transversus.** The lingual gyrus is sometimes subdivided by a furrow (*sulcus sagittalis gyri lingualis*) midway between the collateral sulcus and the inferior margin of the area striata. It is the line of demarcation between the parastriate and peristriate areas, and when deep is often mistaken for the collateral sulcus.

THE PARIETAL REGION.

We have seen that the acoustic pathway leads into the temporal region and the visual pathway into the occipital region. The facts of clinical medicine show that large areas in these two regions beyond the limits of the cortex in which the acoustic and optic radiations end are concerned with the functions of hearing and vision. A large part of the parietal area is interposed between these temporal and occipital territories, and its integrity and normal functioning are necessary conditions for the proper performance of many acts, such as reading written or printed documents, in the appreciation of which both hearing and vision have played some part. But the parietal region also includes the cortical area in which a part, at least, of the chief thalamo-cerebral tract ends—the bundle of fibres that represents the third stage of the great sensory pathway, the first stage of which is formed by the spinal and cerebral sensory nerves and their central prolongations, and the second stage by the spino-thalamic, bulbo-thalamic, and ponto-thalamic fasciculi, which pass upwards in the medial lemniscus and end in the ventral nucleus of the thalamus (Figs. 545, 546).

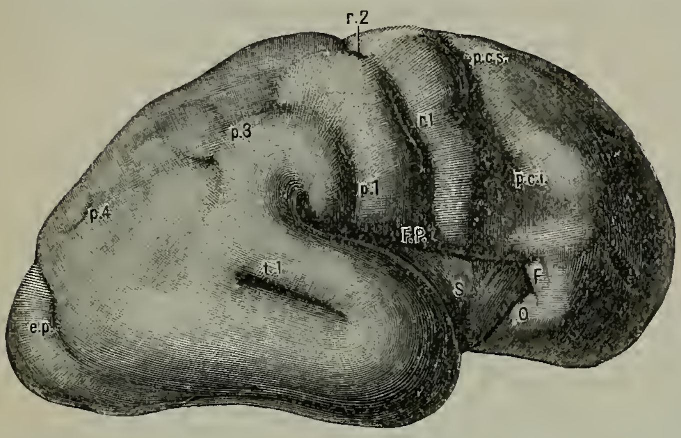

FIG. 558.—LEFT CEREBRAL HEMISPHERE, from a fœtus in the early part of the seventh month of development.

p.c.s.	Sulcus præcentralis superior.
p.c.i.	Sulcus præcentralis inferior.
r^1.	Inferior part of central sulcus
r^2.	Superior part of central sulcus.
p^1.	Inferior postcentral sulcus.
p^3.	Sulcus interparietalis proprius.
p^4.	Sulcus paroccipitalis.
t^1.	Superior temporal sulcus.
S.	Lateral fossa.
F.P.	Fronto-parietal wall.
F.	Frontal wall.
O.	Orbital wall.

The sensory area in question forms part of the **gyrus centralis posterior,** which intervenes between two oblique furrows, the **sulcus centralis** and the **sulcus postcentralis,** which extend across the whole breadth of the hemisphere above the sulcus lateralis (Fig. 548).

Sulcus Centralis.—During the sixth and seventh months of fœtal life the expanding posterior central area becomes raised up into a prominent ridge, and a similar ridge is formed immediately in front of it (Fig. 590) from the area which emits the great efferent or motor tract to control all the motor nuclei upon the other side of the brain and spinal medulla. As these ridges become raised up a depression is left between them: this is the **sulcus centralis.** At first it consists of two parts, a superior and an inferior (Fig. 590, r^2 and r^1); but as a rule these become confluent later.

The sulcus centralis in the adult takes an oblique course across the lateral convex surface of the cerebral hemisphere, and intervening between the frontal and parietal regions it forms the immediate posterior boundary of the motor area of the cortex. Its upper end cuts the supero-medial border of the hemisphere a short distance behind the mid-point between the frontal and occipital poles, whilst its inferior end terminates above the middle of the posterior ramus of the lateral fissure. Its superior extremity, as a rule, turns round the supero-medial border of the hemisphere, and is then continued backwards for a short distance on the medial surface. Although, in its general direction, the sulcus is oblique, it is very far from being straight. It takes a sinuous course across the hemisphere. This is largely due to the varying breadth of the motor areas representing the lower limb, trunk, upper limb, and head, respectively, which are placed immediately in front of it.

When the sulcus centralis is widely opened up, so that its bottom and its opposed sides may be fully inspected, it will be seen that the two bounding gyri are dovetailed into each other by a number of interlocking gyri, which do not appear on the surface (Fig. 559). Further, two of these, placed on opposite sides of the fissure, are frequently joined across the bottom of the sulcus in the form of a sunken bridge of connexion, which constitutes what is termed a *deep transitional gyrus.* The continuity of the sulcus is thus, to some extent, interrupted. This condition is rendered interesting when considered in connexion with the development of the sulcus. The deep interlocking gyri indicate a great exuberance of cortical growth in this situation in the early stages of the development of the sulcus; and the presence of the deep transitional gyrus is explained by the fact that the sulcus generally develops in two pieces, which run into each other to form the continuous sulcus of the adult, viz., a part corresponding to the inferior two-thirds, and a superior part, which represents the superior third and which appears at a slightly later date. In certain very rare cases the sulcus centralis is found to remain double throughout life, through a failure of its two pieces to unite. In such cases the deep transitional gyrus, which is frequently seen at the bottom of the furrow, remains on the surface. Heschl, who examined 2174 cerebral hemispheres, found this anomaly only six times; Eberstaller met with it twice in 200 brains.

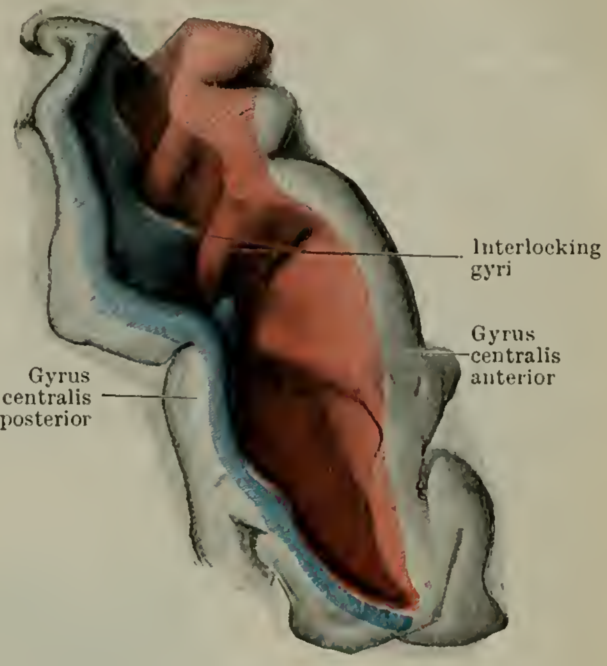

FIG. 559.—RIGHT SULCUS CENTRALIS FULLY OPENED UP, so as to exhibit the interlocking gyri and deep transitional gyrus within it.

Motor cortex coloured *red*, sensory cortex *blue*.

If a section is made at right angles to this sulcus in a fresh brain (Fig. 560), it will be seen that its anterior (gyrus centralis anterior) and posterior (gyrus centralis posterior) walls present a marked contrast the one to the other, and that the transition from the one type of cortex to the other takes place precisely at, or near to, the bottom of the sulcus. The anterior wall is composed of thick (3·5 to 4 mm.) motor cortex thickly laden with medullary matter arranged in the form of three or four pale bands with blurred edges and multitudes of fine pencils of fibres passing to and fro between it and the white matter of the hemisphere. The posterior wall is composed of thin (1·5 mm.) cortex containing two narrow and sharply defined white lines.

This sensory area forms little more than the posterior wall of the sulcus centralis, and barely emerges upon the surface to form the posterior lip of the sulcus (Fig. 548). Here it becomes continuous with a slightly thicker cortex with doubled lines which are less dense than those of the sensory cortex; this area forms the crest of the gyrus centralis posterior, and then gives place to another slightly modified type of cortex which forms the anterior wall of the sulcus postcentralis. Thus the sensory cortex has two fringing bands analogous to those already noticed alongside the visual and acoustic areas.

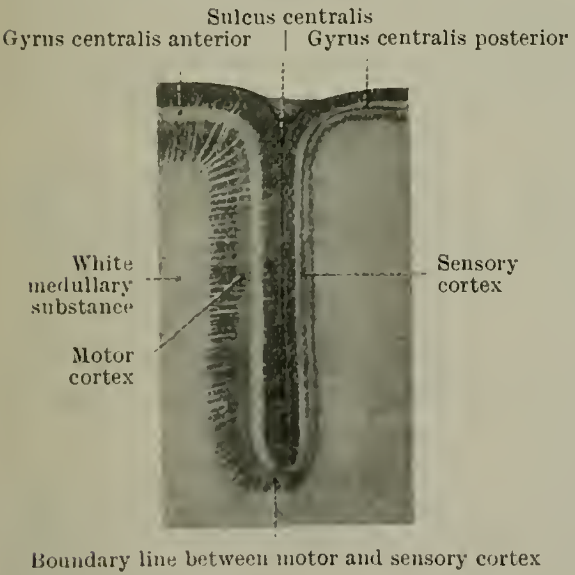
Sulcus centralis
Gyrus centralis anterior
Gyrus centralis posterior
White medullary substance
Motor cortex
Sensory cortex
Boundary line between motor and sensory cortex

FIG. 560.—SECTION ACROSS THE SUPERIOR PART OF THE SULCUS CENTRALIS IN A FRESH BRAIN.

The motor and sensory areas cross on to the medial aspect of the hemisphere, into a region known as the **lobulus paracentralis.** In this region a furrow (**sulcus paracentralis**) is sometimes found along the line of demarcation of the medial parts of the motor and sensory areas (Fig. 557).

That portion of the parietal region which intervenes between the gyrus centralis posterior and the occipital region is usually subdivided into two distinct parts (**lobulus parietalis superior** and **lobulus parietalis inferior**) by a horizontal furrow, called the **sulcus interparietalis proprius**. The term **sulcus interparietalis** is usually applied in a purely arbitrary and artificial manner to a complex of four genetically distinct and independent furrows (Fig. 561, p^1, p^2, p^3, and p^4), the **sulcus postcentralis inferior** (p^1), the **sulcus postcentralis superior** (p^2), the **sulcus interparietalis proprius (ramus horizontalis)** (p^3), and the **sulcus paroccipitalis (ramus occipitalis)** (p^4), which ends in the **sulcus occipitalis transversus**.

These four furrows develop quite independently one of the other, the postcentral sulci as the posterior boundary of the sensory territory, the paroccipital sulcus as the supero-lateral boundary of the visual territory, and the more variable horizontal ramus (the sulcus interparietalis, in the strict sense of the term) as a demarcation between the two parietal lobules. The four furrows may unite to form any possible combination.

The superior parietal lobule is composed of moderately thick cortex (2·5 to 3 mm.) placed between the interparietal sulcus (ramus horizontalis) and the superior border of the hemisphere, where it becomes continuous on the medial surface with the precuneus. Each of these parts is subdivided by a transverse sulcus, the superior lobule by the **sulcus parietalis superior** and the precuneus by the **sulcus præcunei** (Fig. 557).

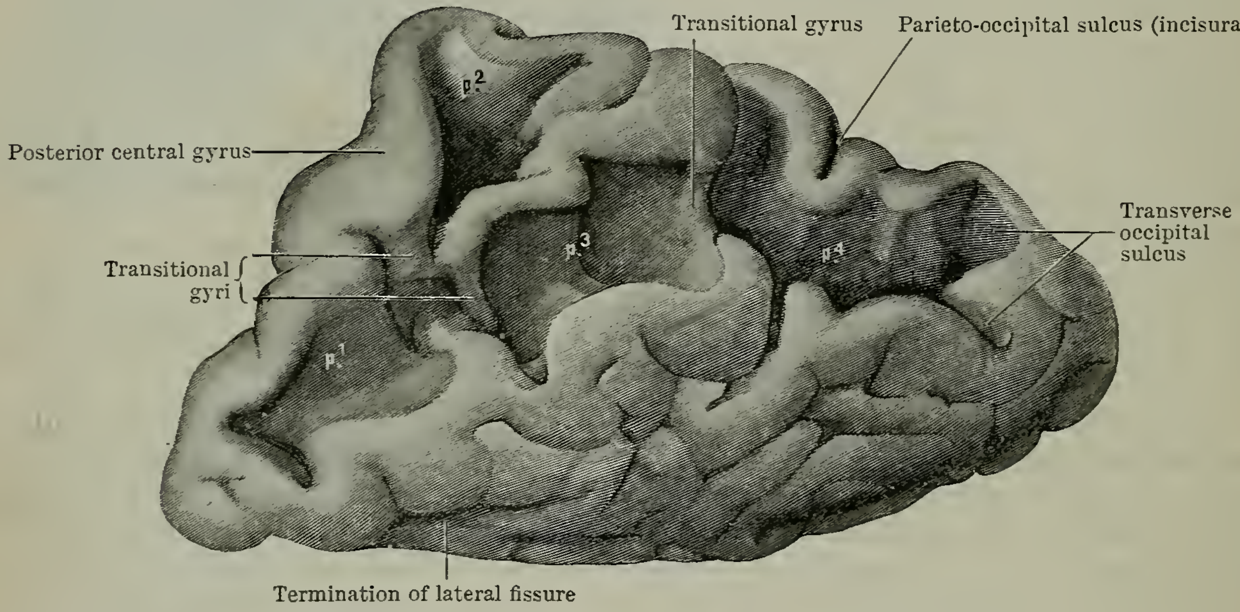
Transitional gyrus
Parieto-occipital sulcus (incisura)
Posterior central gyrus
p.2
Transverse occipital sulcus
Transitional gyri
p.3
p.4
p.1
Termination of lateral fissure

FIG. 561.—THE FOUR SULCI OF THE INTERPARIETAL COMPLEX OPENED UP, so as to show the deep transitional gyri intervening between them.

p^1. Sulcus postcentralis inferior.
p^2. Sulcus postcentralis superior.
p^3. Ramus horizontalis (sulcus interparietalis proprius).
p^4. Ramus occipitalis (sulcus paroccipitalis).

The latter sulcus usually joins a small inverted ∪-shaped furrow (**sulcus subparietalis**), which encloses a cortical territory of distinctive structure—the **area parasplenalis [præcunei]**.

The **inferior parietal lobule**, which from its position is the natural meeting-place for impressions coming from the visual, acoustic, and tactile territories, is naturally a region of great functional significance. It is composed of a series of areas differing in thickness and texture. The anterior region forms a convolution (**gyrus supramarginalis**) surrounding the upturned extremity of the lateral fissure; behind it there is a second convolution called the **gyrus angularis**, which surrounds a vertical **sulcus angularis**, often described as the extremity of the sulcus temporalis superior; but in reality it is quite independent of the latter furrow, but it often becomes confluent with it. Behind the gyrus angularis and separated from it by a transverse furrow (**sulcus occipitalis anterior**) there is a cortical territory (**area parieto-occipitalis**) which may perhaps be looked upon as a specialised and outlying part of the peristriate area of the visual cortex.

THE FRONTAL REGION.

The frontal region is the biggest of the main cortical areas—the so-called "lobes." On the lateral surface of the hemisphere, it is bounded behind by the sulcus centralis and below, in part, by the lateral fissure. It presents a lateral surface, a medial surface, and an inferior or orbital surface.

On its lateral aspect the surface is broken up by a large series of furrows, which exhibit considerable variability.

The **inferior precentral sulcus** consists of a vertical and an oblique part. The *vertical portion* lies in front of the inferior part of the sulcus centralis, whilst the *oblique part* extends forwards and upwards (Fig. 562).

The **superior precentral sulcus** is a short vertical sulcus which lies at a higher level than the inferior precentral sulcus, in front of the upper part of the sulcus centralis. It is almost invariably connected with the posterior end of the superior frontal sulcus.

The **anterior central gyrus** is a long continuous gyrus, which is limited in front by the two precentral furrows and behind by the sulcus centralis. Inferiorly it is continuous with the area subcentralis which links it to the posterior central gyrus. The area subcentralis is limited in front and behind by the *anterior and posterior subcentral sulci* (not labelled in Fig. 562).

The **superior frontal sulcus** extends forwards in a more or less horizontal direction from the sulcus præcentralis superior.

The **gyrus frontalis superior** is the narrow convolution between the supero-medial border of the hemisphere and the superior frontal sulcus and the continuation of this convolution into a broad area upon the medial surface.

The **inferior frontal sulcus** occupies a lower level than the superior frontal sulcus. Its posterior end is placed in the angle between the vertical and horizontal parts of the inferior precentral sulcus, and is not infrequently confluent with one or other of these. It proceeds forwards towards the superciliary margin of the hemisphere and ends a short distance from this in a terminal bifurcation (Fig. 562).

The **gyrus frontalis medius** is the name given to the broad convolution which lies between the superior and inferior frontal sulci.

The **gyrus frontalis inferior** is that portion of the lateral surface of the frontal region which is placed in front of the inferior precentral sulcus and below the inferior frontal sulcus. The inferior frontal convolution includes three cortical areas (Fig. 562) differing in structure the one from the other. The **sulcus diagonalis** separates the intermediate of these from the posterior.

The **sulcus frontalis medius** begins midway between the anterior ends of the superior and inferior frontal sulci and proceeds obliquely forwards towards the frontal pole. When the furrow reaches the superciliary margin of the hemisphere it ends near a transverse furrow, called the **fronto-marginal sulcus.**

On the *medial aspect of the frontal lobe* there are two convolutions, the larger peripheral area which forms part of the gyrus frontalis superior and a smaller inner part encircling the corpus callosum, which is called the **gyrus cinguli**. These gyri are separated by the **sulcus cinguli** (Fig. 556).

The posterior part of the sulcus cinguli is genetically distinct from the anterior part and it circumscribes a broader area, the **lobulus paracentralis**, which is continuous with the gyri centrales of the lateral surface of the hemisphere.

On the *orbital aspect of the frontal region* there are two sulci, viz., the olfactory and the orbital.

The **olfactory sulcus** is a straight furrow which runs parallel to the medial orbital border of the hemisphere. It is occupied by the olfactory tract and bulb, and it cuts off a narrow strip of the orbital surface close to the medial border, which receives the name of **gyrus rectus**.

The **orbital sulcus** is a composite furrow which assumes many different forms. It consists essentially of a U-shaped furrow, the convexity of which is directed anteriorly (Fig. 551), and one or two variable branches passing forwards from it.

The conventional manner of subdividing the cortical territory anterior to the sulcus centralis into gyri, which has just been sketched, is apt to convey a misleading idea of the distribution of the anatomical areas of differentiated cortex.

The gyrus centralis anterior together with the major portion of the paracentral lobule and the posterior part of the middle and superior frontal gyri form a natural subdivision of the cortex, which Brodmann calls the **regio præcentralis.** It is composed of a series of areas of different structure, which may be grouped as the area **præcentralis posterior** (the true motor area) the **area præcentralis intermedius**, and the **area præcentralis anterior** (Fig. 562). Most of the motor area is hidden in the sulcus centralis, but towards the supero-medial margin of the hemisphere a considerable area emerges upon the surface of both the gyrus centralis anterior and the paracentral lobule.

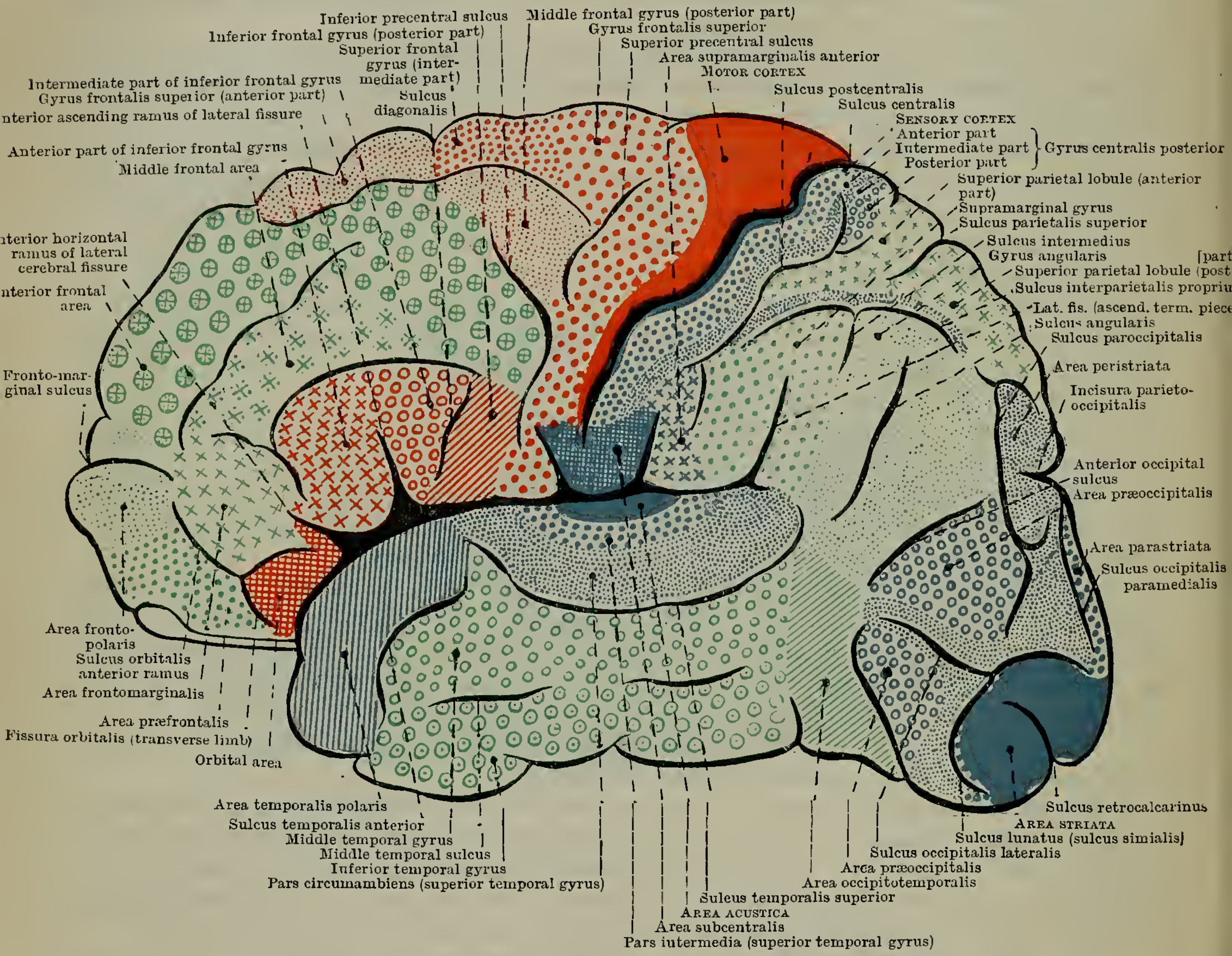
Inferior precentral sulcus
Inferior frontal gyrus (posterior part)
Superior frontal gyrus (intermediate part)
Intermediate part of inferior frontal gyrus
Gyrus frontalis superior (anterior part)
nterior ascending ramus of lateral fissure
Sulcus diagonalis
Anterior part of inferior frontal gyrus
Middle frontal area
Middle frontal gyrus (posterior part)
Gyrus frontalis superior
Superior precentral sulcus
Area supramarginalis anterior
MOTOR CORTEX
Sulcus postcentralis
Sulcus centralis
SENSORY CORTEX
Anterior part
Intermediate part
Posterior part
Gyrus centralis posterior
Superior parietal lobule (anterior part)
Supramarginal gyrus
Sulcus parietalis superior
Sulcus intermedius
Gyrus angularis
Superior parietal lobule (post [part
Sulcus interparietalis propriu
Lat. fis. (ascend. term. piece
Sulcus angularis
Sulcus paroccipitalis
Area peristriata
Incisura parieto-occipitalis
Anterior occipital sulcus
Area præoccipitalis
Area parastriata
Sulcus occipitalis paramedialis
iterior horizontal ramus of lateral cerebral fissure
nterior frontal area
Fronto-marginal sulcus
Area frontopolaris
Sulcus orbitalis anterior ramus
Area frontomarginalis
Area præfrontalis
Fissura orbitalis (transverse limb)
Orbital area
Area temporalis polaris
Sulcus temporalis anterior
Middle temporal gyrus
Middle temporal sulcus
Inferior temporal gyrus
Pars circumambiens (superior temporal gyrus)
Sulcus temporalis superior
AREA ACUSTICA
Area subcentralis
Pars intermedia (superior temporal gyrus)
Area occipitotemporalis
Area præoccipitalis
Sulcus occipitalis lateralis
Sulcus lunatus (sulcus simialis)
AREA STRIATA
Sulcus retrocalcarinus

FIG. 562.—AREAS ON LATERAL ASPECT OF LEFT CEREBRAL HEMISPHERE.

The superior, middle, and inferior frontal sulci are not labelled. The middle is in the midst of the green area, the superior and inferior respectively at its superior and inferior boundaries.

Brodmann calls the rest of the frontal territory the **regio frontalis**; but in the colour scheme adopted in Figs. 562, 557, and 552 the inferior frontal gyrus and the orbital area posterior to the orbital sulcus have been associated with the "precentral" rather than the "frontal" regions.

WEIGHT OF THE BRAIN.

The average weight of the adult male brain may be said to be about 1360 grammes. The female brain weighs rather less, but this is to be expected from the smaller bulk of the female body. Probably the relative weight of the brain in the two sexes is very much the same. The variations met with in brain-weight are very great, but it is doubtful if normal intellectual functions could be carried on in a brain which weighs less than 960 grammes. In microcephalic idiots brains of extremely small size are met with.

THE MENINGES OF THE ENCEPHALON AND MEDULLA SPINALIS.

The brain and spinal medulla are enclosed within three membranes, which are termed the meninges or meningeal membranes. From without inwards these are: (1) the dura mater, (2) the arachnoid, and (3) the pia mater. The space between the dura mater and the arachnoid receives the name of subdural space, while the much more roomy interval between the arachnoid and the pia mater is called the subarachnoid space.

Dura Mater.

The dura mater is a dense and thick fibrous membrane which possesses a very considerable degree of strength. Its arrangement within the cranial cavity is so different from that within the vertebral canal that it is customary to speak of it as consisting of two parts, viz., a cranial and a vertebral, although in adopting this subdivision it must be clearly understood that both portions are continuous with each other at the foramen magnum.

Dura Mater Encephali.—The cranial dura mater is adherent to the inner surface of the cranial wall, and performs a double office. It serves as an internal periosteum for the bones which it lines and it constitutes an envelope for the brain. Its inner surface, which bounds the subdural space, is smooth and glistening, and is covered with a layer of endothelial cells. The outer surface, when separated from the cranial wall, is rough, this being due to numerous fine fibrous processes and blood-vessels which pass between it and the bones. Its degree of adhesion to the cranial wall differs considerably in different regions. To the vault of the cranium, except along the lines of the sutures, the connexion is by no means strong, and in the intervals between the fibrous processes which pass into the bone there are small lymph spaces (epidural spaces) where the outer surface of the membrane is covered by endothelial cells. So long as the sutures are open the dura mater is connected with the periosteum on the exterior of the skull, along the sutural lines, by a thin layer of fibrous tissue which intervenes between the bony margins. Around the foramen magnum, and on the floor of the cranium, the dura mater is very firmly adherent to the bone. This is more particularly marked in the case of the projecting parts of the cranial floor, as, for example, the petrous portions of the temporal bones, the clinoid processes, and so on. This firm adhesion in these regions is still further strengthened because the nerves, as they leave the cranium through the various foramina, are followed by sheaths of the fibrous dura mater. Outside the cranium these prolongations of the membrane blend with the fibrous sheaths of the nerves, and likewise become connected with the periosteum on the exterior of the skull. In the child, during the growth of the cranial bones, and also in old age, the dura mater is more adherent to the cranial wall than during the intermediate portion of life.

The cranial dura mater is composed of two layers intimately connected with each other, but yet capable of being demonstrated in most regions of the cranium. Along certain lines these two layers separate from each other so as to form channels lined with endothelium. These channels are the **venous blood-sinuses** which receive the blood from veins which come from various parts of the brain. They are described in the section dealing with the Vascular System.

Strong fibrous partitions or septa are given off along certain lines from the deep surface of the dura mater. These project into the cranial cavity, and subdivide it partially into compartments which all freely communicate with each other, and each of which contains a definite subdivision of the brain. These septa are: (1) the falx cerebri; (2) the tentorium cerebelli; (3) the falx cerebelli; and (4) the diaphragma sellæ.

The **falx cerebri** is a sickle-shaped partition which descends in the great longitudinal fissure between the two hemispheres of the cerebrum. In front it is narrow, and attached to the crista galli of the ethmoid bone. As it is followed backwards it increases in breadth, and posteriorly it is attached, along the median plane, to the upper surface of the tentorium. The anterior narrow part of the falx is frequently cribriform, and is sometimes perforated by apertures to such an extent that it almost resembles lace-work. Along each border it splits into two layers, so as to enclose a blood-sinus. Along its superior convex attached border runs the *superior sagittal sinus*; along its concave free border sometimes courses the much smaller *inferior sagittal sinus*; whilst along its attachment to the tentorium is enclosed the *straight sinus*.

The **tentorium cerebelli** is a large crescentic partition of dura mater, which forms a membranous tent-like roof for the posterior cranial fossa, and thus intervenes between the posterior portions of the cerebral hemispheres and the cerebellum. It is accurately applied to the superior surface of the cerebellum. Thus, its highest point is in front and in the median plane, and from this it slopes downwards towards its attached border. It is kept at a high degree of tension, and this depends on the integrity of the falx cerebri, which is attached to its superior aspect in the median plane.

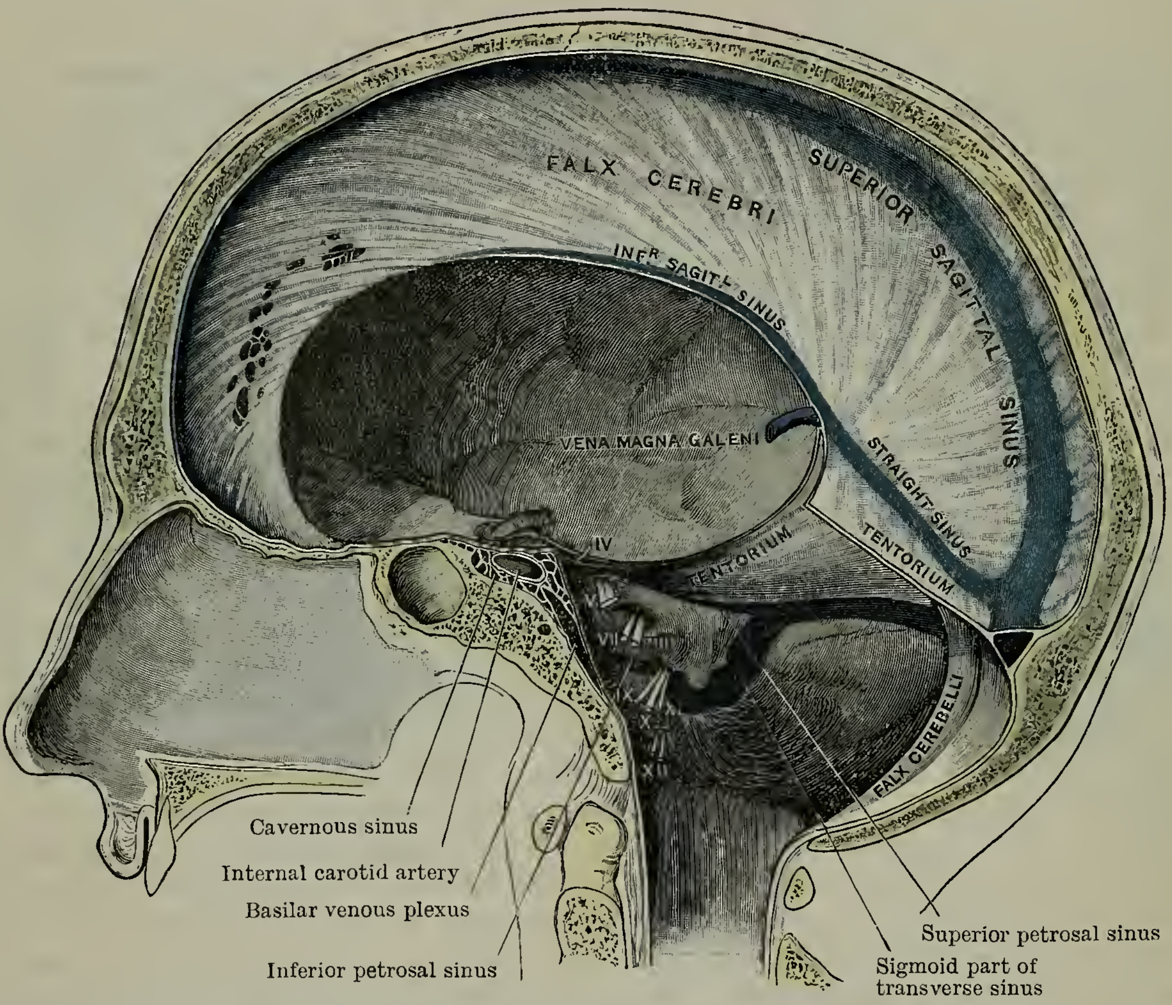

FIG. 563.—SAGITTAL SECTION THROUGH THE SKULL, A LITTLE TO THE LEFT OF THE MEDIAN PLANE to show the arrangement of the dura mater.

The cerebral nerves are indicated by numerals.

The *posterior border* of the tentorium is convex, and is attached to the horizontal ridge which marks the deep surface of the occipital bone. Beyond this, on each side, it is fixed to the postero-inferior angle of the parietal bone, and then forwards and medially along the superior border of the petrous portion of the temporal bone. From the internal occipital protuberance to the postero-inferior angle of the parietal bone this border encloses the *sinus transversus*, whilst along the superior border of the petrous bone it encloses the *superior petrosal sinus*. The *anterior border* of the tentorium is sharp, free, and concave, and forms with the dorsum sellæ an oval opening shaped posteriorly like a pointed arch. This opening receives the name of the **incisura tentorii**, and within it is placed the mesencephalon, or the stalk of connexion between the parts which lie in the posterior cranial fossa and the cerebrum. Beyond the apex of the petrous part of the temporal bone the two margins of the tentorium cross each other like the limbs of the letter X; the free margin is continued forwards, to be attached to the anterior clinoid process, whilst the attached border proceeds medially, to be fixed to the posterior clinoid process.

The **falx cerebelli** is a small, sickle-shaped process of dura mater placed below the tentorium, which projects forwards in the median plane from the internal occipital crest. It occupies the notch which separates the two hemispheres of the cerebellum posteriorly. Inferiorly it bifurcates into two small diverging ridges which gradually fade away as they are traced forwards on each side of the foramen magnum.

The **diaphragma sellæ** is a small circular fold of dura mater which forms a roof for the fossa hypophyseos. A small opening is left in its centre for the transmission of the infundibulum.

Dura Mater Spinalis.—In the vertebral canal the dura mater forms a tube which encloses the spinal medulla, and which extends from the foramen magnum above to the level of the second or third piece of the sacrum below. It is very loosely applied to the spinal medulla and the nerve-roots which form the cauda equina; in other words, it is very capacious in comparison with the volume of its contents. Moreover, its calibre is not uniform. In the cervical and lumbar regions it is considerably wider than in the thoracic region, whilst in the sacral canal it rapidly contracts, and finally ends by blending with the filum terminale externum, the chief bulk of which it forms. At the superior end of the vertebral canal the spinal dura mater is firmly fixed to the third cervical vertebra, to the epistropheus vertebra, and around the margin of the foramen magnum. In the sacral canal the filum terminale externum, with which it blends, extends downwards to the back of the coccyx, to the periosteum of which it is fixed. The inferior end of the tube is thus securely anchored and held in its place.

Within the cranial cavity the dura mater is closely adherent to the bones, and forms for them an internal periosteum. As it is followed into the vertebral canal its two constituent layers separate. The inner layer is carried downwards as the long cylindrical tube which encloses the spinal medulla. The outer layer, which is much thinner, becomes continuous behind and on each side of the foramen magnum with the periosteum on the exterior of the cranium, whilst in front it is prolonged downwards into the vertebral canal in connexion with the periosteum and ligaments on the anterior wall of the canal. The spinal dura mater, therefore, corresponds to the inner layer of the cranial dura mater, and to it alone. It is separated from the walls of the vertebral canal by an interval, the **cavum epidurale**, which is occupied by soft fat and a plexus of thin-walled veins. In connexion with the spinal dura mater there are no blood-sinuses such as are present in the cranial cavity, but it should be noted that the veins in the epidural space, placed as they are between the periosteum of the vertebral canal and tube of dura mater, occupy the same morphological plane as the cranial blood-sinuses. Another feature which serves to distinguish the spinal dura mater from the cranial dura mater consists in the fact that it gives off from its deep surface no partitions or septa.

The cylindrical tube of spinal dura mater does not lie quite free within the vertebral canal. Its attachments, however, are of such a character that they in no way interfere with the free movement of the vertebral column. On each side the spinal nerve-roots, as they pierce the dura mater, carry with them into the intervertebral foramina tubular sheaths of the membrane, whilst in front loose fibrous prolongations—more numerous above and below than in the thoracic region—connect the tube of dura mater to the posterior longitudinal ligament of the vertebral column. No connexion of any kind exists between the dura mater and the posterior wall of the vertebral canal.

When the interior of the tube of spinal dura mater is inspected, the series of apertures of exit for the roots of the spinal nerves is seen. These are ranged in pairs opposite each intervertebral foramen.

Viewed from the inside of the tube of dura mater, each of the two roots of a spinal nerve is seen to carry with it a special and distinct sheath. When examined on the outside, however, the appearance is such that one might be led to conclude that both roots are enveloped in one sheath of dura mater. This is due to the fact that the two sheaths are firmly held together by intervening connective tissue. The two tubular sheaths remain distinct as far as the ganglion on the posterior root, and then blend with each other.

Cavum Subdurale.—The dura mater and the arachnoid are closely applied to each other, and the capillary interval between them is termed the **subdural space.** It contains a minute quantity of fluid, which is just sufficient in amount to moisten the opposed surfaces of the two bounding membranes.

The subdural space in no way communicates with the subarachnoid space. The fluid which it contains is led into the venous blood-sinuses around the arachnoideal granulations (O.T. Pacchionian bodies), and thus gains exit. The subdural space is carried outwards for a very short distance on the various nerves which are connected with the brain and the spinal medulla, and it has a free communication with the lymph-paths present in these nerves. In the case of the optic nerve the sheath of dura mater is carried along its whole length, and with it the subdural space is likewise prolonged to the back of the eyeball.

ARACHNOIDEA.

The **arachnoid** is a very thin membrane, remarkable for its delicacy and transparency, which envelops both the brain and the spinal medulla between the dura mater and the pia mater. The cranial part of the arachnoid or the **arachnoidea encephali**, except in the case of the longitudinal and the lateral fissures, does not dip into the sulci on the surface of the brain. In this respect it differs from the pia mater. It bridges over the inequalities on the surface of the brain. Consequently, on the basal aspect of the encephalon it is spread out in the form of a very distinct sheet over the medulla oblongata, the pons, and the hollow which lies in front of the pons, and in certain of these regions it is separated from the brain-surface by wide intervals.

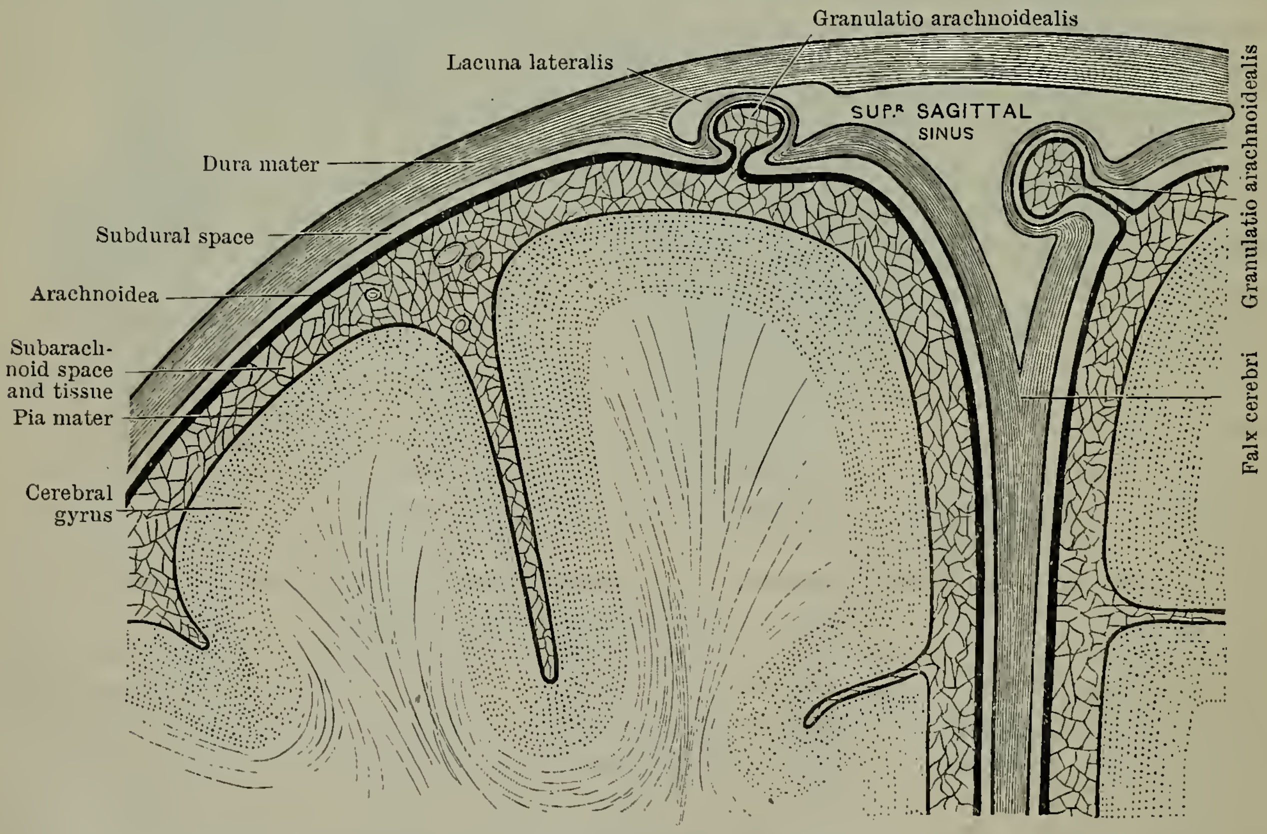

FIG. 564.—DIAGRAM to show the relations of the membranes of the brain to the cranial wall and the cerebral gyri, and also of the arachnoideal granulations to the superior sagittal sinus and the lateral lacunæ.

The spinal part of the arachnoid or **arachnoidea spinalis**, which is directly continuous with the cranial arachnoidea, forms a loose wide investment for the spinal medulla. This arachnoideal sac is most capacious towards its inferior part, where it envelopes the inferior end of the spinal medulla and the collection of long nerve-roots which constitute the cauda equina.

As the nerves, both from the brain and the spinal medulla, pass outwards they receive an investment from the arachnoid, which runs for a short distance upon them and then comes to an end.

Cavum Subarachnoideale.—The interval between the arachnoidea and the pia mater receives the name of the **subarachnoid space.** It contains the cerebro-spinal fluid, and communicates freely, through certain well-defined apertures, with the ventricular cavities in the interior of the brain (aperturæ ventriculi quarti).

Within the cranium the subarachnoid space is broken up by a meshwork of fine filaments and trabeculæ, which connects the two bounding membranes (viz., the arachnoidea and the pia mater) in the most intimate manner, and forms a delicate sponge-like interlacement between them. Where the arachnoidea passes over the summit of a cerebral gyrus, and is consequently closely applied to the subjacent pia mater, the meshwork is so dense and the trabeculæ so short that it is hardly possible to discriminate between the two membranes. To all intents and purposes they form in these localities one lamina. In the intervals between the rounded margins of adjoining gyri, however, distinct angular spaces exist, where the subarachnoid trabecular tissue can be studied to great advantage. These intervals on the surface of the cerebrum constitute numerous communicating channels which serve for the free passage of the subarachnoid fluid from one part of the brain to another. The larger branches of the arteries and veins of the brain traverse the subarachnoid space; their walls are directly connected with the subarachnoid trabeculæ, and are bathed by subarachnoid fluid.

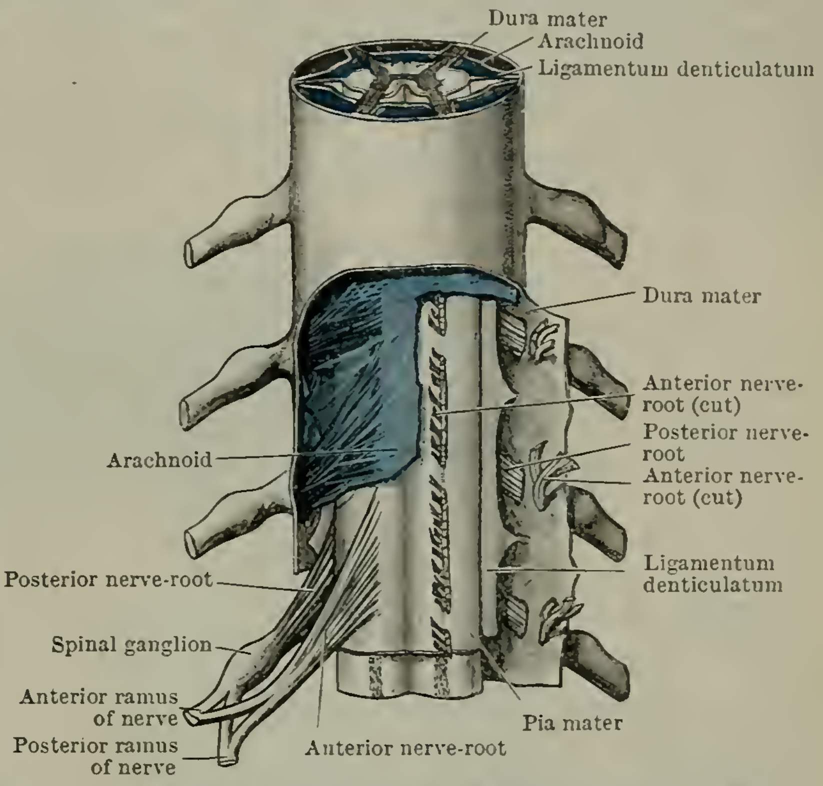

Fig. 565.—Membranes of the Spinal Medulla, and the mode of Origin of the Spinal Nerves.

In certain situations within the cranium the arachnoidea is separated from the pia mater by intervals of considerable width and extent. These expanded portions of the subarachnoid space are termed **cisternæ subarachnoideales.** In these the subarachnoid tissue is much reduced. There is no longer a close meshwork; the trabeculæ connecting the two bounding membranes take the form of long filamentous intersecting threads which traverse the spaces. All the subarachnoid cisterns communicate in the freest manner with each other and also with the narrow channels on the surface of the cerebrum.

Certain of these cisterns require special mention. The largest and most conspicuous is the **cisterna cerebellomedullaris.** It is formed by the arachnoid membrane bridging over the wide interval between the posterior part of the inferior surface of the cerebellum and the medulla oblongata. It is continuous through the foramen magnum with the posterior part of the wide subarachnoid space of the spinal medulla.

The **cisterna pontis** is the continuation upwards on the floor of the cranium of the anterior part of the subarachnoid space of the spinal medulla. In the region of the medulla oblongata it is continuous behind with the cisterna cerebello-medullaris, so that this subdivision of the brain, like the spinal medulla, is surrounded by a wide subarachnoid space.

In front of the pons the arachnoidea bridges across between the projecting temporal lobes, and covers in the deep hollow in this region of the brain. This space is called the **cisterna interpeduncularis**, and within it are placed the large arteries which take part in the formation of the arterial circle (of Willis). Leading out from the interpeduncular cistern there are certain wide subarachnoid channels. Two of these are prolonged into the lateral fissures, and in these are accommodated the middle cerebral arteries. Anteriorly the interpeduncular cistern passes into a space in front of the **optic chiasma (cisterna chiasmatis)**, and from this it is continued into the longitudinal fissure above the corpus callosum. In this subarachnoid passage the anterior cerebral arteries are lodged.

The spinal part of the subarachnoid space is a very wide interval which is partially subdivided into compartments by three incomplete septa. One of these is a median partition called the **septum posterius**, which connects the pia mater covering the posterior aspect of the spinal medulla with the arachnoid. In the upper part of the cervical region the septum posterius is imperfect, and is represented merely by some strands passing between the two membranes; in the inferior part of the cervical region and in the thoracic region it becomes more complete. The other two septa are formed by the **ligamenta denticulata** which spread laterally one from each side of the spinal medulla. These will be described with the pia mater.

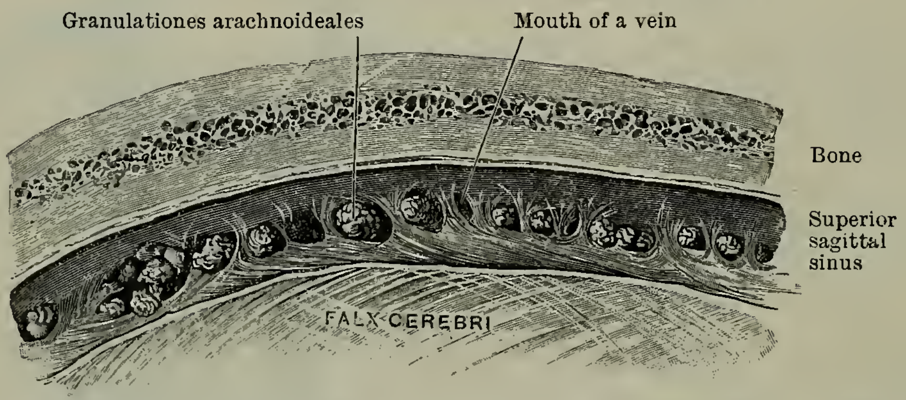

Fig. 566.—Median Section through the Cranial Vault in the Frontal Region, Enlarged. Displays a portion of the superior sagittal sinus and the arachnoideal granulations protruding into it.

Granulationes Arachnoideales.—When the surface of the dura mater is inspected after the removal of the calvaria, a number of small fleshy-looking excrescences, purplish-red in colour, are seen ranged in clusters on each side of the superior sagittal sinus, and when this sinus is opened they are also observed protruding in considerable numbers into its interior. These are the arachnoideal granulations (O.T. Pacchionian bodies), and they are found also, in smaller numbers and distinctly smaller size, in connexion with other blood-sinuses, such as the transverse sinus, the straight sinus, and the cavernous sinus. At first sight they appear to belong to the dura mater, but in reality they are projections from the arachnoid. In the child they are exceedingly small and rudimentary, and it is only as life advances that they become large and conspicuous.

Each granulation is a bulbous protrusion of the arachnoid. It is attached to the arachnoid by a narrow pedicle, and into its interior there is prolonged, through this pedicle, a continuation of the subarachnoid space and its characteristic meshwork. The granulations do not pierce the dura mater. As they push their way into a blood-sinus they carry before them a thin covering continuous with the sinus wall. On each side of the superior sagittal sinus there is a number of irregular spaces in the dura mater which communicate with the sinus either by a small aperture or a narrow channel. These spaces are called the **lacunæ laterales**, and certain of the meningeal veins and some of the diploic veins open into them. Granulations push themselves into the lateral lacunæ from below in such a manner that they receive a complete covering from the layer of dura mater which forms the sinus floor. Nor does the bone escape. As the granulations enlarge they cause absorption of the cranial wall, and small pits are hollowed out on its internal surface for their reception. It must be clearly understood, however, that in such cases the granulation is separated from the bone by the following: (1) A continuation round the granulation of the subdural space; (2) the thinned floor of the lateral lacuna; (3) the lumen of the sinus; and (4) the greatly thinned upper wall of the sinus.

The granulations have a special function to perform. Through them fluid can pass from the subarachnoid space into the venous sinuses with which they stand in connexion. Whenever the pressure of blood in the sinuses is lower than that of the fluid in the subarachnoid space and the ventricles of the brain, the cerebrospinal fluid filters through the granulations into the blood-sinuses. This is not the only way that subarachnoid fluid may obtain exit. The subarachnoid space is carried outwards for a short distance on the nerves in connexion with their arachnoideal sheaths, and communicates with the lymph channels of the nerves. This connexion is more complete in the case of the olfactory, the optic, and the acoustic nerves than in other nerves. A very free communication is said to exist between the subarachnoid space and the lymph vessels of the nasal mucous membrane.

THE PIA MATER.

The pia mater forms the immediate investment of the brain and spinal medulla. It is a delicate and very vascular membrane.

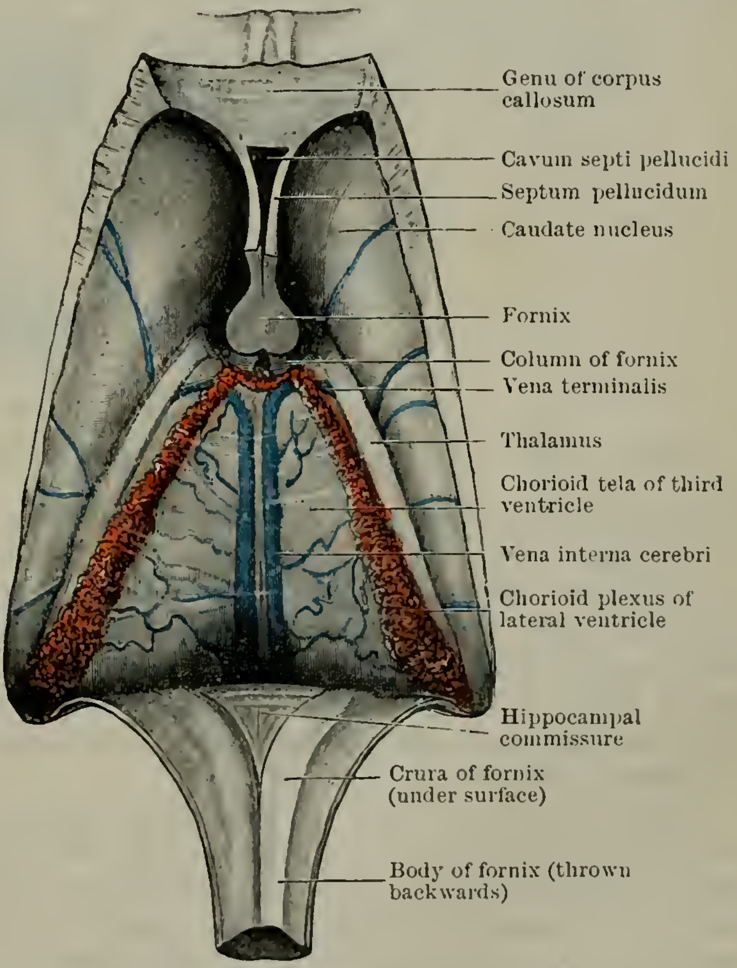

FIG. 567.—DISSECTION TO SHOW THE CHORIOID TELA OF THE THIRD VENTRICLE, AND THE PARTS IN IMMEDIATE RELATION TO IT.

Pia Mater Encephali.—The pia mater which covers the brain is finer and more delicate than that which clothes the spinal medulla. It follows closely all the inequalities on the surface of the brain, and in the case of the hemisphere it dips into each sulcus in the form of a fold which lines it completely. On the cerebellum the relation is not so intimate; it is only into the larger fissures that it penetrates in the form of folds.

The larger blood-vessels of the brain lie in the subarachnoid space. The finer twigs ramify in the pia mater before they proceed into the substance of the brain. As they enter they carry with them sheaths derived from the pia mater. When a portion of the membrane is raised from the surface of the encephalon, numerous fine processes are withdrawn from the cerebral surface. These are the blood-vessels with their sheaths, and they give the deep surface of the pia mater a rough and flocculent appearance.

As the pia mater is carried over the inferior part of the roof or posterior wall of the fourth ventricle of the brain it receives the name of the **tela chorioidea ventriculi quarti**, and it is in connexion with this portion of the pia mater that the chorioid plexuses of that cavity are developed. The **tela chorioidea ventriculi tertii** (O.T. **velum interpositum**) is a fold of pia mater which is invaginated into the brain, so that it comes to lie over the third ventricle and to project, in the shape of chorioid plexuses, into the lateral ventricles. This invagination requires special notice.

The **tela chorioidea ventriculi tertii** (O.T. **velum interpositum**) is a double layer or fold of pia mater which intervenes between the body of the fornix, which lies above it, and the epithelial roof of the third ventricle and the two thalami, which lie below it. Between its two layers are blood-vessels, and some subarachnoid trabecular tissue. In shape the chorioid tela of the third ventricle is triangular, and the narrow anterior end or apex reaches forwards as far as the interventricular foramina. The base lies under the splenium of the corpus callosum, and here the two layers of the tela separate and become continuous with the investing pia mater on the surface of the brain by passing out through a cleft called the **transverse fissure.**

Along each margin the tela chorioidea of the third ventricle is bordered by the chorioid plexus of the central part of the lateral ventricle, which projects into the ventricular cavity from under cover of the free margin of the fornix. It should be borne in mind that the epithelial lining of the ventricle gives a complete covering to the chorioid plexus. Posteriorly the chorioid plexus is continuous with the similar structure in the inferior horn of the ventricle, whilst in front it narrows greatly, and becomes continuous across the median plane with the corresponding plexus of the opposite side, behind the epithelial layer which lines the interventricular foramen. From this median junction two much smaller chorioid plexuses run backwards on the under surface of the tela chorioidea, and project downwards into the third ventricle. These are the chorioid plexuses of the third ventricle.

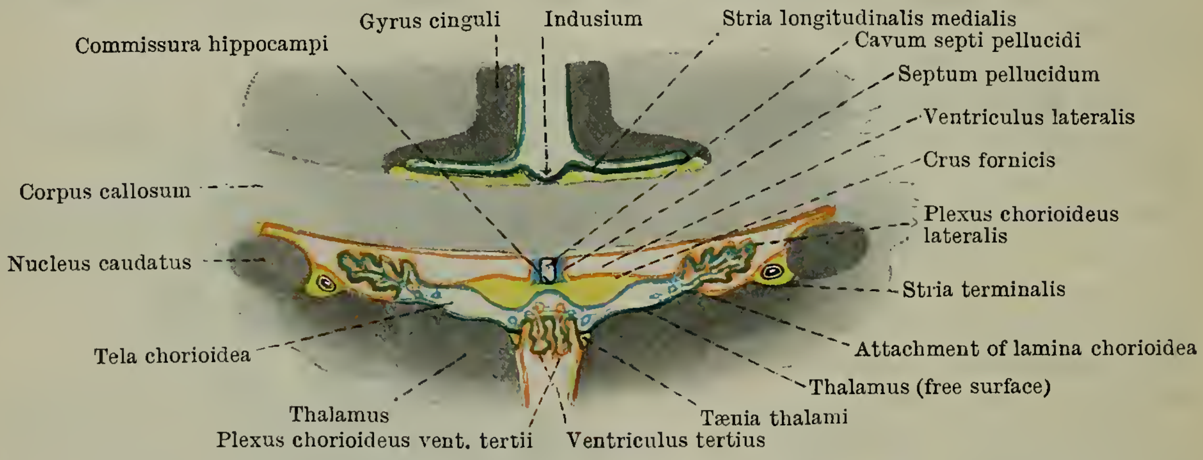

FIG. 568.—DIAGRAM OF A FRONTAL SECTION ACROSS THE CHORIOID TELA OF THE THIRD VENTRICLE.

The most conspicuous blood-vessels in the tela chorioidea are the two internal cerebral veins, which run backwards, one on each side of the median plane. In front, each is formed at the apex of the fold by the union of the vena terminalis and a large vein issuing from the chorioid plexus; behind, they unite to form the **vena cerebri magna** [**Galeni**], and this pours its blood into the anterior end of the straight sinus (Fig. 567, p. 671).

The continuous cleft in the brain through which the chorioid tela of the third ventricle and the chorioid plexuses of the inferior horns of the two lateral ventricles are introduced into the interior of the brain is sometimes called the **transverse fissure.** It consists of a superior intermediate part and two lateral parts. The former passes forwards between the corpus callosum and the fornix above and the roof of the third ventricle and the thalami below. It is limited on each side by the epithelial covering of the chorioid plexuses, which shuts out these structures from the cavity of the lateral ventricles. The lateral part is the **chorioidal fissure.** This is continuous with the intermediate part, and has already been described in connexion with the inferior horn of the lateral ventricle (p. 634).

Pia Mater Spinalis.—The pia mater of the spinal medulla is thicker and denser than that of the brain. This is largely due to the addition of an outside fibrous layer, in which the fibres run chiefly in the longitudinal direction. The pia mater is very firmly adherent to the surface of the spinal medulla, and in front it sends a fold into the anterior-median fissure of the spinal medulla. The posterior median septum is likewise firmly attached to its deep surface. In front of the anterior-median fissure of the spinal medulla the pia mater is thickened in the form of a longitudinal glistening band, termed the **linea splendens**, which runs along the whole length of the spinal medulla, and blends with the filum terminale below. The blood-vessels of the spinal medulla lie between the two layers of the pia mater.

The nerves which leave both the brain and spinal medulla receive closely applied sheaths from the pia mater. These blend with the connective-tissue sheaths of the nerves.

The **ligamentum denticulatum** is a strong fibrous band which stretches out like a wing from the pia mater on each side of the spinal medulla, so as to connect the pia mater with the dura mater. The pial or medial attachment of the ligament extends in a continuous line between the anterior and posterior nerve-roots, from the level of the foramen magnum above to the level of the first lumbar vertebra below. Its lateral margin is serrated or denticulated, and for the most part free. From twenty to twenty-two denticulations may be recognised. They occur in the intervals between the spinal nerves, and, pushing the arachnoid before them, they are attached by their pointed ends to the inner surface of the dura mater. The ligamenta denticulata partially subdivide the wide subarachnoid space in the vertebral canal into an anterior and a posterior compartment. The anterior nerve-roots traverse the anterior compartment, whilst the posterior nerve-roots traverse the posterior compartment. Further, the posterior compartment is imperfectly subdivided into a right and a left half by the septum posterius.

By means of the ligamenta denticulata the spinal medulla is suspended in the middle of the tube of dura mater.

II.—THE PERIPHERAL NERVOUS SYSTEM.

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The Peripheral Nervous System, as distinct from the Central Nervous System comprised by the brain and spinal medulla, is broadly divisible into three series of fibres. (I.) The **cerebral nerves**, which are attached to the brain and pass through openings in the base of the skull, to be distributed for the most part to the head region. (II.) The **spinal nerves**, which are attached to the spinal medulla, pass through the intervertebral foramina, and innervate the trunk and limbs, that is, the somatic area of the body (these two sets of fibres being sometimes grouped together as the cerebro-spinal system of nerves). (III.) The **sympathetic system** of nerves and ganglia, which is connected chiefly with the spinal nerves and also, though less obviously, with the cerebral ones. It lies for the greater part of its bulk in the body cavity, and governs the visceral or splanchnic area of the body. No one of these three groups can be considered wholly apart from the others, since, although presenting certain differences in structure, arrangement, and distribution, they are not independent or separate systems; the subdivision is, however, the most convenient one for descriptive purposes.

Number.	Name.	Function.	Superficial Attachment to Brain.
I.	**Olfactory**	Smell	Olfactory bulb.
II.	**Optic**	Sight	Optic chiasma.
III.	**Oculo-motor**	Motor to most of the muscles of eyeball and orbit	Cerebral peduncle.
IV.	**Trochlear**	Motor to superior oblique muscle of eyeball	Anterior medullary velum.
V.	**Trigeminal**	Sensory to face, tongue, and teeth; motor to muscles of mastication	Pons.
VI.	**Abducent**	Motor to lateral rectus muscle of eyeball	Junction of pons and medulla oblongata.
VII.	**Facial**	Motor to muscles of scalp and face, sensory to tongue	Medulla oblongata.
VIII.	**Acoustic**	Hearing and equilibrium	Medulla oblongata.
IX.	**Glossopharyngeal**	Sensory to tongue and pharynx; motor to stylo-pharyngeus	Medulla oblongata.
X.	**Vagus**	Sensory to pharynx, œsophagus, and stomach, and respiratory organs	Medulla oblongata.
XI.	**Accessory**	(*a*) **Accessory to vagus.**—Motor to muscles of palate, pharynx, œsophagus, stomach and intestines, and respiratory organs; inhibitory for the heart	Medulla oblongata.
		(*b*) **Spinal part.**—Motor to trapezius and sterno-mastoid	Spinal medulla.
XII.	**Hypoglossal**	Motor to muscles of the tongue	Medulla oblongata.

I. THE CEREBRAL NERVES.

The cerebral nerves are twelve pairs of symmetrically arranged nerves which are attached to the brain, leave the skull through foramina at its base, and are generally distributed to the various structures of the head. The site where the nerve fibres composing it enter or leave the brain surface is usually termed the **superficial origin** of the nerve, and the more deeply placed group of cells from which the fibres arise or about which they terminate is called the **nucleus of origin** or of **reception** respectively, and forms the **deep origin** of the nerve. It is also customary to trace the course of a nerve from its superficial origin to the periphery irrespective of the actual direction of the impulses carried by it. In this chapter the cerebral nerves are described from their superficial origins onwards; their deep origins and intra-cerebral connexions are dealt with in the section which treats of the Brain (pp. 590-609), and certain general points in connexion with them are also touched upon in the chapter introductory to the Nervous System (p. 498 *et seq.*).

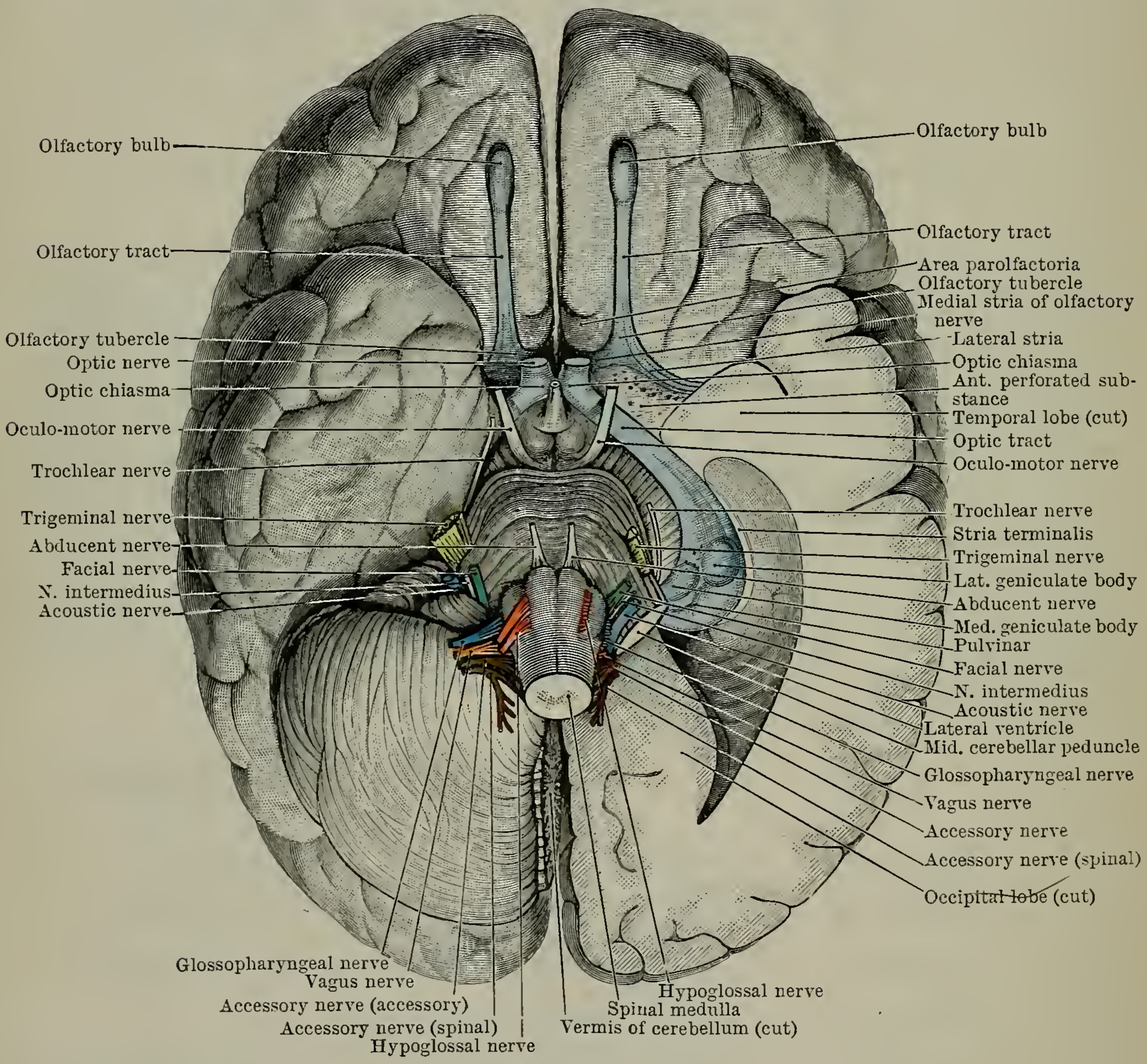


FIG. 569.—VIEW OF THE INFERIOR SURFACE OF THE BRAIN, with the lower portion of the temporal and occipital lobes, and the cerebellum on the left side removed, to show the origins of the cerebral nerves.

Classification of the Cerebral Nerves.—Recent studies of the central connexions and peripheral distribution of the cerebral nerves would point to those designated as the fifth, seventh, and eighth under the customary terminology, being each really divisible, both anatomically and physiologically, into two components, which are given separate names. None of the cerebral nerves corresponds closely to a typical spinal nerve with motor and sensory roots. The fifth nerve, sometimes so compared, might well be considered as composed of a sensory nerve, the trigeminal, allied to a separate motor nerve, the *masticator* (nervus masticatorius or motor root of the fifth) which accompanies for part of its course the mandibular division only of the former. Similarly, the usually designated seventh nerve can be resolved into two components, the facial proper and the *glossopalatine* (nervus intermedius or intermediate part of the seventh), the latter including the genicular ganglion and chorda tympani nerve (see note on p. 695). The separation of the eighth nerve into two entirely different functional elements, the cochlear and vestibular divisions, though both are sensory, is more obvious. Such a re-classification would give fifteen pairs of nerves instead of the customary twelve.

NERVI OLFACTORII.

In the older accounts, the **first** or **olfactory nerve** is described as consisting of several parts: (1) a series of fine **nerves**, which arise from (2) the **olfactory bulb**. This again is connected by (3) the **olfactory tract** with the brain, to which it is attached by (4) two **striæ** or roots (Fig. 569).

The anatomy of the olfactory bulb, the olfactory tract and its roots is described on pp. 621 to 624; and the histology of the cells on p. 621.

The **olfactory nerve** consists of about twenty separate filaments which arise in the olfactory mucous membrane and terminate in the olfactory bulb. The fibres are non-medullated. After their origins from the olfactory cells of the olfactory region on the upper third of the nasal septum and nearly the whole of the opposed superior nasal concha (Figs. 146, 147), the nerve fibres form fine plexuses from which the terminal filaments pass through the cribriform plates of the ethmoid on their way to the olfactory bulb. Each filament has a sheath of dura mater.

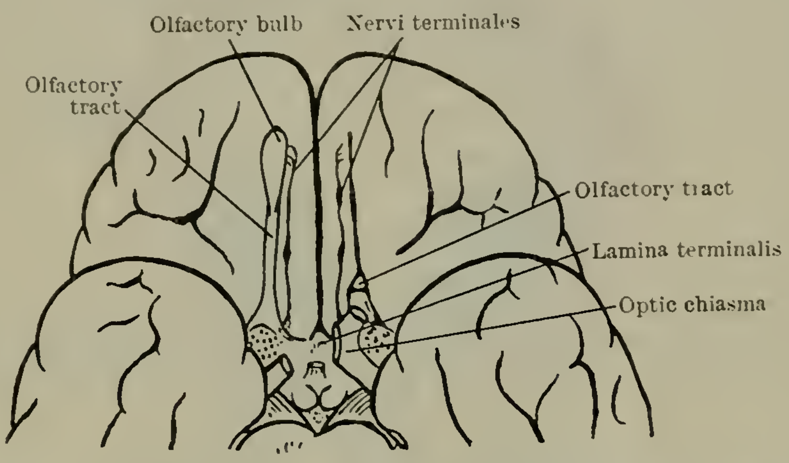


FIG. 570.—DIAGRAM OF PART OF THE VENTRAL SURFACE OF AN ADULT HUMAN BRAIN to show the position of the central parts of the Nervi Terminales and their relations to the Olfactory Tracts and Gyri Recti. (After Brookover).

The olfactory bulb and part of the tract have been removed on the left side, and the right optic nerve and the greater part of the optic chiasma have been cut away to expose the lamina terminalis.

Two other pairs of nerves have been found related to the olfactory system in lower vertebrates and in mammals with a well-developed sense of smell. Both are closely related to the olfactory nerve itself throughout its course. These are: (1) the *vomero-nasal nerve*, which supplies the vomero-nasal (Jacobson's) organ, and in the domestic animals joins the olfactory nerve itself to terminate in an accessory olfactory bulb; in man Jacobson's organ is rudimentary after birth, and the nerve is absent; (2) the terminal nerve.

The **terminal nerve** (*nervus terminalis*) has been found present in all groups of vertebrates, in the human embryo, and recently in the human adult. It is a very fine plexiform nerve consisting of non-medullated fibres with small groups of ganglion cells, and may be discovered in the cranial cavity as two or three strands in the pia mater covering the gyrus rectus along the medial side of the olfactory tract. Peripherally (anteriorly) its fibres join the olfactory nerve filaments and have a similar distribution to the nasal mucosa; in some mammals they have been traced to end in the walls of the anterior cerebral artery and in the vascular plexus of the nasal septum up to the region of the vomero-nasal organ. Centrally, the nerve strands pass over the medial olfactory stria towards the anterior perforated substance. The evidence points to the conclusion that the nerve is functional in mammals, and, from the appearance of its fibres and ganglia, among other features, it may eventually be recognised as related in part at least to the sympathetic system rather than as representing a separate nerve (Johnstone, Brookover, Larsell).

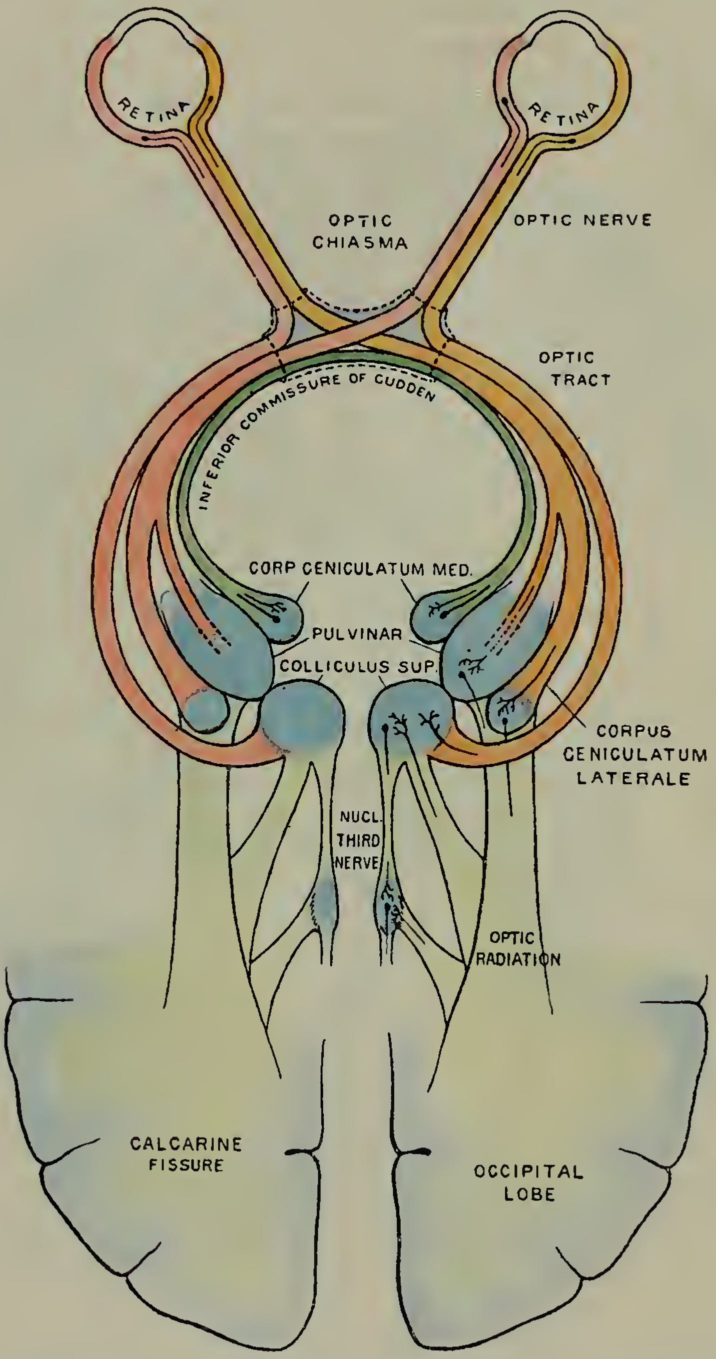


Fig. 571.—Central Connexions of the Optic Nerve and Optic Tracts.

Nervus Opticus.

The **second** or **optic nerve** consists of nerve fibres which spring from the ganglion cells of the retina, and converge to the optic papilla, where they are grouped together to form the optic nerve. The nerve pierces the outer layers of the retina, the chorioid, and the sclera. It pierces the sclera 3 mm. (one-eighth of an inch), to the medial side of the posterior pole of the eyeball, and enters the orbital fat, surrounded by the ciliary vessels and nerves. It then runs backwards and slightly medially towards the apex of the orbit, being crossed by the ophthalmic artery and naso-ciliary nerve, and is pierced on its inferior surface by the central artery of the retina. It is surrounded by sheaths from all three membranes of the brain, that formed by the dura being especially robust, and by prolongations of the subdural and subarachnoid spaces which lie between them. At the apex of the orbit it passes through the annulus tendineus communis of Zinn, from which the four recti muscles of the eyeball arise, to enter the optic foramen of the sphenoid bone. In the foramen it is separated from the sphenoidal air sinus by only a thin plate of bone, and the ophthalmic artery accompanies it on its lateral side. It then enters the middle fossa of the skull and ends in the optic chiasma, which lies at the base of the brain, anterior to the interpeduncular area and between the right and the left anterior perforated substance. The chiasma is in close relation on either side to the internal carotid artery, but lies a little distance superior to the hypophysis cerebri.

From each of the two postero-lateral angles of the optic chiasma an optic tract sweeps round to the back of the thalamus and to the mid-brain, between the pedunculus cerebri and the hippocampal gyrus of the corresponding side, and each tract terminates in connexion with the pulvinar, the lateral geniculate body, the superior brachium, and the medial geniculate body—all of the same side.

When the optic nerve reaches the optic chiasma some of its fibres pass to the optic tract of the same side and some to the optic tract of the opposite side. Therefore, each optic nerve is connected with both sides of the brain. But each optic tract, in addition to some fibres of both optic nerves, contains also fibres passing from the medial geniculate body of one side to the medial geniculate body of the opposite side; these fibres constitute the inferior commissure of Gudden (p. 616).

NERVUS OCULOMOTORIUS.

The **third** or **oculo-motor nerve** supplies the levator palpebræ superioris, and all the ocular muscles, save the lateral rectus and superior oblique. It arises from the brain, in the region of the posterior perforated substance, by several fila radicularia (radicles) emerging from the **oculo-motor sulcus**, on the medial side of the cerebral peduncle, just in front of the pons (Fig. 569). Passing forwards, between, and close to the posterior cerebral and superior cerebellar arteries, then along the lateral aspect of the posterior communicating artery through the cisterna interpeduncularis, the nerve pierces the dura mater beside the posterior clinoid process, in a small triangular space between the free and attached borders of the tentorium cerebelli. Embedded in the dura mater the nerve courses through the lateral wall of the cavernous sinus, above the trochlear nerve, and enters the orbit through the superior orbital fissure and then lies within the *annulus tendineus communis* of Zinn from which the four recti muscles arise. The space within the annulus not occupied by the optic nerve is termed in

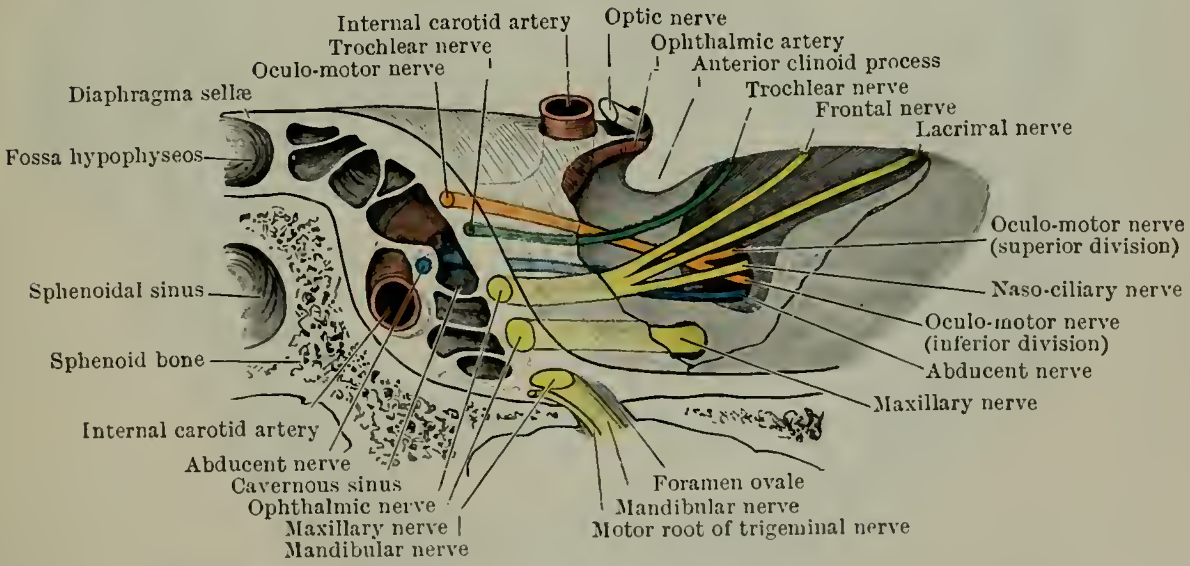


FIG. 572.—RELATIONS OF STRUCTURES IN THE CAVERNOUS SINUS AND SUPERIOR ORBITAL FISSURE.

consequence the **oculo-motor foramen** (Fig. 579, p. 686). At this point of entry into the orbit the nerve divides into upper and lower branches, separated by the naso-ciliary nerve.

Branches.—The **superior branch** of the nerve supplies two muscles of the orbit —the superior rectus and the levator palpebræ superioris.

The **inferior branch** passes forwards, and after giving branches to the medial and inferior recti, ends in the inferior oblique muscle.

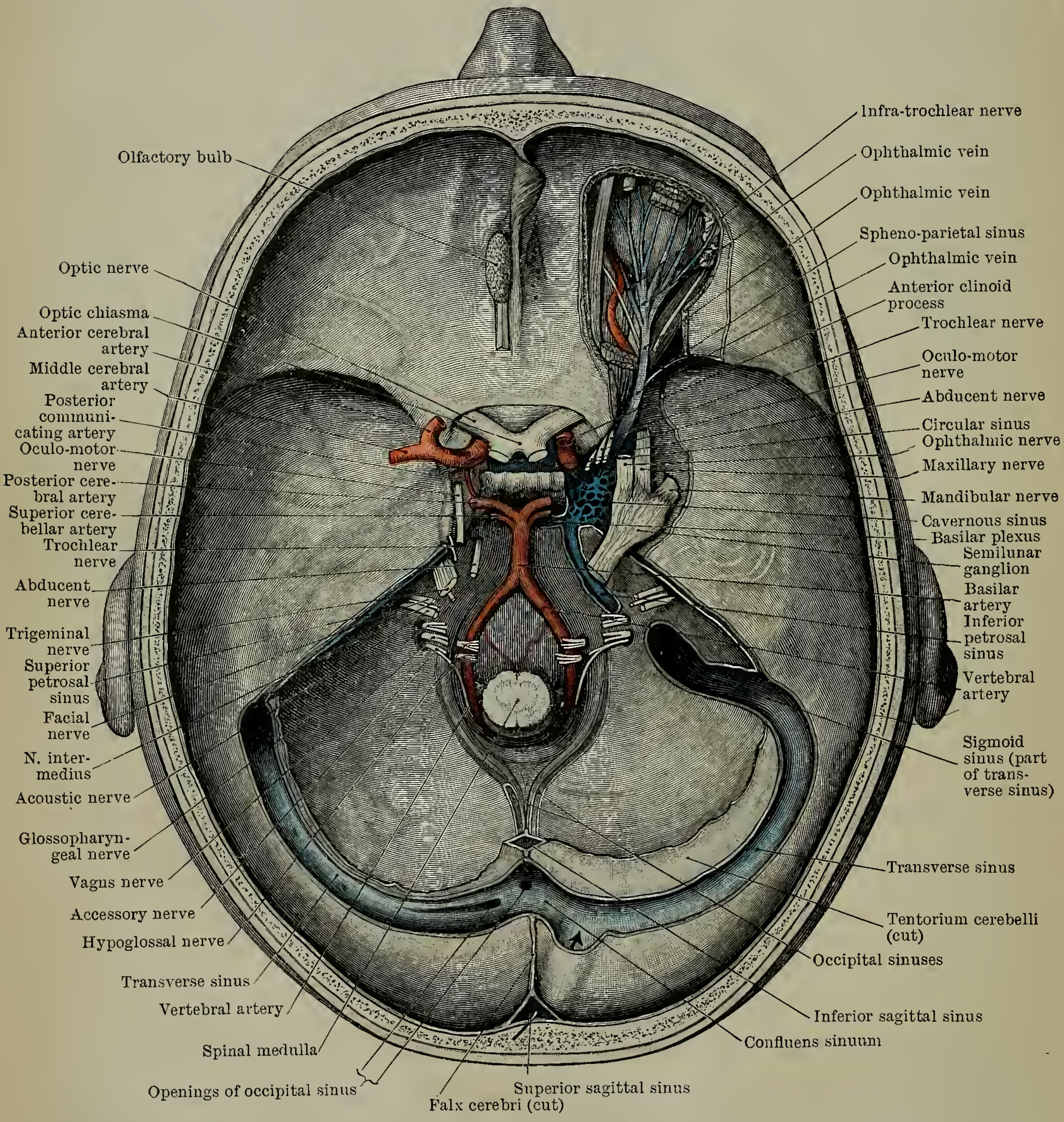


FIG. 573.—THE BASE OF THE SKULL, to show the dura mater, sinuses, arteries, and nerves.

Communications.—1. In the cavernous sinus the oculo-motor nerve is usually stated to receive filaments from the sympathetic cavernous plexus on the internal carotid artery. 2. In the cavernous sinus it also receives a slender sensory communication from the ophthalmic division of the trigeminal nerve. 3. The **short motor root of the ciliary ganglion** passes upwards from the branch of the nerve which supplies the inferior oblique muscle, by means of which the ciliary and sphincter pupillæ muscles of the eyeball are innervated.

NERVUS TROCHLEARIS.

The **fourth** or **trochlear nerve** supplies only the superior oblique muscle of the eyeball. It emerges from the dorsal surface of the mid-brain. It arises at the side of the *frenulum veli* from the anterior end of the anterior medullary velum, just behind the inferior corpora quadrigemina (Fig. 483, p. 577). It is extremely slender, and of considerable length. Passing round the cerebral peduncle, the nerve appears at the base of the brain behind the optic tract, in the interval between the cerebral peduncle and the temporal lobe of the brain, and between the superior cerebellar and posterior cerebral arteries. Continued forwards to the base of the skull, it pierces the free border of the tentorium cerebelli, postero-lateral to the oculo-motor nerve, and proceeds forwards, in the lateral wall of the cavernous sinus, to the superior orbital fissure, lying between the oculo-motor nerve and the ophthalmic division of the trigeminal nerve. It enters the orbit above the muscles of the eyeball, turns medially between the levator palpebræ superioris and the periosteum of the orbital roof, and terminates in the orbital (superior) surface of the superior oblique muscle.

Communications.—In the cavernous sinus the nerve receives (1) probably a communicating branch from the cavernous or carotid plexus on the internal carotid artery, and (2) a slender filament from the ophthalmic division of the trigeminal nerve.

NERVUS TRIGEMINUS.

The **fifth** or **trigeminal nerve**, the largest of the cerebral nerves, is the nerve of common sensation to the superficial and deep parts of the face and is motor to the muscles of mastication (see summary of distribution on p. 691).

It arises from the inferior surface of the pons in its lateral part by two roots, a large **sensory root** and a small **motor root** (Fig. 569, p. 676). The two roots proceed forwards in the posterior fossa of the skull, and piercing the dura mater beneath the attachment of the tentorium cerebelli to the superior angle of the petrous part of the temporal bone, enter a cavity in the dura mater (*cavum Meckelii*) over the apex of the petrous bone. The large sensory root gradually conceals the small motor root in its course forwards, and expands beneath the dura mater into a large flattened ganglion—the **semilunar (O.T. Gasserian) ganglion.** This ganglion occupies an impression on the apex of the petrous portion of the temporal bone, and from it three large trunks arise—the **ophthalmic** or first, the **maxillary** or second, and the **mandibular** or third **divisions** of the nerve. The small motor root of the nerve passes forward beneath the ganglion, and is incorporated wholly with the mandibular division of the nerve; on developmental and functional grounds it is sometimes described as a separate nerve, the **masticator** (*nervus masticatorius*).

NERVUS OPHTHALMICUS.

The **ophthalmic nerve** passes forwards to the orbit through the middle fossa of the skull, in the dura mater. It lies in the lateral wall of the cavernous sinus, at a lower level than the trochlear nerve, and reaches the orbit through the superior orbital fissure (Fig. 573).

In the wall of the cavernous sinus the ophthalmic nerve gives off (1) a small recurrent branch to the dura mater (*n. tentorii*), (2) communicating branches to the cavernous plexus of the sympathetic on the internal carotid artery, and (3) small communicating sensory twigs to the trunks of the oculo-motor, trochlear, and abducent nerves.

In the superior orbital fissure the nerve divides into three main branches—lacrimal, frontal, and naso-ciliary (Fig. 579).

N. Lacrimalis.—The **lacrimal nerve** enters the orbit through the lateral angle of the superior orbital fissure, above the orbital muscles. It passes forwards, between the periosteum and the orbital contents, to the anterior part of the orbit, and ends by supplying branches (*a*) to the lacrimal gland, (*b*) to the conjunctiva, and (*c*) to the skin of the lateral commissure of the eye.

The lacrimal nerve *communicates* in the orbit with the zygomatic branch of the maxillary nerve (whereby secretory fibres are conveyed to the lacrimal gland), and on the face, by its terminal branches, with the temporal branches of the facial nerve.

N. Frontalis.—The **frontal nerve** enters the orbital cavity through the superior orbital fissure, courses forwards above the ocular muscles, and divides at a variable point into two branches—a larger supra-orbital and a smaller supra-trochlear nerve.

N. Supraorbitalis.—The **supra-orbital nerve** passes directly forwards, and leaves the orbit, through the supra-orbital groove or foramen, to reach the forehead. It gives off the following secondary branches: (1) the **frontal** branches **(rami frontales)** are distributed to the forehead and scalp, reaching backwards as far as the vertex; (2) small branches supply the upper eyelid; and (3) twigs are distributed to the frontal sinus. On the forehead the supra-orbital nerve communicates with the temporal branches of the facial nerve.

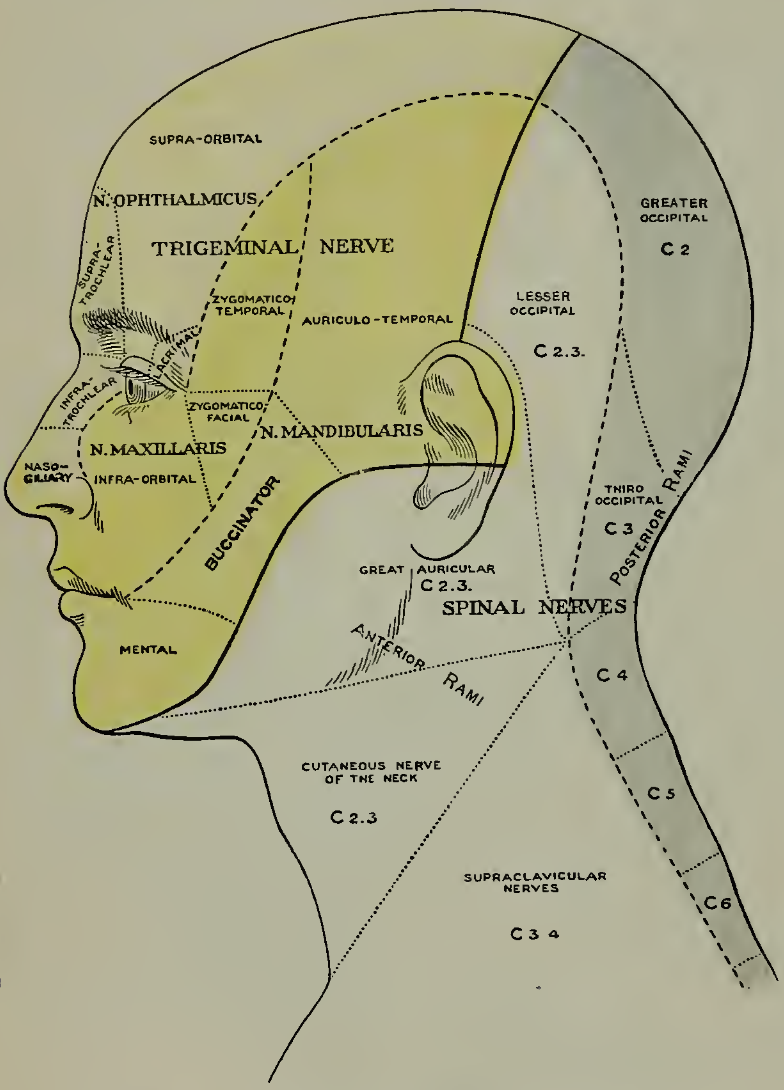


Fig. 574.—Distribution of Sensory Nerves to the Head and Neck.

N. Supratrochlearis.—The **supra-trochlear nerve** courses obliquely forwards and medially, above the tendon of the superior oblique muscle, to reach the medial side of the supra-orbital arch, where it leaves the cavity of the orbit; it is distributed to the skin of the medial part of the forehead, the root of the nose, and the medial commissure of the eye.

It communicates with the infra-trochlear branch of the naso-ciliary nerve, either before or after leaving the orbital cavity.

N. Nasociliaris.—The **naso-ciliary nerve** (O.T. nasal) enters the orbit through the superior orbital fissure, inside the annulus of Zinn, and between the two divisions of the oculo-motor nerve (Fig. 579, p. 686). It crosses the orbital cavity obliquely to reach the anterior ethmoidal foramen, lying in its course below the superior rectus and superior oblique muscles, and above the optic nerve and medial rectus muscle. The nerve is transmitted, under the name of *anterior ethmoidal*, through the anterior ethmoidal foramen into the cranial cavity, where it lies embedded in dura mater on the lamina cribrosa of the ethmoid bone. It enters the nasal cavity through the nasal fissure, and terminates by dividing into medial and lateral branches. The medial division supplies the mucous membrane over the upper and anterior part of the nasal septum. The lateral branch, after supplying collateral offsets to the lateral wall of the nasal cavity, finally appears on the face, as the **external nasal nerve**, between the nasal bone and lateral cartilage, and supplies branches to the skin of the lower part and tip of the nose. The anterior ethmoidal nerve supplies, then, the cartilaginous end of the nose, both internally and externally.

The **branches** of the naso-ciliary nerve may be divided into three sets, arising (*a*) in the orbit, (*b*) in the nose, and (*c*) on the face.

In the orbit the branches are given off in three situations—lateral to, above, and medial to the optic nerve. (*a*) As the nerve lies on the lateral side of the optic nerve, it gives off the **radix longa ganglii ciliaris (long or sensory root of the ciliary ganglion).** (*b*) As it crosses above the optic nerve, **nn. ciliares longi (two long ciliary branches)** arise, and pass forwards alongside the optic nerve to the eyeball. They convey fibres to the dilatator pupillæ muscle of the iris. (*c*) On the medial side of the optic nerve the **n. infratrochlearis (infra-trochlear nerve)** arises, a slender branch which courses forwards below the pulley of the superior oblique muscle to the front of the orbit. It ends on the face by supplying the skin of the root of the nose and the eyelids, and communicates either in the orbit or on the face with the supra-trochlear nerve. On the face it also communicates with zygomatic branches of the facial nerve. A minute *posterior ethmoidal branch* may arise from the nerve near the back of the orbit, and enter the foramen of the same name to be distributed to the sphenoidal sinus and posterior ethmoidal cells.

In the nose the **rami nasales mediales (medial nasal branches)** supply the mucous membrane of the anterior part of the nasal septum; the **rami nasales laterales (lateral nasal branches)** supply the anterior part of the lateral wall of the nasal cavity.

On the face the terminal filaments of the nerve are distributed, as the **ramus nasalis externus (external nasal branch)**, to the skin of the lower half and tip of the nose. The terminal branch communicates with the zygomatic branches of the facial nerve.

Ganglion Ciliare.—The **ciliary (lenticular or ophthalmic) ganglion**, though associated with the naso-ciliary branch of the ophthalmic nerve and with the inferior division of the oculo-motor nerve, is regarded more properly as belonging to the sympathetic system (see p. 692). It is a small reddish ganglion, about the size of a pin's head, placed near the back of the orbit, between the lateral rectus muscle and the optic nerve, and in front of the ophthalmic artery. Its *roots* are three in number: (1) **sensory** or long, derived from the naso-ciliary branch of the ophthalmic nerve; (2) **motor** or short, derived from the inferior division of the oculo-motor nerve; and (3) **sympathetic**, a slender filament from the cavernous plexus on the internal carotid artery, which may exist as an independent root or may be incorporated with the long root from the naso-ciliary nerve. The branches from the ganglion are twelve to fifteen **nn. ciliares breves (short ciliary nerves)**, which pass to the eyeball in two groups above and below the optic nerve. They convey motor fibres (from the third nerve) to the constrictor pupillæ fibres of the iris and the ciliary muscle, sympathetic fibres to the blood-vessels, and they carry sensory fibres from all parts of the eyeball.

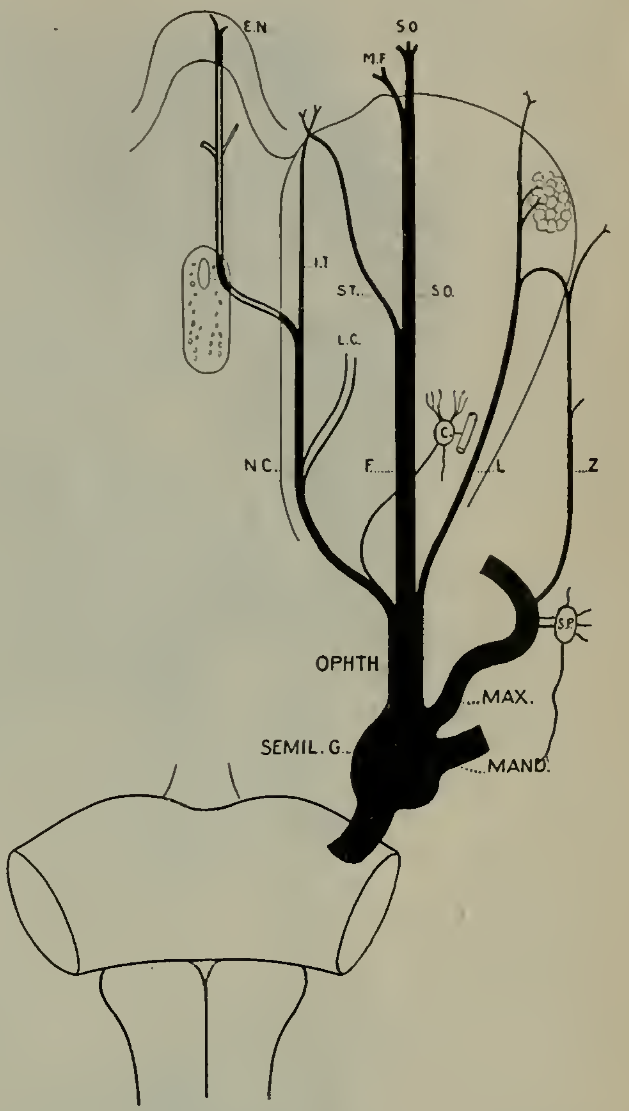


FIG. 575.—SCHEME TO SHOW THE DISTRIBUTION OF THE OPHTHALMIC DIVISION OF THE TRIGEMINAL NERVE.

F., frontal nerve, giving off the supra-trochlear branch (S.T.) and afterwards being known as the supra-orbital (S.O.), which may divide before leaving the orbit into a medial frontal branch (M.F.) and a lateral frontal or supra-orbital proper.
N.C., the naso-ciliary nerve; it is shown to give off the sensory root to the ciliary ganglion (C.), the two long ciliary nerves (L.C.) to the eyeball, and, just before leaving the orbit through the anterior ethmoidal canal, the infra-trochlear nerve (I.T.); the rest of its course up to its termination on the nose as the external nasal nerve (E.N.) illustrates the description given in the text.
L., the lacrimal nerve, the anastomosis of which with the zygomatico-temporal branch of the zygomatic nerve (Z.) is represented.
S.P., the spheno-palatine ganglion.

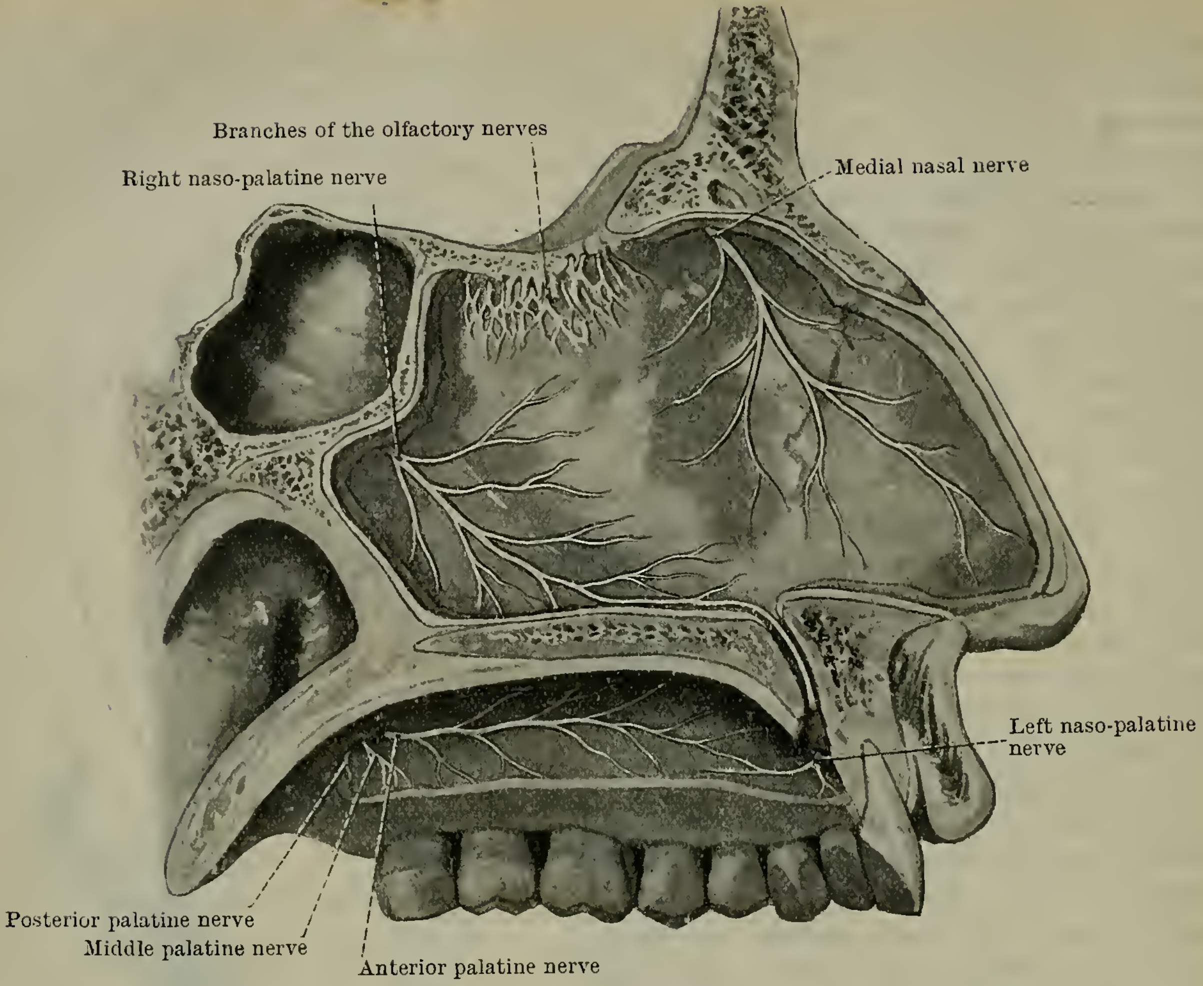


FIG. 576.—INNERVATION OF NASAL SEPTUM AND PALATE.

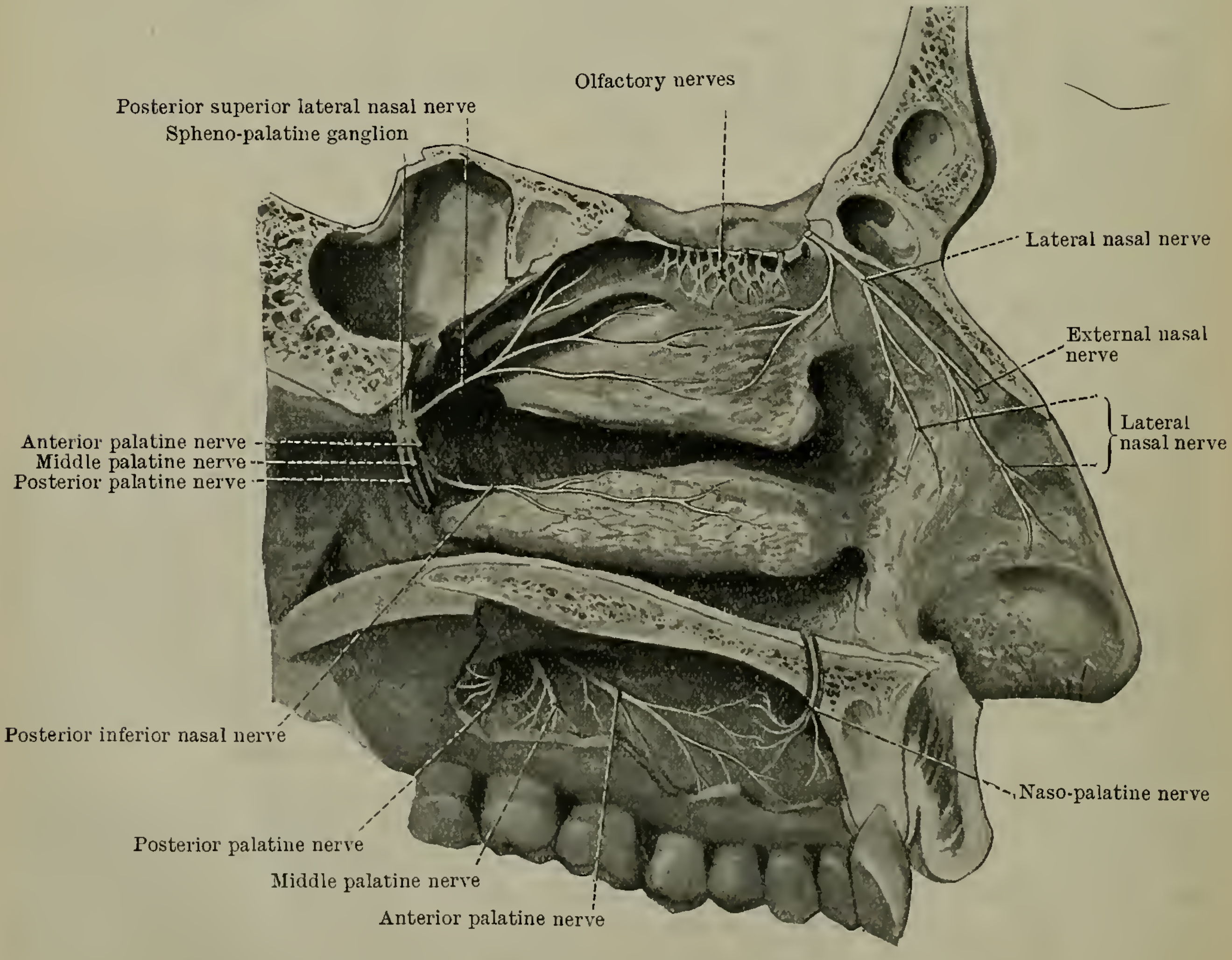


FIG. 577.—INNERVATION OF LATERAL WALL OF NASAL CAVITY AND PALATE.

NERVUS MAXILLARIS.

The Maxillary Nerve.—This large nerve courses forwards from its origin in the semilunar ganglion through the middle fossa of the skull, in the dura mater, and in relation to the lower part of the cavernous sinus (Fig. 573, p. 680). It passes through the foramen rotundum, traverses the pterygo-palatine fossa, and enters the orbit as the infra-orbital nerve, through the inferior orbital fissure. In the orbit it occupies successively the infra-orbital groove and canal, and it finally appears on the face through the infra-orbital foramen (Fig. 581).

The branches and communications of this nerve occur (*a*) in the cavity of the cranium, (*b*) in the pterygo-palatine fossa, (*c*) in the infra-orbital canal, and (*d*) on the face.

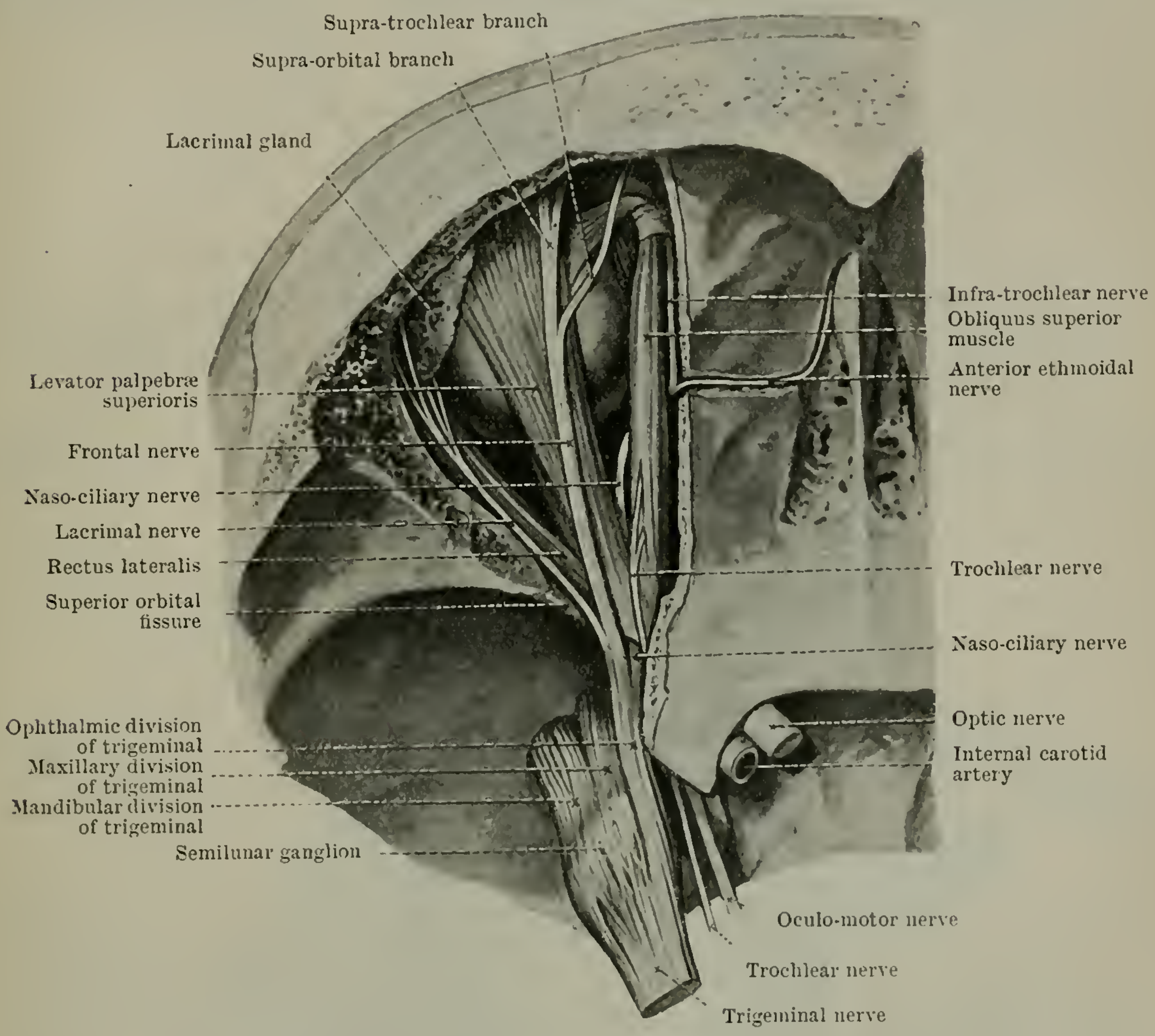


FIG. 578.—THE NERVES OF THE ORBIT FROM ABOVE.

In the cavity of the cranium the nerve gives off a minute (**n. meningeus medius**) **middle meningeal nerve** (O.T. **recurrent nerve**) to the dura mater of the middle fossa of the skull.

In the pterygo-palatine fossa the nerve gives off—(1) two short thick **spheno-palatine nerves**, the sensory roots of the spheno-palatine ganglion. Most of their fibres, however, do not traverse the ganglion but pass over it to enter its branches.

(2) **Posterior superior alveolar nerves**, usually two, descend through the pterygo-maxillary fissure to the posterior surface of the maxilla, and proceed forwards along the alveolar arch, in company with the posterior superior alveolar artery. They supply the gum and the upper molar teeth by branches which perforate the bone to reach the alveoli; they also supply the mucous membrane of the maxillary antrum. The nerves form a fine superior dental plexus, which is joined by the middle alveolar nerve before finally reaching the teeth.

(3) A small **orbital branch**, the *nervus zygomaticus*, enters the orbital cavity through the inferior orbital fissure, and proceeding along the lateral wall, divides into two branches. The **zygomatico-facial branch** appears on the face, after traversing the zygomatic bone through the zygomatic foramen, and supplies the skin over that bone. It communicates with the zygomatic branches of the facial nerve. The **zygomatico-temporal branch** perforates the temporal surface of the zygomatic bone, or passes through the spheno-zygomatic suture, and is

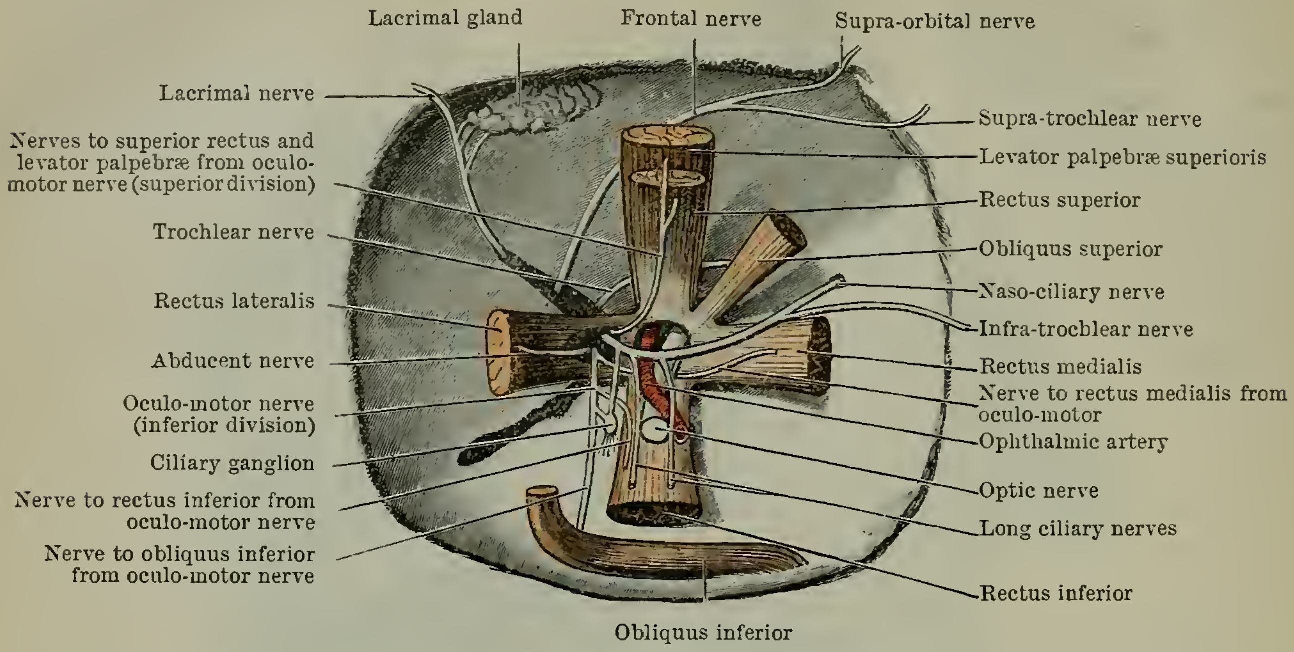


FIG. 579.—SCHEMATIC REPRESENTATION OF THE NERVES WHICH TRAVERSE THE CAVITY OF THE ORBIT.

Note that the lacrimal, frontal, and trochlear nerves, after entering the orbit through the superior orbital fissure, pass outside the annulus tendineus communis of Zinn from which the recti muscles arise; whilst the oculo-motor, abducent, and naso-ciliary nerves, together with the optic nerve and ophthalmic artery, enter the orbit within the annulus, and therefore lie at first within the cone formed by the ocular muscles as they diverge forwards from it.

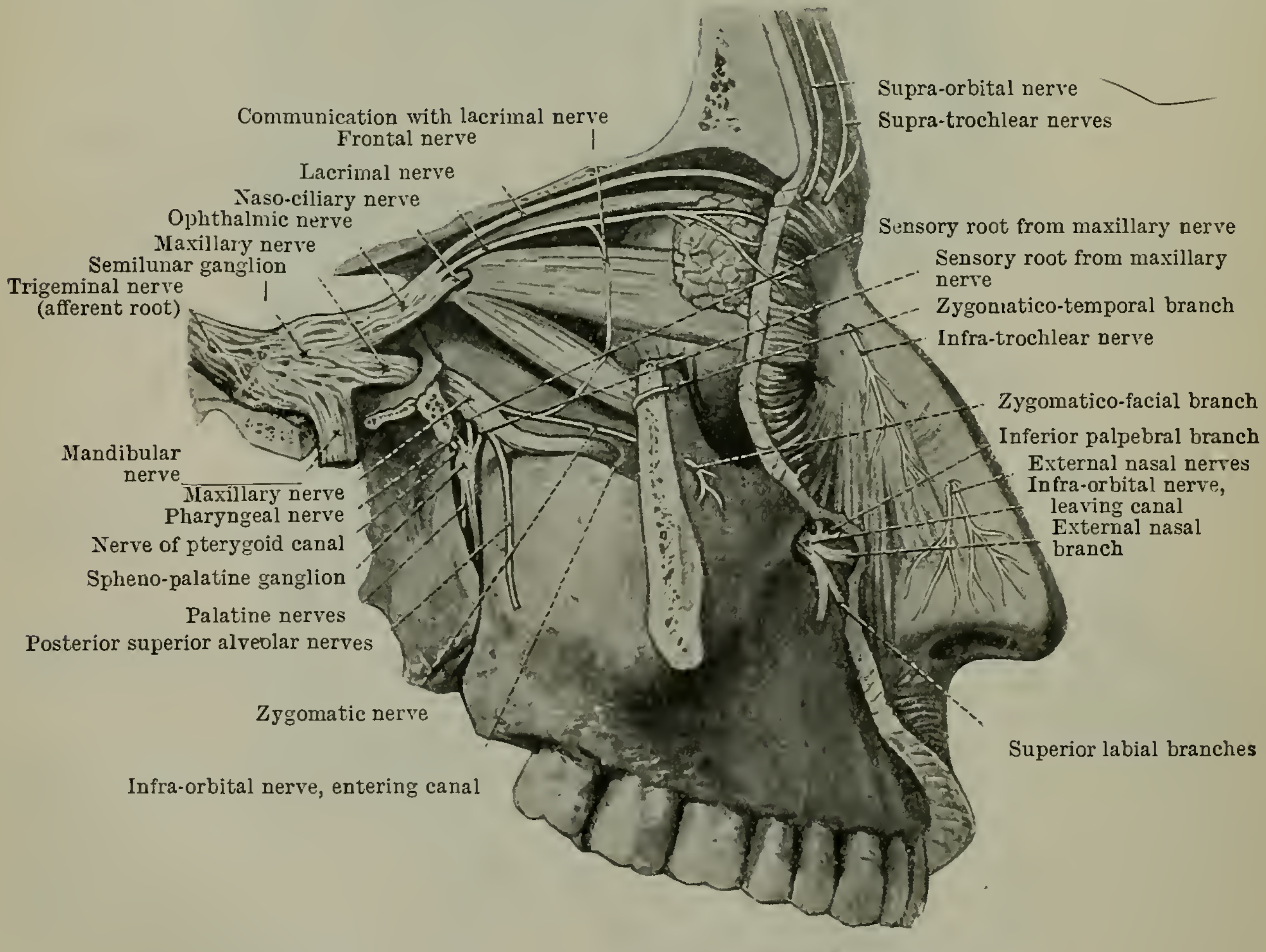


FIG. 580.—THE COURSE OF THE OPHTHALMIC AND MAXILLARY NERVES.

distributed, after piercing the temporal fascia, to the skin over the anterior part of the temple. In the orbit it communicates with the lacrimal nerve, and on the face with the temporal branches of the facial nerve. It may be very minute, and not pass further than the temporal fascia, between the two layers of which it may form a communication with the facial nerve.

(4) The **infra-orbital nerve** is the terminal branch of the maxillary nerve, which enters the orbit through the inferior orbital fissure and traverses the infra-orbital canal to reach the face.

In the infra-orbital canal the infra-orbital nerve supplies one and sometimes two branches to the teeth—the **middle** and **anterior superior alveolar nerves.** The former may be only a secondary branch of one of the latter nerves, or it may arise independently from the infra-orbital nerve. However formed, the nerves descend, in bony canals which may form internal bony ridges in the wall of the maxillary sinus (to the lining of which branches are given), and reach the alveolar arch, where they form minute plexuses containing gangliform enlargements, and supply the teeth (joining posteriorly with the branches of the posterior superior alveolar nerves). The anterior superior alveolar nerve supplies the incisor and canine teeth, and also gives off a nasal branch which enters the nasal fossa through a minute foramen to supply the forepart of the inferior concha and nasal floor; the middle superior alveolar nerve supplies the premolar teeth.

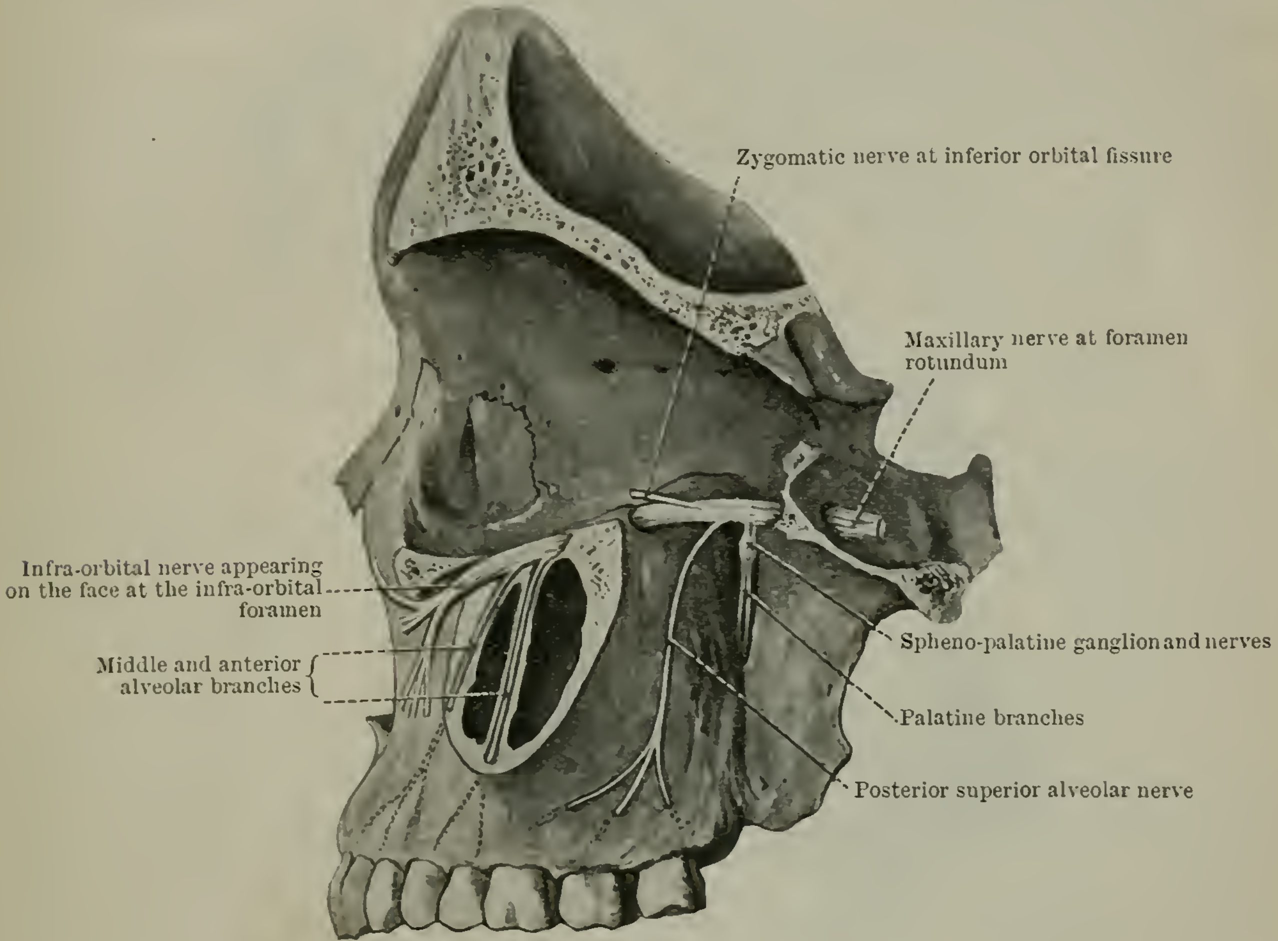

Zygomatic nerve at inferior orbital fissure
Maxillary nerve at foramen rotundum
Infra-orbital nerve appearing on the face at the infra-orbital foramen
Middle and anterior alveolar branches
Spheno-palatine ganglion and nerves
Palatine branches
Posterior superior alveolar nerve

Fig. 581.—Course and Branches of the Maxillary Nerve.

After emerging on the face from the infra-orbital foramen, the infra-orbital nerve divides into a number of radiating branches arranged in three sets—(*a*) **inferior palpebral (rami palpebrales inferiores)**, for the skin and conjunctiva of the lower eyelid; (*b*) **external nasal**, for the skin of the side of the nose; and (*c*) **superior labial**, for the cheek and upper lip. These branches form communications with the zygomatic branches of the facial nerve, and give rise to the *infra-orbital plexus* (Fig. 580, p. 686).

Ganglion Spheno-palatinum (see note on p. 782).—The **spheno-palatine** (O.T. **Meckel's**) **ganglion** lies deeply in the upper part of the pterygo-palatine fossa, close to the spheno-palatine foramen. It is a small reddish-gray ganglion, suspended from the maxillary nerve by the two **spheno-palatine branches** which constitute its sensory roots. The **motor** and **sympathetic roots** of the ganglion are derived from the **nerve of the pterygoid canal** (O.T. **Vidian Nerve**). This nerve is formed in the cranial cavity, upon the cartilage filling up the foramen lacerum, by the union of the *greater superficial petrosal nerve*, from the genicular ganglion of the facial nerve, with the *deep petrosal nerve*, a branch of the sympathetic plexus on the internal carotid artery; it also receives a communication from the otic ganglion. The nerve of the pterygoid canal passes through the pterygoid canal (which may form a ridge in the wall of the sphenoidal air sinus) to the pterygo-palatine fossa, where it joins the spheno-palatine ganglion.

The **branches from the ganglion** are seven in number. They pass backwards to the pharynx, downwards to the palate, inwards to the nasal cavity, and upwards to the orbit.

(*a*) The **pharyngeal** branch passes backwards through the pharyngeal canal to supply the mucous membrane of the roof of the pharynx.

(*b*) **Nervi Palatini.**—The **palatine nerves**, three in number, are directed downwards to the palate through the palatine canals.

The **anterior** or **great palatine nerve** emerges on the under surface of the palate through the greater palatine foramen, and at once separates into numerous branches for the supply of the mucous membrane of the soft and the hard palate, which they groove. Its anterior filaments reach to the incisor teeth and communicate with branches of the naso-palatine nerve. The main nerve gives off, as it lies in the palatine canal, a small **posterior inferior lateral nasal nerve**, which enters the nasal cavity and supplies the mucous membrane of the inferior concha.

The **middle** or **external palatine nerve** descends through a small palatine canal, and, piercing the pyramidal process of the palate bone, is distributed to the mucous membrane of the soft palate, uvula, and palatine tonsil.

The **posterior** or **small palatine nerve** consists of one or more small twigs which pass through the lesser palatine canals, and supply branches to the mucous membrane of the tonsil, soft palate, and uvula. It was formerly thought to convey motor fibres from the facial nerve to the levator veli palatini and uvular muscles, but these are now considered to be supplied by the accessory nerve through the pharyngeal plexus.

(*c*) The branches directed medially from the spheno-palatine ganglion enter the nasal cavity through the spheno-palatine foramen. They are two in number—the posterior superior lateral nasal and the naso-palatine. (1) The **posterior superior lateral nasal branch** is a small nerve destined for the mucous membrane of the superior and middle conchæ of the nasal cavity. (2) The **naso-palatine nerve**, after passing through the spheno-palatine foramen, crosses the roof of the nasal cavity, and extends obliquely downwards and forwards along the nasal septum, grooving the vomer, in its course between the mucous membrane and periosteum, to reach the incisive foramen near the front of the hard palate. The nerves pass through the subordinate median foramina (of Scarpa), the left nerve in front of the right. In the incisive foramen the two nerves communicate together. They then turn backwards and supply the mucous membrane of the hard palate. They communicate posteriorly with terminal filaments of the anterior palatine nerves. In its course through the nasal cavity each naso-palatine nerve furnishes collateral branches to the mucous membrane of the roof and septum of the nose (*posterior superior medial branches*) (Fig. 576, p. 684).

(*d*) **Rami Orbitales.**—The **orbital branches**, one or more minute branches, pass upwards to the periosteum of the orbit from the spheno-palatine ganglion.

NERVUS MANDIBULARIS.

The **mandibular nerve** is formed by the union of two roots; a large **sensory root**, from the semilunar ganglion, and the small **motor root** of the trigeminal nerve, which is wholly incorporated with the mandibular trunk. The two roots pass together, in the dura mater of the middle fossa of the base of the skull, to the foramen ovale, through which they emerge into the infra-temporal fossa.

Outside the skull they combine to form a single trunk, which soon separates into anterior and posterior divisions, as noted above. The motor root is sometimes considered as a separate nerve.

At its emergence from the skull the nerve is deeply placed beneath the middle of the zygomatic arch, and is concealed by the ramus of the mandible, and by the masseter, temporal, and external pterygoid muscles; behind it lies the middle meningeal artery.

The branches of the nerve may be divided into two series—(1) those derived from the undivided nerve, and (2) those derived from its terminal divisions.

The branches of the undivided nerve are two in number, and arise from its medial aspect. (*a*) A small **nervus spinosus** (O.T. **recurrent nerve**) arises just outside the skull, and accompanying the middle meningeal artery through the foramen spinosum, supplies the dura mater and mastoid cells. (*b*) In the infratemporal region a small branch arises for the supply of the **internal pterygoid muscle.** This nerve forms a connexion with the otic ganglion, through which fibres are conveyed to the tensor tympani and tensor veli palatini muscles.

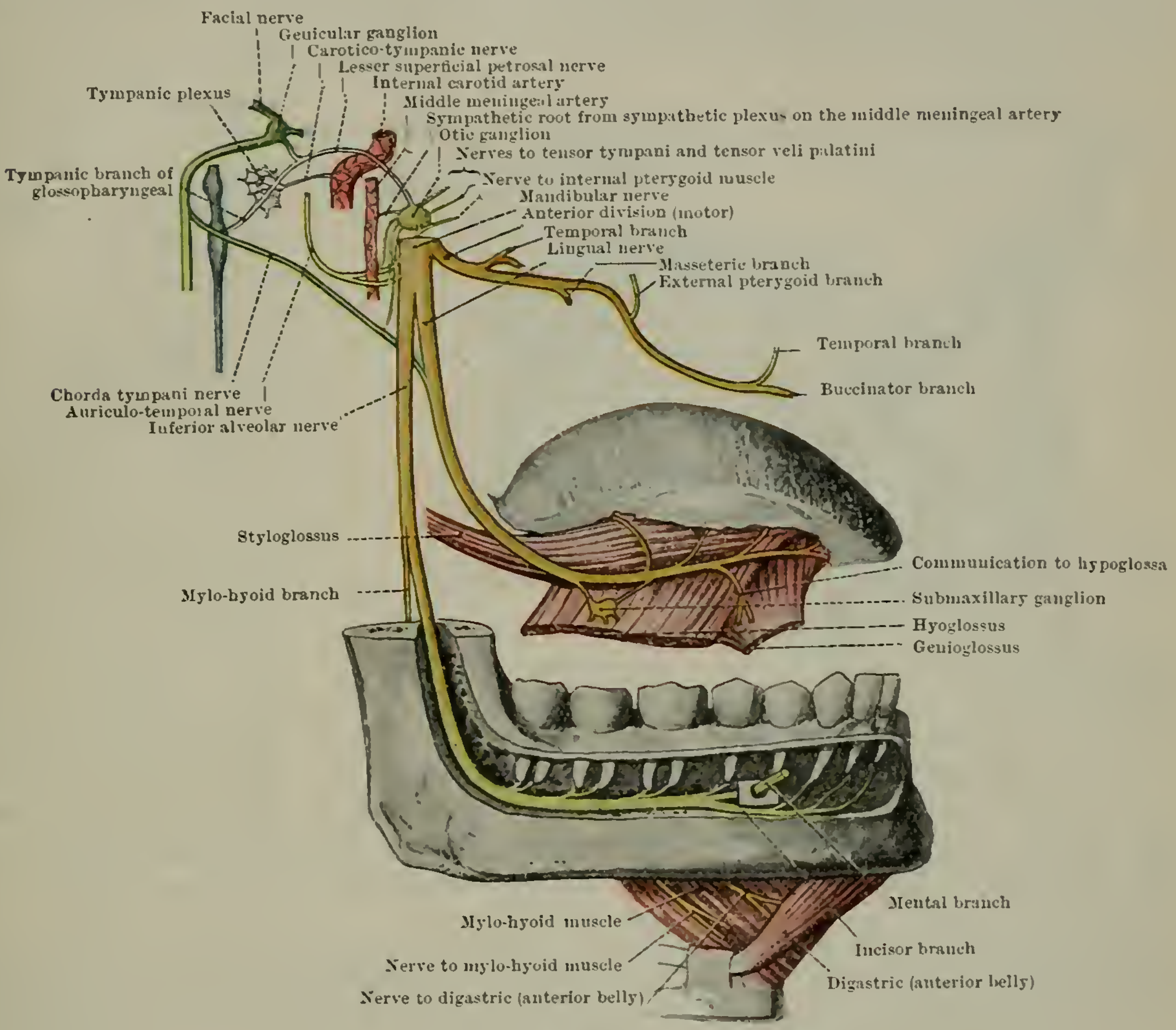


FIG. 582.—THE MANDIBULAR NERVE.

The terminal divisions of the nerve are a small anterior and a large posterior trunk.

The small **anterior trunk (nervus masticatorius** or **masticator nerve)** passes downwards and forwards medial to the external pterygoid muscle, and separates into the following branches: (1) A branch for the external pterygoid muscle, which supplies it on its deep surface; (2) a branch to the masseter muscle, which passes over the superior border of the external pterygoid and through the mandibular notch of the mandible and gives a filament to the temporo-mandibular joint; (3) and (4) two deep temporal branches, an anterior (which often accompanies the nerve to the buccinator) and a posterior (with sometimes a third, the middle) to the temporal muscle, which also ascend above the external pterygoid muscle; and (5) the buccinator nerve, which passes obliquely forwards between the two heads of the external pterygoid to reach the buccinator muscle. *This nerve is sensory*, and its fibres are, in part, distributed to the skin of the cheek (communicating with buccal branches of the facial nerve, which supplies the muscle itself); they are also, in part, distributed to the mucous membrane of the inside of the mouth, to reach which they pierce the fibres of the buccinator muscle.

The large **posterior trunk** extends downwards a short way medial to the external pterygoid muscle. After giving off, by two roots, the auriculo-temporal nerve, it ends by dividing into two, the lingual and the inferior alveolar nerves.

N. Auriculotemporalis.—The **auriculo-temporal nerve** is formed by the union of two roots which embrace the middle meningeal artery. The nerve passes backwards, medial to the external pterygoid muscle and between the spheno-mandibular ligament and the neck of the mandible. After passing through the parotid gland, it is directed upwards to the temple over the zygoma, in company with the superficial temporal artery. It is finally distributed as a cutaneous nerve of the temple and scalp, and reaches almost to the vertex of the skull.

The auriculo-temporal nerve gives off the following branches: (1) A small branch to the mandibular articulation. (2) Branches to the parotid gland. (3) A twig for the supply of the skin of the external acoustic meatus and membrana tympani. (4) Branches to the superior half of the auricle on its lateral aspect. (5) Terminal branches to the skin of the temple and scalp.

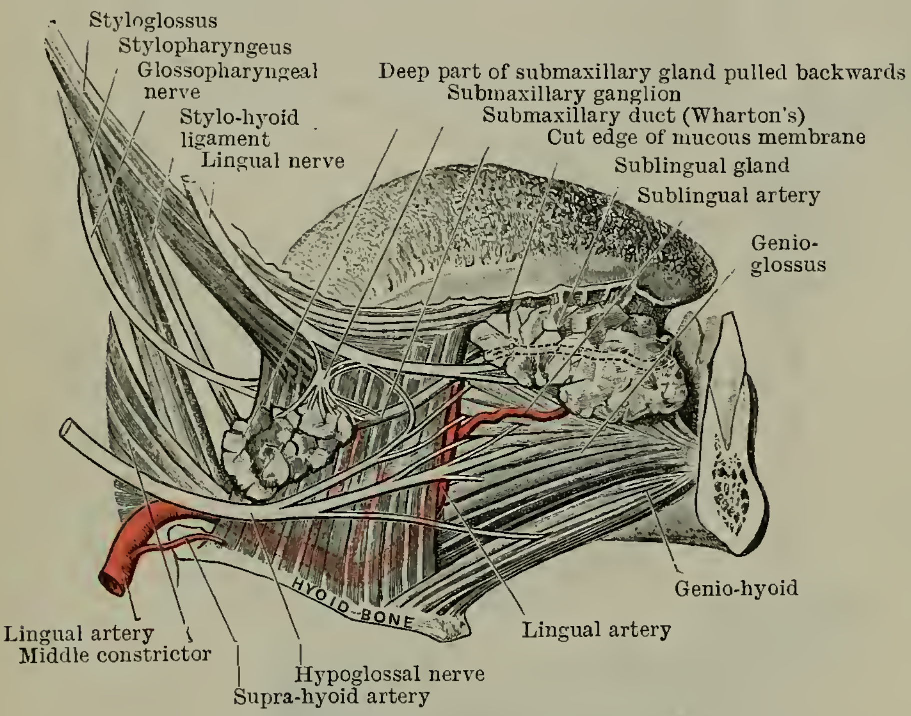


Fig. 583.—The Lingual and Hypoglossal Nerves in the Submaxillary Region.

It has the following **communications** with other nerves: (1) Important communications are effected by the roots of the nerve, which are separately joined by small branches from the otic ganglion; these probably convey secretory fibres from the glosso-pharyngeal nerve and the sympathetic system to the parotid gland. (2) The parotid and temporal branches of the nerve are connected with branches of the facial nerve in the substance of the gland.

N. Lingualis.—The **lingual nerve** is the smaller of the two terminal branches of the posterior division of the mandibular trunk. It proceeds downwards in front of the inferior alveolar nerve, medial to the external pterygoid muscle, to its inferior border. After passing between the internal pterygoid muscle and the ramus of the mandible close to the last molar tooth, it crosses beneath the mucous membrane of the floor of the mouth in the interval between the mylo-hyoid and hyoglossus muscles, first lateral to, then beneath the duct of the submaxillary gland. It sweeps forwards and medially to the side of the tongue, to the mucous membrane over the anterior two-thirds of which it is distributed.

Three nerves communicate with the lingual nerve in its course to the tongue: (1) The **chorda tympani branch** of the facial nerve joins it at an acute angle medial to the external pterygoid muscle, and is incorporated with it in its distribution to the tongue. (2) At a lower level it usually communicates with the inferior alveolar nerve. (3) The **hypoglossal nerve** forms larger or smaller loops of communication with the lingual nerve as they course forwards together over the hyoglossus muscle (**rami anastomotici cum nervo hypoglosso**).

Besides supplying the aforesaid branches to the mucous membrane over the sides and dorsum of the tongue in its anterior two-thirds, the lingual nerve supplies the mucous membrane of the side wall and floor of the mouth and the sublingual gland. It also assists, along with the chorda tympani nerve, in forming the roots of the submaxillary ganglion.

Ganglion Submaxillare (see note on p. 692).—The **submaxillary ganglion** is a minute reddish ganglion placed on the hyoglossus muscle, between the lingual nerve and the duct of the submaxillary gland. It is suspended from the former by two trunks, consisting for the most part of fibres of the lingual and chorda tympani nerves, which at that point become separated from the lingual nerve and incorporated with the ganglion. The **roots** of the ganglion are—(1) a sensory root, derived from the lingual nerve; (2) a motor root, derived from the chorda tympani; and (3) a sympathetic root, from the sympathetic plexus upon the external maxillary artery.

The **branches from the ganglion** are distributed to the submaxillary gland and duct (**rami submaxillares**), and by fibres which become reunited with the trunk of the lingual nerve, to the sublingual gland.

N. Alveolaris Inferior.—The **inferior alveolar nerve** is larger than the lingual nerve. It passes from beneath the inferior border of the external pterygoid muscle to reach the interval between the ramus of the mandible and the spheno-mandibular ligament. It enters the mandibular canal through the mandibular foramen in company with the inferior alveolar artery, traverses the substance of the ramus and body of the mandible, distributing branches to the teeth in its course, and terminates by emerging on the face through the mental foramen.

Branches.—(1) The **mylo-hyoid nerve** is a small branch arising just before the inferior alveolar nerve passes through the mandibular foramen. Piercing the spheno-mandibular ligament and grooving the ramus in its course, it descends into the submaxillary triangle on the superficial aspect of the mylo-hyoid muscle. Concealed in this situation by the submaxillary gland and the external maxillary artery, it is distributed to the mylo-hyoid muscle and the anterior belly of the digastric muscle. (2) The **dental branches** arise from the nerve whilst in the mandibular canal, and form a fine inferior dental plexus from which filaments supply the molar and bicuspid teeth and adjacent gums. (3) The **mental branch** of the inferior alveolar nerve is a trunk of considerable size arising from the main nerve in the mandibular canal. It emerges from the mandible through the mental foramen, and is distributed by many branches to the chin and lower lip. It communicates, under cover of the facial muscles, with the ramus marginalis mandibulæ of the facial nerve (Fig. 586, p. 694). (4) The **incisor branch** is the terminal part of the inferior alveolar nerve remaining after the origin of the mental branch. It supplies the canine tooth and the incisor teeth.

Ganglion Oticum.—The **otic ganglion** is situated deep to the mandibular nerve just below the foramen ovale, at the posterior border of the internal pterygoid muscle. Like the other ganglia described above, it possesses three roots: (1) A *motor root*, derived from the nerve to the internal pterygoid muscle; (2) a *sensory root*, formed by the *lesser superficial petrosal nerve* from the tympanic plexus (through which communications are effected with the tympanic branch of the glossopharyngeal nerve, and a branch from the genicular ganglion of the facial nerve); (3) a *sympathetic root*, from the plexus on the middle meningeal artery (Fig. 585).

Five **branches** arise from the ganglion—three communicating and two motor branches. The three **communicating nerves** are fine branches which join respectively the nerve of the pterygoid canal (sphenoidal branch), the roots of the auriculo-temporal nerve, and the chorda tympani nerve. The two **motor nerves** supply the tensor tympani and tensor veli palatini muscles.

Summary.—The trigeminal, the largest and most complex of the cerebral nerves, is (1) the chief sensory nerve for the face, the anterior half of the scalp, the orbit and eyeball, the nose and nasal cavity and accessory sinuses, the lips, teeth, mouth, and anterior two-thirds of the tongue;

(2) the motor fibres of the nerve supply the muscles of mastication, the mylo-hyoid and anterior belly of the digastric, and the tensor tympani and tensor veli palatini muscles (through the otic ganglion); (3) it supplies the salivary glands, the temporo-mandibular joint, and the dura mater; (4) through the ganglia placed on the three divisions of the nerve, not only are important organs, areas, and muscles innervated, but communications are also effected with the sympathetic system, with the oculo-motor nerve (ciliary ganglion), facial nerve (spheno-palatine and otic ganglia), and glossopharyngeal nerve (otic ganglion).

In its distribution to the skin of the face the branches of the fifth nerve present two striking peculiarities: (1) While the branches to the skin reach the surface at many points and in diverse ways, the three main divisions are severally, by their branches, responsible for the supply of three clearly demarcated cutaneous areas (Fig. 574, p. 682). Moreover, since in embryonic life the general distribution of the nerve is outlined by the outgrowth from the semilunar ganglion of the three main divisions, ophthalmic, maxillary, and mandibular, into the fronto-nasal, maxillary, and mandibular processes respectively, each nerve trunk supplies, broadly speaking, the deeper structures of the face lying behind its own area of cutaneous distribution. (2) By numerous communications with the facial nerve, sensory fibres are given to the muscles of expression supplied by the facial nerve.

Though the **ganglia associated with the fifth nerve**, namely, the ciliary, spheno-palatine, otic, and submaxillary, are conveniently described in their relations to its branches, it should be realised that functionally this nerve has less to do with them than any of the other cerebral nerves with which they are connected. These ganglia properly belong to the sympathetic system; they may be considered to represent an upward extension of the ganglia of the paired sympathetic trunks lying alongside the vertebral column, and can be termed the principal **cephalic sympathetic ganglia** (p. 782). In structure they largely consist of the stellate or multipolar neurones characteristic of this system elsewhere; and developmentally they are formed by cell bodies which have migrated from the semilunar ganglion along the branches of the trigeminal nerve, an origin paralleled by that of the ganglia of the trunks in the lower part of the system. Moreover, the fibres they receive from other nerves (the ciliary ganglion from the oculo-motor, the submaxillary and spheno-palatine ganglia from the facial, and the otic ganglion from the glossopharyngeal) may be likened to the splanchnic efferent fibres received by the ganglia of the sympathetic cord through the white rami of the spinal nerves. Their development is described together with that of the Sympathetic System on p. 780.

Each of the ganglia contains three varieties of fibres: (1) sensory, visceral, and somatic; (2) motor, visceral, derived from one of the cerebral nerves; and (3) sympathetic, which may be somatic motor and sensory, or visceral sensory in character, and are derived from the superior cervical ganglia. Many of the roots and branches are mixed, though they are generally named according to the predominating kind of fibres they contain. Lastly, it is to be noted that nearly all the fibres of a so-called sensory root pass uninterruptedly through a ganglion to reach their destination.

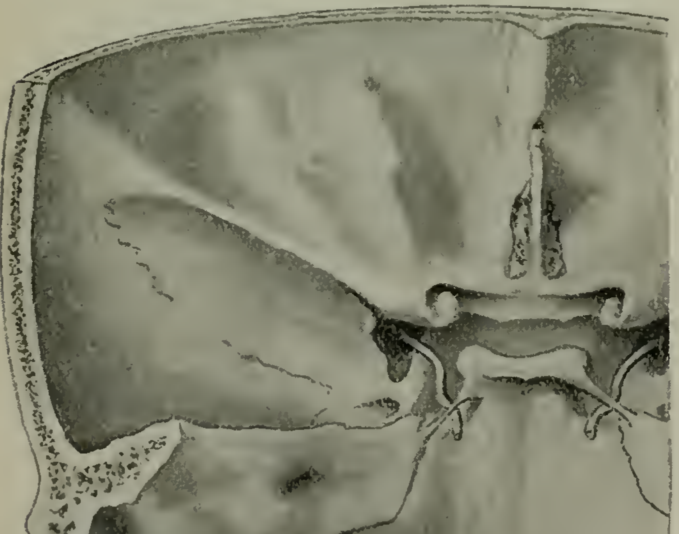


FIG. 584.—THE PETRO-SPHENOIDAL LIGAMENT. The interior of the base of the skull viewed from behind to illustrate a dissection of the abducent nerve passing beneath the ligament before entering the cavernous sinus. The ligament, which is formed by the deeper or osteogenetic layer of the dura mater, presents differences in its extent and attachments, as is illustrated on the two sides.

NERVUS ABDUCENS.

The **sixth** or **abducent nerve** supplies only the lateral rectus muscle of the eyeball. It issues from the brain at the inferior border of the pons, just above the pyramid of the medulla oblongata (for the deep origin, see p. 598). It is directed forwards, it pierces the dura mater in the posterior fossa of the base of the skull alongside the dorsum sellæ, passing beneath the petro-sphenoidal ligament (Fig. 584), and enters the cavernous sinus (Fig. 572, p. 679). In the sinus it is placed close to the lateral side of the internal carotid artery. After it leaves the sinus it passes through the superior orbital fissure below the oculo-motor and naso-ciliary nerves and enters the orbit within the annulus of Zinn

(Fig. 579, p. 686). In the cavity of the orbit it supplies the lateral rectus muscle on its deep (ocular) surface.

Communications.—In the cavernous sinus the sixth nerve receives two communicating filaments: (1) From the carotid plexus of the sympathetic, and (2) from the ophthalmic division of the trigeminal nerve.

Nervus Facialis.

The **seventh** or **facial nerve** is a mixed nerve, and consists of two parts, a larger motor, which supplies all the superficial muscles of the scalp, face, and neck, and some of the deep ones, and a smaller sensory part, the *nervus intermedius*, or nerve of Wrisberg, which contains taste fibres for the anterior two-thirds of the tongue. It emerges from the brain at the inferior border of the pons, below the trigeminal nerve and medial to the acoustic nerve (for the deep origin, see p 596). Between it and the acoustic nerve is the minute *nervus intermedius* (Fig. 587, p. 696). The facial nerve enters the internal acoustic meatus, and passing through the canalis facialis in the petrous portion of the temporal bone, emerges at the base of the skull by the stylo-mastoid foramen, and passes forwards through the parotid gland to supply the muscles of the face. *In the internal acoustic meatus* the nerve is placed upon the acoustic nerve, the *nervus intermedius* intervening, and all three are surrounded by sheaths of the dura, arachnoid, and pia. *In the canalis facialis* the nerve first passes forwards and laterally to the hiatus of the canal, then abruptly backwards on the medial side of the tympanum, and finally downwards behind the tympanum, in the medial wall of the tympanic antrum. *In the parotid gland* it crosses the external carotid artery and the posterior facial vein superficially. *On the face* its branches radiate from the anterior border of the parotid gland and enter the deep surface of the facial muscles.

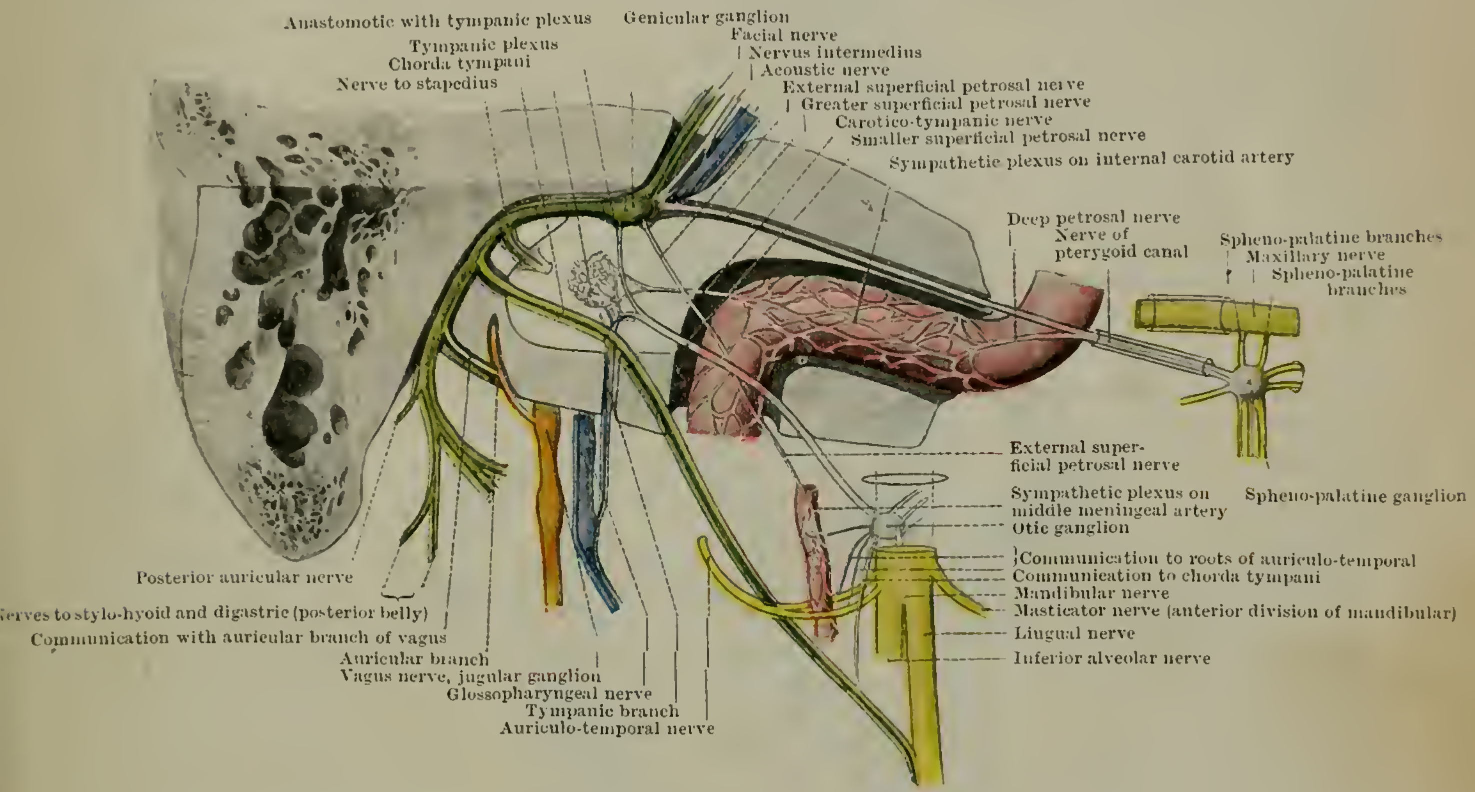

Anastomotic with tympanic plexus
Tympanic plexus
Chorda tympani
Nerve to stapedius
Genicular ganglion
Facial nerve
Nervus intermedius
Acoustic nerve
External superficial petrosal nerve
Greater superficial petrosal nerve
Carotico-tympanic nerve
Smaller superficial petrosal nerve
Sympathetic plexus on internal carotid artery
Deep petrosal nerve
Nerve of pterygoid canal
Spheno-palatine branches
Maxillary nerve
Spheno-palatine branches
External superficial petrosal nerve
Sympathetic plexus on middle meningeal artery
Spheno-palatine ganglion
Otic ganglion
Communication to roots of auriculo-temporal
Communication to chorda tympani
Mandibular nerve
Masticator nerve (anterior division of mandibular)
Lingual nerve
Inferior alveolar nerve
Posterior auricular nerve
Nerves to stylo-hyoid and digastric (posterior belly)
Communication with auricular branch of vagus
Auricular branch
Vagus nerve, jugular ganglion
Glossopharyngeal nerve
Tympanic branch
Auriculo-temporal nerve

Fig. 585.—The Connexions of the Facial Nerve in the Temporal Bone.

Branches and Communications.—(i.) *In the internal acoustic meatus* the nervus intermedius, lying between the facial and acoustic nerves, sends communicating branches to both of them. The branch to the acoustic nerve probably separates from it again to join the genicular ganglion of the facial nerve (Fig. 587, p. 696).

(ii.) *In the canalis facialis* the **ganglion geniculi** is formed at the point where the facial nerve bends backwards (the genu). It is an oval swelling on the nerve, and is joined by a branch from the upper (vestibular) trunk of the acoustic nerve, by which it probably receives fibres of the nervus intermedius. From the ganglion three small nerves arise: (1) The **greater superficial petrosal nerve** passes forwards through the hiatus canalis facialis to the middle fossa of the skull. It contains chiefly sensory fibres, derived from the intermediate nerve, which, after traversing the spheno-palatine ganglion, are distributed by the middle and posterior palatine nerves to the mucous membrane of the soft palate. It receives a twig from the tympanic plexus and probably also contains a few motor fibres. In the upper part of the foramen lacerum it is joined by the **deep petrosal nerve** from the sympathetic plexus on the internal carotid artery to form the nerve of the pterygoid canal (O.T. Vidian nerve), which, after traversing the pterygoid canal, ends in the spheno-palatine ganglion. (2) A minute nerve (*ramus anastomoticus cum plexu tympanico*) pierces the temporal bone and joins the tympanic branch of the glossopharyngeal in the substance of the bone. By their union the **lesser superficial petrosal nerve** is formed, which pierces the temporal bone and ends in the otic ganglion. (3) The **external superficial petrosal nerve** is a minute inconstant branch which joins the sympathetic plexus on the middle meningeal artery.

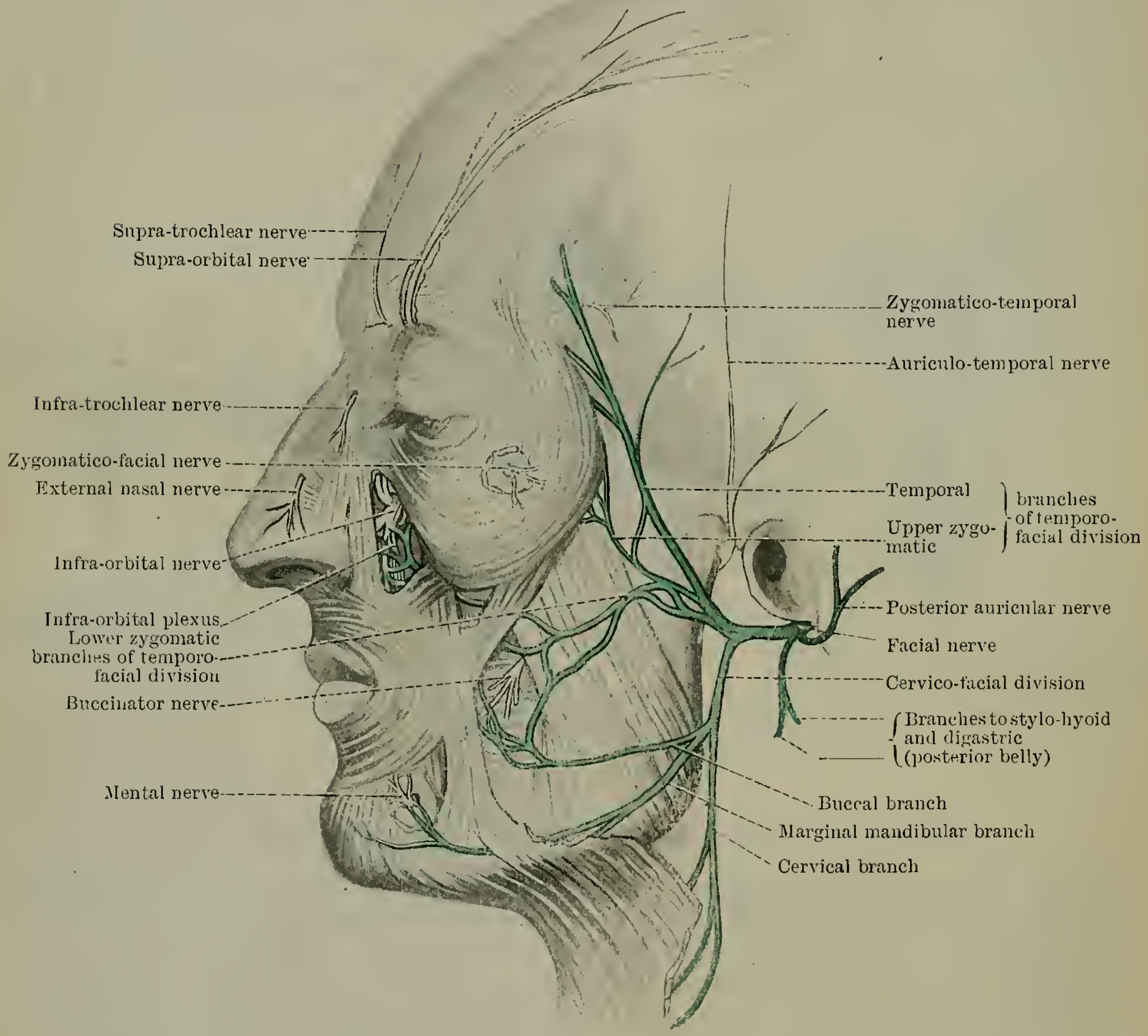


FIG. 586.—THE DISTRIBUTION OF THE TRIGEMINAL AND FACIAL NERVES ON THE FACE.

In the course of the facial nerve in the lower part of the canalis facialis, behind the tympanum, three branches arise: (1) **N. Stapedius.**—The small nerve to the **stapedius muscle**, which passes forwards to the tympanum. (2) **Chorda Tympani.**—The **chorda tympani nerve** (associated with the nervus intermedius; see note on p. 695), which enters the tympanic cavity through the *tympanic aperture of the canaliculus chordæ*, passes over the membrana tympani and the handle of the malleus, and leaves the cavity through the *medial end of the petro-tympanic* *fissure* to reach the infra-temporal fossa. Medial to the external pterygoid muscle, after receiving a fine communication from the otic ganglion, it becomes incorporated with the lingual branch of the mandibular nerve, and in its further course is inseparable from that nerve. It supplies a root to the submaxillary ganglion, and is finally distributed to the side and dorsum of the tongue in its anterior two-thirds. It largely consists of sensory (taste) fibres derived from the genicular ganglion, but also contains some secretory ones which enter the submaxillary ganglion and thence supply the submaxillary and sublingual glands. (3) Before it leaves the canalis facialis a fine **communicating branch** arises from the facial nerve to join the auricular branch of the vagus nerve.

(iii.) *In the neck* the facial nerve gives off three muscular branches: (1) and (2) **Ramus Stylohyoideus, Ramus Digastricus.** — Small branches, frequently arising together, supply the **stylo-hyoid** and the posterior belly of the **digastric**, the latter nerve sometimes communicating with the glossopharyngeal. (3) **N. Auricularis Posterior.**—The **posterior auricular nerve** bends backwards and upwards over the anterior border of the mastoid process along with the posterior auricular artery. It divides into two branches—an *auricular branch* for the posterior auricular muscle and the intrinsic muscles of the auricle, and an *occipital branch* for the occipital belly of the epicranius muscle. The posterior auricular nerve, in its course, communicates with the great auricular, lesser occipital, and auricular branch of the vagus nerves.

(iv.) *In the parotid gland* the facial nerve spreads out in an irregular series of branches (**plexus parotideus** or *pes anserinus*), indefinitely divided into an upper temporo-facial and a lower cervico-facial division. Communications occur in the substance of the gland between the main trunks and the great auricular and auriculo-temporal nerves.

The **temporo-facial division** gives off two series of subordinate branches which radiate forwards and upwards from the parotid gland.

1. **Rami Temporales.**—The **temporal branches** are of large size, and, sweeping out of the parotid gland over the zygomatic arch, are distributed to the orbicularis oculi, frontalis, corrugator supercilii, auriculares anterior and superior. The temporal branches communicate in their course with the auriculo-temporal, zygomatico-temporal, lacrimal, and supra-orbital branches of the trigeminal nerve.

2. **Rami Zygomatici.**—The **upper zygomatic branches** are small, and sometimes are inseparable from the temporal or lower zygomatic nerves. Extending forwards across the zygomatic bone, they supply the orbicularis oculi and zygomatic muscles, and communicate with the zygomatico-facial branch of the maxillary nerve.

The lower **zygomatic branches** are of considerable size. Passing forwards over the masseter muscle in company with the parotid duct, they supply the orbicularis oculi, the zygomaticus, buccinator, and the muscles of the nose and upper lip. The **infra-orbital plexus** is formed by the union of these nerves with the infra-orbital branch of the maxillary nerve below the lower eyelid. Smaller communications occur with the infra-trochlear and nasal nerves on the side of the nose.

The **cervico-facial division** of the facial nerve supplies three series of secondary branches.

1. **Rami Buccales.**—The **buccal branch** (or branches) extends forwards to the angle of the mouth to supply the muscles converging to the mouth, including the buccinator. It communicates with the buccinator branch of the mandibular nerve in front of the anterior border of the masseter muscle.

2. **Ramus Marginalis Mandibulæ.**—The **marginal branch of the mandible** passes along the mandible to the interval between the lower lip and chin, and supplies the triangularis oris, quadratus labii inferioris, and orbicularis oris. It communicates with the mental branch of the inferior alveolar nerve.

3. **Ramus Colli.**—The **cervical branch** emerges from the parotid gland near its lower end, and sweeps forwards, below the angle of the mandible, to the front of the neck. It supplies the platysma, and forms loops of communication with the nervus cutaneus colli.

Though the facial nerve is commonly described as above, as a mixed nerve, the sensory or intermediate part can be considered, on the basis of its origin and distribution, as well as on the really mixed nature of its fibres, as a separate nerve, the **glossopalatine.** Under this term are included the so-called sensory root of the facial, the pars intermedia, genicular ganglion, chorda tympani, and part of the greater superficial petrosal nerve. Its central connexions and peripheral distribution resemble those of the glossopharyngeal nerve, and suggest its being considered as an aberrant part of the latter.

NERVUS ACUSTICUS.

The **eighth** or **acoustic nerve** (O.T. **auditory**) consists of two functionally entirely different parts, the vestibular nerve, concerned with equilibration, and the cochlear nerve, the true nerve of hearing; they differ also in their peripheral endings and central connexions.

The combined trunk arises from the brain by two roots, medial and lateral. The **medial, vestibular root** emerges between the olive and the restiform body. The **lateral, cochlear root,** continuous through the cochlear nucleus with the striæ medullares of the fourth ventricle, winds round the lateral side of the restiform body (for the deep connexions, see p. 602). The two roots unite with one another to form the trunk of the acoustic nerve, which is attached to the brain on the lateral side of the facial nerve and nervus intermedius, at the lower border of the pons (Fig. 569, p. 676).

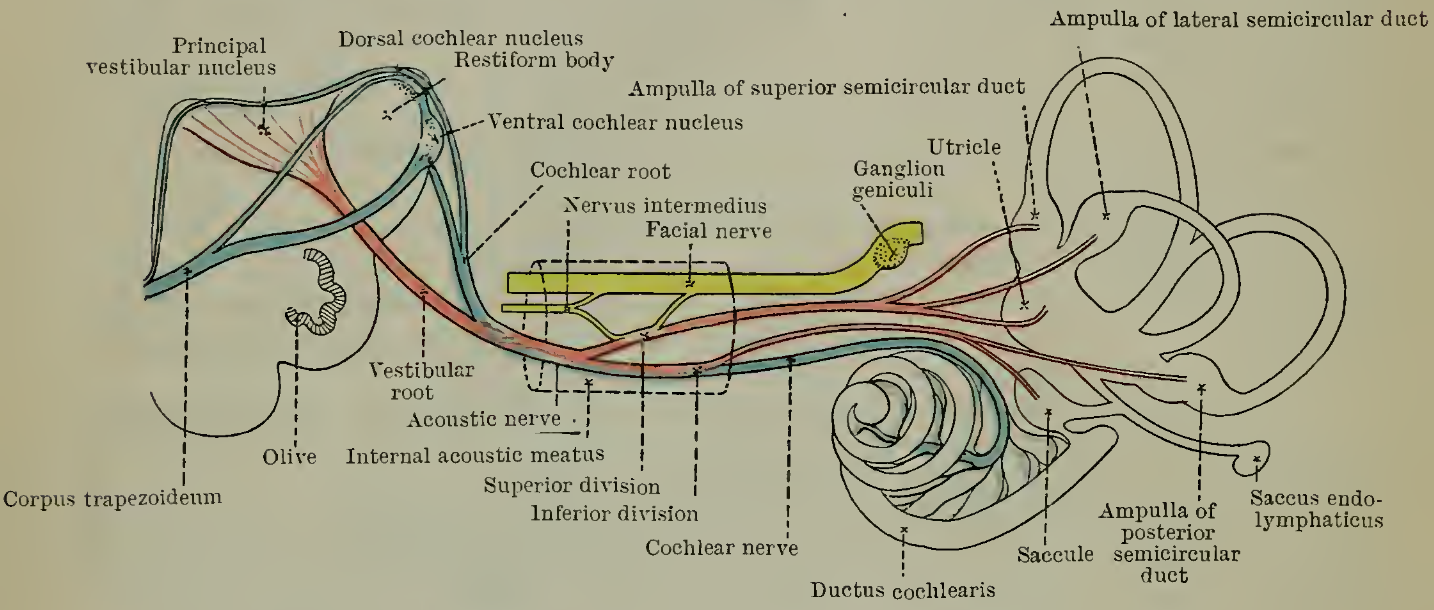


FIG. 587.—SCHEME OF THE ORIGIN AND DISTRIBUTION OF THE ACOUSTIC NERVE.

The nerve passes laterally through the internal acoustic meatus, lying below the facial nerve and nervus intermedius (Fig. 573, p. 680). In the meatus the trunk separates into two divisions, an upper consisting of vestibular fibres only, and a lower which consists mainly of cochlear fibres but contains also some vestibular fibres. The divisions subdivide, and their branches pass through the lamina cribrosa, to supply the several parts of the labyrinth.

The **superior division** in the internal acoustic meatus usually receives fibres from the nervus intermedius, and gives off a communicating branch to the genicular ganglion of the facial nerve. It then separates into three terminal branches which pierce the lamina cribrosa. (1) **N. Utricularis.**—The **utricular nerve** supplies the macula acustica of the **utricle.** (2) and (3) **Nn. Ampullaris Superior et Lateralis.**—The **superior** and **lateral ampullary nerves** supply the ampullæ of the **superior** and **lateral semicircular ducts.**

The **inferior division** gives off (1) **n. saccularis,** a **saccular nerve** to the macula acustica of the **saccule,** (2) **n. ampullaris inferior,** an **inferior ampullary nerve** to the ampulla of the **posterior semicircular duct,** and (3) is continued through the lamina cribrosa to the labyrinth as the **cochlear nerve,** which is distributed through the modiolus and osseous spiral lamina to the organ of Corti in the cochlea.

Both the vestibular and cochlear nerves contain among their fibres collections of bipolar nerve cells, forming in each nerve a distinct ganglion—the **vestibular ganglion** on the vestibular trunk at the bottom of the internal acoustic meatus, and the **spiral ganglion of the cochlea** on the cochlear trunk within the modiolus.

Nervus Glossopharyngeus.

The **ninth** or **glossopharyngeal nerve** is a mixed nerve, consisting of a smaller motor element which supplies the stylopharyngeus, and a larger sensory part which supplies the pharynx and tongue. It arises from the brain by five or six fine fila radicularia (radicles) which emerge from the medulla oblongata, between the posterior and lateral columns, close to the facial nerve above, and in series with the fila of the vagus nerve below (Fig. 569, p. 676; for the deep connexions, see p. 595). The fila combine to form a nerve which passes through the jugular foramen, along with the vagus and accessory nerves, but separated from them by the inferior petrosal sinus and enveloped in a separate sheath of dura mater (Fig. 573, p. 680). Reaching the neck, the nerve arches downwards and forwards to the interval between the hyoid bone and the mandible. In its course to the side of the pharynx it lies at first between the internal carotid artery and the internal jugular vein, and then lower down between the internal and external carotid arteries. Passing medial to the styloid process, it sweeps round the lower border of, and then crosses, the stylopharyngeus muscle and the stylo-hyoid ligament, and disappears medial to the hyoglossus muscle, to reach its termination in the tongue (Fig. 588).

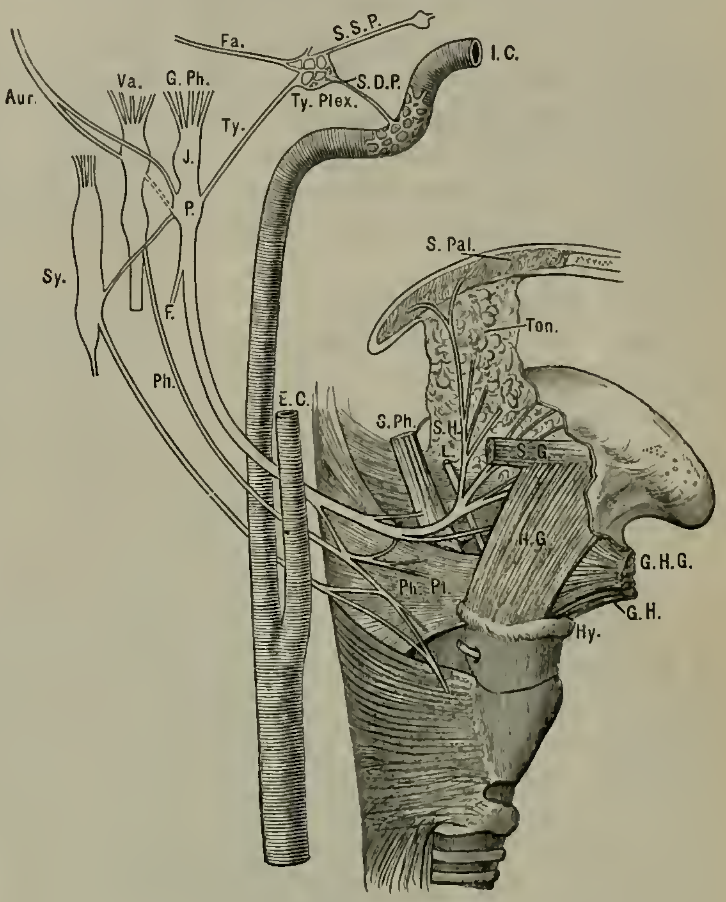


Fig. 588.—Scheme of the Distribution of the Glossopharyngeal Nerve.

G.Ph., Glossopharyngeal nerve ; J., Superior, and P., Petrous ganglia ; Ty., Tympanic nerve ; Ty.Plex., Tympanic plexus ; Fa., Root from genicular ganglion of facial nerve ; S.S.P., Lesser superficial petrosal nerve to the otic ganglion ; S.D.P., Carotico-tympanic nerve ; I.C., Internal carotid artery ; Va., Vagus nerve ; Aur., Auricular branch of vagus ; Sy., Superior cervical sympathetic ganglion ; F., Communicating branch to facial nerve ; Ph., Pharyngeal branch of vagus ; E.C., External carotid artery ; Ph.Pl., Pharyngeal plexus ; S.Ph., Stylopharyngeus muscle ; S.H.L., Stylo-hyoid ligament ; H.G., Hyoglossus ; S.G., Styloglossus ; Ton., Palatine tonsil ; S. Pal., Soft palate ; G.H.G., Genioglossus ; G.H., Genio-hyoid ; Hy., Hyoid bone.

The **branches** of the nerve may be classified in three series according to their origin—(i.) in the jugular foramen ; (ii.) in the neck ; (iii.) in relation to the tongue.

In the jugular foramen there are two enlargements upon the trunk of the nerve—the superior and petrous ganglia. The **superior ganglion** is small, does not implicate the whole width of the nerve, and may be fused with the petrous ganglion, or even absent altogether. No branches arise from it.

Ganglion Petrosum. — The **petrous or inferior ganglion** is distinct and constant. It is placed upon the nerve at the lower part of its course through the jugular foramen.

Branches and Communications of the Petrous Ganglion.—N. Tympanicus.—The **tympanic branch** is the most important offset from this ganglion. It passes through a small canal in the bridge of bone between the jugular foramen and the carotid canal to reach the cavity of the tympanum, where it breaks up into branches, to form, along with the carotico-tympanic branches from the carotid plexus of the sympathetic on the internal carotid artery (*nn. caroticotympanici superior et inferior*, O.T. *small deep petrosal*), and a twig from the genicular ganglion of the facial nerve, the **tympanic plexus**. This plexus lies on the promontory of the medial wall of the middle ear, and supplies the mucous lining of the tympanum, mastoid cells, and auditory tube (Fig. 585, p. 693). The fibres of the tympanic branch of the glossopharyngeal nerve become reunited to form, by their union with a small nerve from the genicular ganglion of the facial nerve (*anastomotic with the tympanic plexus*), the **lesser superficial petrosal nerve** in the substance of the temporal bone. This passes forwards through the temporal bone, and eventually joins the otic ganglion.

Besides forming the tympanic branch, the petrous ganglion of the glossopharyngeal nerve communicates with three other nerves—(1) with the superior cervical ganglion of the sympathetic; (2) with the auricular branch and sometimes with the jugular ganglion of the vagus; and (3) sometimes with the facial nerve.

In the neck the glossopharyngeal nerve gives off two groups of branches: (1) As it crosses over the **stylopharyngeus muscle** it supplies the nerve to that muscle, fibres of which pierce the muscle to reach the mucous membrane of the pharynx. (2) The **pharyngeal branches** of the nerve supply the mucous membrane of the pharynx directly after piercing the superior constrictor muscle, and indirectly after joining, along with the pharyngeal offsets from the vagus and the superior cervical ganglion of the sympathetic, in the formation of the **pharyngeal plexus** (Fig. 589).

The **terminal branches** of the nerve supply the mucous membrane of the tongue and adjacent parts. A **tonsillar branch** forms a plexus to supply the mucous membrane covering the palatine tonsil, the adjacent part of the soft palate, and the palatine arches. **Lingual branches** supply the mucous membrane and vallate papillæ of the dorsal third and lateral half of the tongue, extending backwards to the glosso-epiglottic folds and the front of the epiglottis.

Nervus Vagus.

The **tenth or vagus nerve** is a mixed nerve, and is the most widely distributed of the cerebral nerves, passing through the neck and thorax to reach the abdomen. It supplies sensory fibres chiefly to the pharynx, œsophagus, stomach, larynx, trachea, and lungs; motor fibres to the unstriped musculature of the same series of organs, as well as to most of the voluntary muscles of the soft palate, pharynx, and larynx; and special fibres to the heart and abdominal viscera. Each nerve is connected with the seventh, ninth, eleventh, and twelfth cranial nerves (the cerebral part of the eleventh contributing most of the motor fibres of the vagus) with the first and second cervical spinal nerves, and with the sympathetic system.

It arises from the brain by numerous fila radicularia attached to the floor of the postero-lateral sulcus of the medulla oblongata, in series with the glossopharyngeal nerve above and the accessory nerve below it (for the deep connexions, see p. 594). The fila of the nerve unite to form a single trunk which emerges into the neck through the jugular foramen.

In the jugular foramen the nerve occupies the same sheath of dura mater as the accessory nerve, it is placed behind the glossopharyngeal nerve, and a small ganglion—the **jugular ganglion**—is developed upon it.

In the neck the vagus nerve pursues a vertical course in front of the vertebral column. It occupies the carotid sheath, lying between and behind the internal and common carotid arteries and the internal jugular vein. It enters the thorax behind the large veins: *on the right side,* after crossing over the first part of the subclavian artery; *on the left side,* in the interval between the left common carotid and subclavian arteries. In the upper part of the neck, immediately below the jugular foramen, a second and larger ganglion—the **ganglion nodosum**—is developed on the trunk of the nerve.

In the thorax the nerves occupy the superior and posterior mediastinal spaces, and their relations are different on the two sides. (*a*) *In the superior mediastinum* the *right nerve* continues its course alongside the innominate artery and the trachea, and behind the right innominate vein and superior vena cava, to the posterior surface of the root of the lung. The *left nerve* courses downwards between the left common carotid and subclavian arteries, and behind the left innominate vein

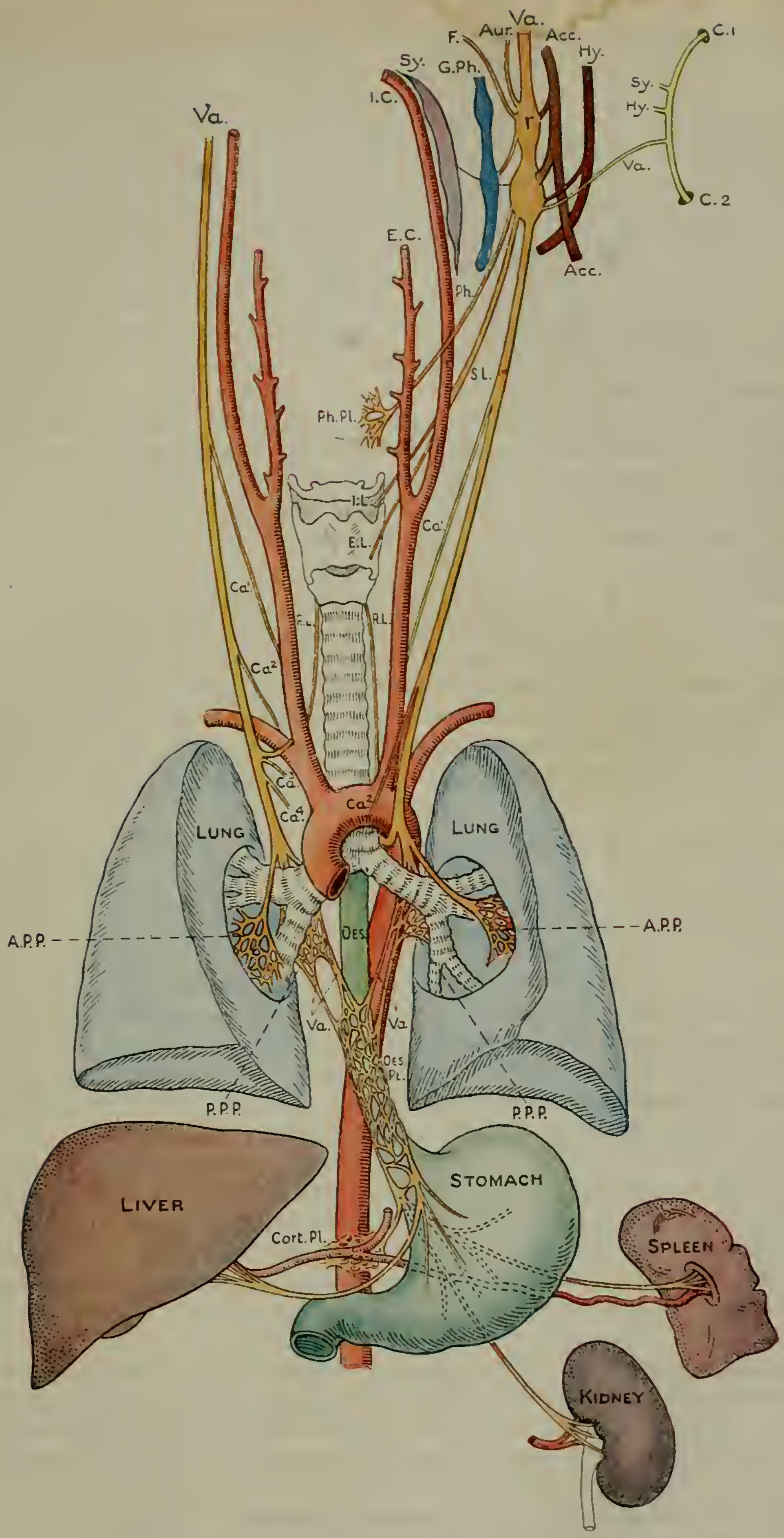


FIG. 589.—THE DISTRIBUTION OF THE VAGUS NERVE.

Va., Right and left vagi; r, Ganglion jugulare and connexions with Sy., Sympathetic, superior cervical ganglion: G.Ph., Glossopharyngeal; Acc., Accessory nerve; F, Meningeal branch; Aur., Auricular branch; Va., Connexion with ganglion nodosum of vagus; Sy., Nerve to stylo-hyoid; Hy., Nerve to hyoglossus; C1. C2, Loop between the first two cervical nerves; Sy., Sympathetic, superior cervical ganglion; Acc., Accessory nerve; Ph., Pharyngeal branch; Ph.Pl., Pharyngeal plexus; S.L., Superior laryngeal nerve; I.L., Internal laryngeal branch; E.L., External laryngeal branch; I.C., Internal, and E.C., External carotid arteries: Ca1, Upper cervical cardiac branch; Ca2, Lower cervical cardiac branch; R.L., Recurrent nerve (the right is drawn by error as passing over instead of under the subclavian artery); Ca3, Cardiac branches from recurrent nerves; Ca4, Thoracic cardiac branch (right vagus); A.P.P., Anterior, and P.P.P., Posterior pulmonary plexuses; Oes.Pl., Œsophageal plexus; Cort.Pl., Cœliac plexus.

and the phrenic nerve. It passes over the aortic arch, and then proceeds to the posterior surface of the root of the left lung. (*b*) *In the posterior mediastinum* the vagi nerves are concerned in the formation of two great plexuses—the pulmonary and the œsophageal. Behind the root of each lung both nerves break up to form the large **posterior pulmonary plexus**, from the lower end of which two nerves emerge on each side. These nerves on the right side pass obliquely over the vena azygos; on the left side they cross the descending thoracic aorta. Both series reach the œsophagus, and divide into small anastomosing branches which form the **œsophageal plexus.** At the œsophageal opening of the diaphragm two single nerves become separated from the plexus, and entering the abdomen—the left nerve in front of the œsophagus, the right nerve behind it—they terminate by supplying the stomach and other abdominal organs.

The **communications** and **branches** of the vagus nerve may be described as (i.) ganglionic, (ii.) cervical, (iii.) thoracic, and (iv.) abdominal (Fig. 589).

Ganglion Jugulare.—The **jugular ganglion** (O.T. **ganglion of the root**) is small and spherical. It occupies the jugular foramen, and gives off two branches—meningeal and auricular.

The **meningeal branch** passes backwards to supply the dura mater of the posterior fossa of the skull.

The **auricular branch** (O.T. **nerve of Arnold**) ascends to the ear through the mastoid canaliculus on the lateral aspect of the jugular fossa. It receives near its origin a twig from the tympanic branch of the glossopharyngeal nerve, and, as it traverses the temporal bone, usually communicates with the facial nerve by a branch arising from the latter in the canalis facialis. The nerve escapes through the tympano-mastoid fissure and is distributed to the back of the auricle and the external acoustic meatus, and communicates superficially with the posterior auricular nerve.

Communications.—Besides supplying the meningeal and auricular branches, this ganglion receives communications from (1) the superior cervical ganglion of the sympathetic; (2) the accessory nerve; and (3) (sometimes) the petrous ganglion of the glossopharyngeal nerve (*ramus anastomoticus cum nervo glossopharyngeo*).

Ganglion Nodosum.—The **ganglion nodosum**, placed immediately below the preceding, is large and fusiform. Like the jugular ganglion, it supplies two branches—the pharyngeal and superior laryngeal nerves.

The **pharyngeal branch** (usually double) receives its motor fibres (through the ganglion) from the accessory nerve. It passes obliquely downwards and medially to the pharynx between the internal and external carotid arteries, and combines with the pharyngeal branches from the glossopharyngeal and superior cervical ganglion of the sympathetic to form the **pharyngeal plexus**, which lies on the wall of the pharynx at the level of the middle constrictor (Fig. 589, p. 699). From this plexus the muscles of the pharynx and soft palate (except the stylopharyngeus and tensor veli palatini) are supplied. The **lingual branch** is a minute nerve which separates itself from the plexus and joins the hypoglossal nerve in the anterior triangle of the neck.

The **superior laryngeal nerve**, which likewise receives its motor fibres from the accessory nerve, passes obliquely downwards and medially, medial to the external and internal carotid arteries, towards the thyreoid cartilage. It is joined by twigs from the sympathetic and the pharyngeal plexus, and is said to give a filament to the internal carotid artery. It ends by dividing in its course into two unequal parts—a larger internal and a smaller external laryngeal branch.

The **internal laryngeal branch** passes medially into the larynx between the middle and inferior constrictor muscles of the pharynx and through the thyreo-hyoid membrane, in company with the corresponding branch of the superior laryngeal artery. It supplies the mucous membrane of the larynx, reaching upwards to the epiglottis and base of the tongue, and forms communications beneath the lamina of the thyreoid cartilage with the branches of the inferior laryngeal nerve (*ramus anastomoticus cum nervo laryngeo inferiore*).

The **external laryngeal branch** passes downwards beneath the infra-hyoid muscles and upon the inferior constrictor muscle of the pharynx. It supplies branches to that muscle, and ends in the crico-thyreoid muscle.

Communications.—Besides supplying these pharyngeal and laryngeal nerves, this ganglion has the following communications with other nerves: (1) with the superior cervical ganglion of the sympathetic; (2) with the hypoglossal; (3) with the loop between the first and second cervical nerves; and (4) with the accessory nerve. This nerve applies itself to the ganglion, and thereby supplies to the vagus nerve the inhibitory fibres for the heart, as well as the motor fibres for the pharynx, œsophagus, stomach and intestines, larynx and respiratory organs.

Branches of the Vagus in the Neck. — In the neck the vagus nerve supplies cardiac branches and (on the right side) the recurrent (laryngeal) nerve (Fig. 589).

The **superior** or **cervical cardiac branches** are **upper** and **lower.** *On the right side* both cardiac branches pass downwards into the thorax behind the subclavian artery, and proceed alongside the trachea to join the deep cardiac plexus. *On the left side* the two nerves separate on reaching the thorax. The *upper nerve* passes deeply alongside the trachea to join the deep cardiac plexus. The *lower nerve* accompanies the vagus nerve over the aortic arch, along with the superior cervical cardiac branch of the sympathetic, to end in the superficial cardiac plexus.

The **right recurrent (laryngeal) nerve** arises at the root of the neck, as the vagus crosses in front of the first part of the subclavian artery. It hooks round the artery, and passes obliquely upwards and medially behind the subclavian and the common carotid, and either in front or behind the inferior thyreoid artery; it then ascends in the groove between the œsophagus and trachea, along the medial side of the corresponding lobe of the thyreoid gland. It finally disappears beneath the inferior border of the inferior constrictor muscle, and, receiving the name of **inferior laryngeal nerve,** it ends in supplying the muscles of the larynx. In its course it gives off the following branches:—

(1) **Cardiac branches** arise as the nerve winds round the subclavian artery, and course downwards alongside the trachea to end in the deep cardiac plexus. These branches are grouped below with the rami cardiaci inferiores.

(2) **Communicating branches** to the inferior cervical ganglion of the sympathetic arise from the nerve behind the subclavian artery.

(3) **Muscular branches** supply the trachea, œsophagus, and the inferior constrictor of the pharynx.

(4) **Terminal branches** supply the muscles of the larynx (except the crico-thyreoid) and communicate beneath the lamina of the thyreoid cartilage with branches of the internal laryngeal nerve.

Branches of the Vagus in the Thorax.—In the thorax the vagi form the great pulmonary and œsophageal plexuses. The right nerve, in addition, furnishes cardiac branches; and the left nerve gives off the recurrent (laryngeal) nerve.

The **left recurrent (laryngeal) nerve** differs from the nerve of the right side mainly in its point of origin and in the early part of its course. It springs from the vagus as it crosses the aortic arch, and, after hooking round the arch, lateral to the *ligamentum arteriosum,* it passes upwards in the superior mediastinum to the neck, where its course and relations are similar to those of the nerve of the right side. The branches of the nerve are the same as those of the right nerve. The **cardiac branches** are larger, and, arising below the aortic arch, proceed to the deep cardiac plexus.

The **inferior cardiac** or thoracic branches on the right side are derived both from the trunk of the vagus as it lies beside the trachea and from its recurrent branch; on the left side they arise only from its recurrent branch. All join the deep cardiac plexus.

Branches of the Vagus in the Abdomen.—After the formation of the œsophageal plexus the two vagi nerves resume their course, and passing along with the gullet through the diaphragm, terminate by supplying the stomach. The *right nerve* enters the abdominal cavity behind the gullet, and is distributed to the posterior surface of the stomach. It sends communicating offsets to the cœliac, splenic, and renal plexuses of the sympathetic system. The *left nerve* applies itself to the anterior surface and small curvature of the stomach, to which it is distributed. It sends communicating offsets along the small curvature of the stomach to the right vagus, and between the layers of the gastro-hepatic ligament to the hepatic plexus.

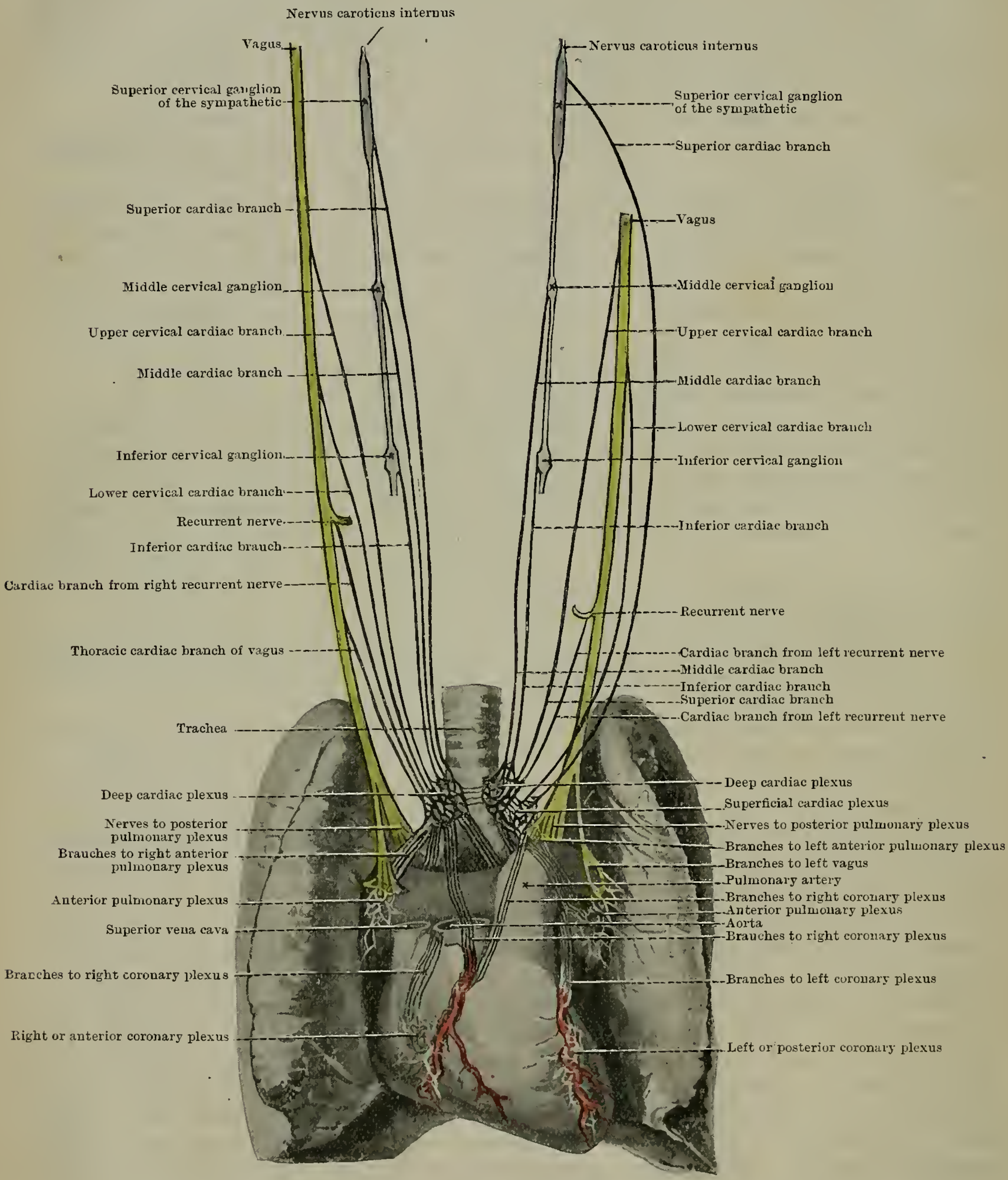

Nervus caroticus internus
Vagus
Superior cervical ganglion of the sympathetic
Superior cardiac branch
Middle cervical ganglion
Upper cervical cardiac branch
Middle cardiac branch
Inferior cervical ganglion
Lower cervical cardiac branch
Recurrent nerve
Inferior cardiac branch
Cardiac branch from right recurrent nerve
Thoracic cardiac branch of vagus
Trachea
Deep cardiac plexus
Nerves to posterior pulmonary plexus
Branches to right anterior pulmonary plexus
Anterior pulmonary plexus
Superior vena cava
Branches to right coronary plexus
Right or anterior coronary plexus
Nervus caroticus internus
Superior cervical ganglion of the sympathetic
Superior cardiac branch
Vagus
Middle cervical ganglion
Upper cervical cardiac branch
Middle cardiac branch
Lower cervical cardiac branch
Inferior cervical ganglion
Inferior cardiac branch
Recurrent nerve
Cardiac branch from left recurrent nerve
Middle cardiac branch
Inferior cardiac branch
Superior cardiac branch
Cardiac branch from left recurrent nerve
Deep cardiac plexus
Superficial cardiac plexus
Nerves to posterior pulmonary plexus
Branches to left anterior pulmonary plexus
Branches to left vagus
Pulmonary artery
Branches to right coronary plexus
Anterior pulmonary plexus
Aorta
Branches to right coronary plexus
Branches to left coronary plexus
Left or posterior coronary plexus

FIG. 590.—THE CARDIAC BRANCHES OF THE VAGUS, AND THE PULMONARY PLEXUSES.

Certain asymmetrical features of the two vagus nerves are explained by a reference to the process of development. The recurrent course of the inferior laryngeal nerves is explained by the absence of neck in the early embryo, and by the primitive aortic arches between which they passed having occupied a higher position before the heart descended into the thorax, when it dragged these branches of the nerves down with it. The corresponding arches (the fourth pair), beneath which they originally passed, develop into the subclavian artery on the right side, the aorta on the left (see Fig. 598, p. 699). The distribution of the right vagus to the posterior surface of the stomach and the left nerve to the anterior aspect is explained by the turning over on its right side of this originally symmetrically situated organ.

Plexus Thoracales.

Of the plexuses formed by the vagus nerves in the thorax—cardiac, pulmonary, and œsophageal—the **cardiac plexuses** are described under the sympathetic system, on p. 787.

Pulmonary Plexuses.—As already stated, the vagus nerve on each side, on reaching the back of the root of the lung, breaks up into numerous plexiform branches for the formation of the posterior pulmonary plexus. From each nerve a few fibres pass to the front of the root of the lung, above its upper border, to form the much smaller anterior pulmonary plexus. These plexuses communicate freely with each other, and are intimately connected with the cardiac plexuses.

The **anterior pulmonary plexus** on each side is joined by a few fibres from the corresponding part of the deep cardiac plexus, and on the left side from the superficial cardiac plexus as well. It surrounds and supplies the constituents of the root of the lung anteriorly.

The **posterior pulmonary plexus,** placed behind the root of the lung, is formed by the greater part of the vagus nerve, reinforced by fine branches from the second, third, and fourth thoracic ganglia of the sympathetic. Numerous branches proceed from it in a plexiform manner along the bronchi and vessels into the substance of the lung.

The Œsophageal Plexus.—The œsophagus in the thorax is supplied by the vagus nerve both in the superior and posterior mediastina. *In the superior mediastinum* it receives branches from the vagus nerve on the right side, and from its recurrent branch on the left side.

In the posterior mediastinum the gullet is surrounded by the œsophageal plexus, formed from the trunks of the vagi nerves emerging from the posterior pulmonary plexuses, which form a large plexus surrounding the gullet. This part of the œsophagus also receives fibres from the greater splanchnic nerve and ganglion. From the œsophageal plexus branches supply the muscular wall and mucous membrane of the œsophagus.

Pericardiac branches are also supplied from the plexus to the posterior surface of the pericardium.

Nervus Accessorius.

The **eleventh** or **accessory nerve** (O.T. **spinal accessory**) consists of two essentially separate parts, different both in origin and in distribution. One, the cerebral or bulbar portion, is **accessory to the vagus nerve,** and arises, in series with the fila of that nerve, from the side of the medulla oblongata; its fibres are contributed to the pharyngeal, laryngeal, and cardiac branches of that nerve. The other, the **spinal portion,** arises from the lateral aspect of the spinal medulla, between the anterior and posterior roots of the spinal nerves, its origin extending from the level of the accessory portion as low as the origin of the fifth or sixth cervical nerve (for the deep origin, see p. 593). This portion of the nerve supplies the sterno-mastoid and trapezius muscles. Successively joining together, the fila form a trunk which ascends in the subdural space of the spinal medulla, posterior to the ligamentum denticulatum, to the foramen magnum. There the two portions unite into a single trunk, which leaves the cranial cavity through the jugular foramen in the same compartment of dura mater as the vagus nerve (Fig. 573, p. 680).

Ramus Internus.—In the jugular foramen the **accessory portion of the nerve** or **internal ramus** (after furnishing a small branch to the jugular ganglion of the vagus) applies itself to the ganglion nodosum, and in part joins the ganglion, in part the trunk of the nerve beyond the ganglion. Its fibres are distributed mainly to the pharyngeal and superior laryngeal branches of the vagus; some probably enter the cardiac branches as well and convey cardio-inhibitory impulses, though there are conflicting views as to this distribution.

Ramus Externus.—The **spinal portion** of the nerve, or **external ramus,** extends into the neck, where at first it lies along with other nerves, in the interval between the internal carotid artery and the internal jugular vein. Passing obliquely downwards and laterally over (sometimes under) the vein, under cover of the posterior belly of the digastric, it descends close beneath the sterno-mastoid muscle, which it supplies as it pierces it on its deep surface. It appears at the posterior border of the muscle, at or below the junction of the upper and middle thirds, and about the level of the upper border of the thyreoid cartilage. After crossing the posterior triangle obliquely downwards the nerve ends by supplying the trapezius muscle on its deep surface. This portion of the nerve *communicates* in three situations with nerves from the cervical plexus—(1) in or beneath the sterno-mastoid, with the branch for the muscle derived from the second cervical nerve; (2) in the posterior triangle, with branches from the third and fourth cervical nerves; (3) beneath the trapezius, with the branches for the muscle derived from the third and fourth cervical nerves.

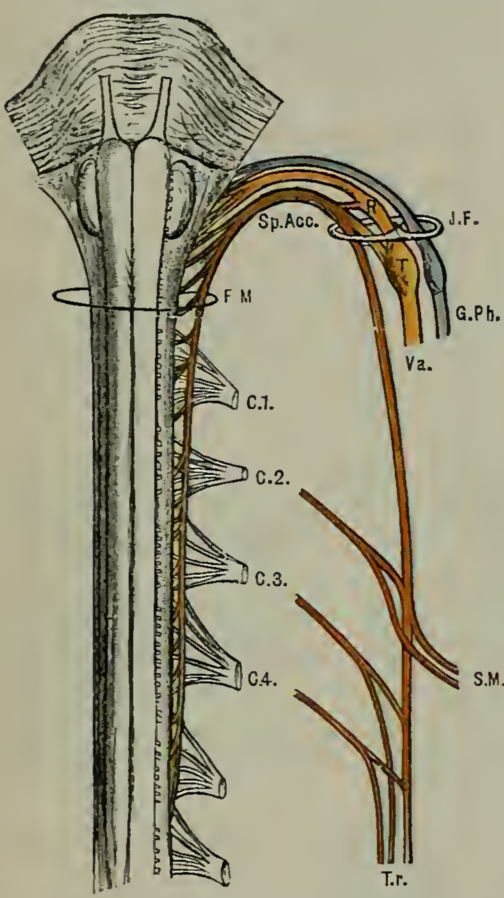


Fig. 591.—Scheme of the Origin, Connexions, and Distribution of the Accessory Nerve.

Sp. Acc., Accessory nerve; C.1-4, First four cervical nerves (posterior roots); Va., Vagus nerve; R, Ganglion jugulare; T, Ganglion nodosum; G.Ph., Glossopharyngeal nerve; S.M., Nerves to sterno-cleido-mastoid; Tr., Nerves to trapezius; F.M., Foramen magnum; J.F., Jugular foramen.

Nervus Hypoglossus.

The **twelfth** or **hypoglossal nerve** is a purely motor nerve, supplying all the muscles of the tongue both intrinsic and extrinsic. It arises by numerous fila radicularia from the front of the medulla oblongata between the pyramid and the olive (Fig. 569, p. 676; for the deep origin, see p. 593). The fila arrange themselves in two bundles which separately pierce the dura mater, and unite in the hypoglossal canal, or after emerging from the skull. In the neck the nerve arches downwards and forwards towards the hyoid bone, and then turns medially among the supra-hyoid muscles to the tongue. At first it is placed deeply, along with other cerebral nerves, on the medial side of the internal jugular vein and internal carotid artery; it then curves forwards round the ganglion nodosum of the vagus, and passes downwards between the above two vessels, lying medial to the digastric and stylo-hyoid muscles. It then crosses the external carotid artery, hooking round the occipital artery, and passes forwards beneath the tendon of the digastric muscle just above the hyoid bone. Above the greater cornu of the hyoid bone the nerve conceals the lingual artery; and it then disappears between the mylo-hyoid and hyoglossus muscles to reach the tongue, in the muscular substance of which it terminates (Fig. 583, p. 690).

Communications.—In its course the hypoglossal nerve has the following communications with other nerves: Near the base of the skull it is connected by small branches with (1) the superior cervical ganglion of the sympathetic; (2) the ganglion nodosum of the vagus; (3) by a larger branch, with the loop between the first two cervical nerves; (4) as it crosses the external carotid artery it receives a communication from the pharyngeal plexus (*lingual branch of the vagus*); and (5) medial to the mylo-hyoid muscle, at the anterior border of the hyoglossus, it forms loops of communication with the lingual branch of the mandibular nerve.

The **branches** of the nerve are: (1) Recurrent; (2) Descending; (3) Thyreo-hyoid; and (4) Lingual.

The **recurrent** (meningeal) **branch** passes from the nerve near its origin to supply the dura mater of the posterior fossa of the base of the skull. It probably derives its fibres from the communication with the first and second cervical nerves.

The descending branch of the hypoglossal nerve is the chief branch given off in the neck. It arises from the hypoglossal nerve as it crosses the internal carotid artery, and descends in the anterior triangle superficial to the carotid sheath. It is joined about the middle of the neck by the **descending cervical nerve** (from the second and third cervical nerves). By their union the **ansa hypoglossi (hypoglossal loop)** is formed, from which branches are distributed to the majority of the infra-hyoid muscles—both bellies of the omo-hyoid, the sterno-hyoid, and the sterno-thyreoid. The descending branch of the hypoglossal nerve derives its fibres from the communication to the hypoglossal nerve from the loop between the first and second cervical nerves; so that the ansa hypoglossi is made up of fibres of the first three cervical nerves.

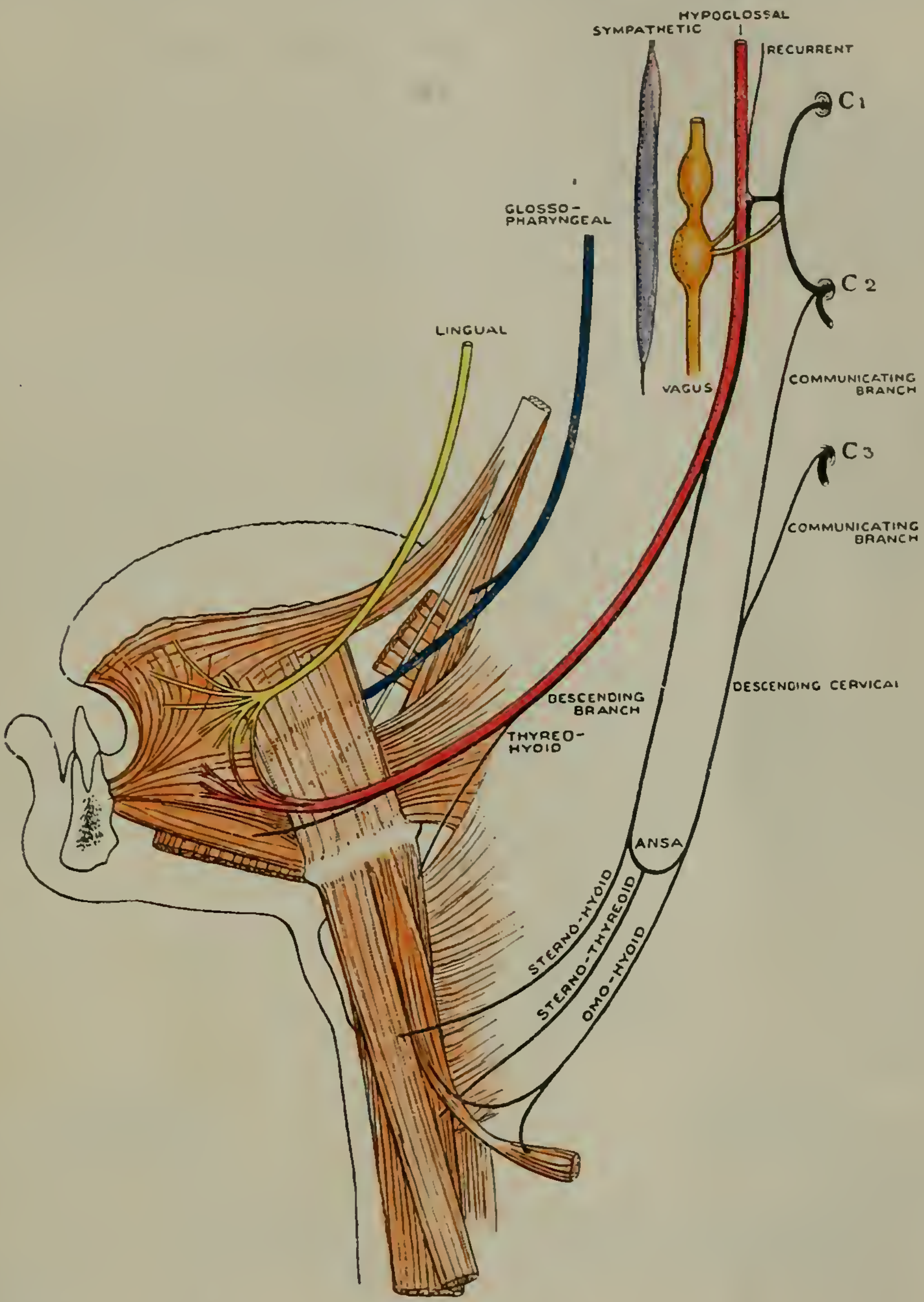


Fig. 592.—The Muscles of the Hyoid Bone and Styloid Process, and the Extrinsic Muscles of the Tongue, with their Nerves.

The nerve to the thyreo-hyoid muscle is a small branch which arises from the hypoglossal nerve before it passes medial to the mylo-hyoid muscle. It descends behind the greater cornu of the hyoid bone to reach the muscle. When traced backwards this nerve is found associated with the loop between the first and second cervical nerves.

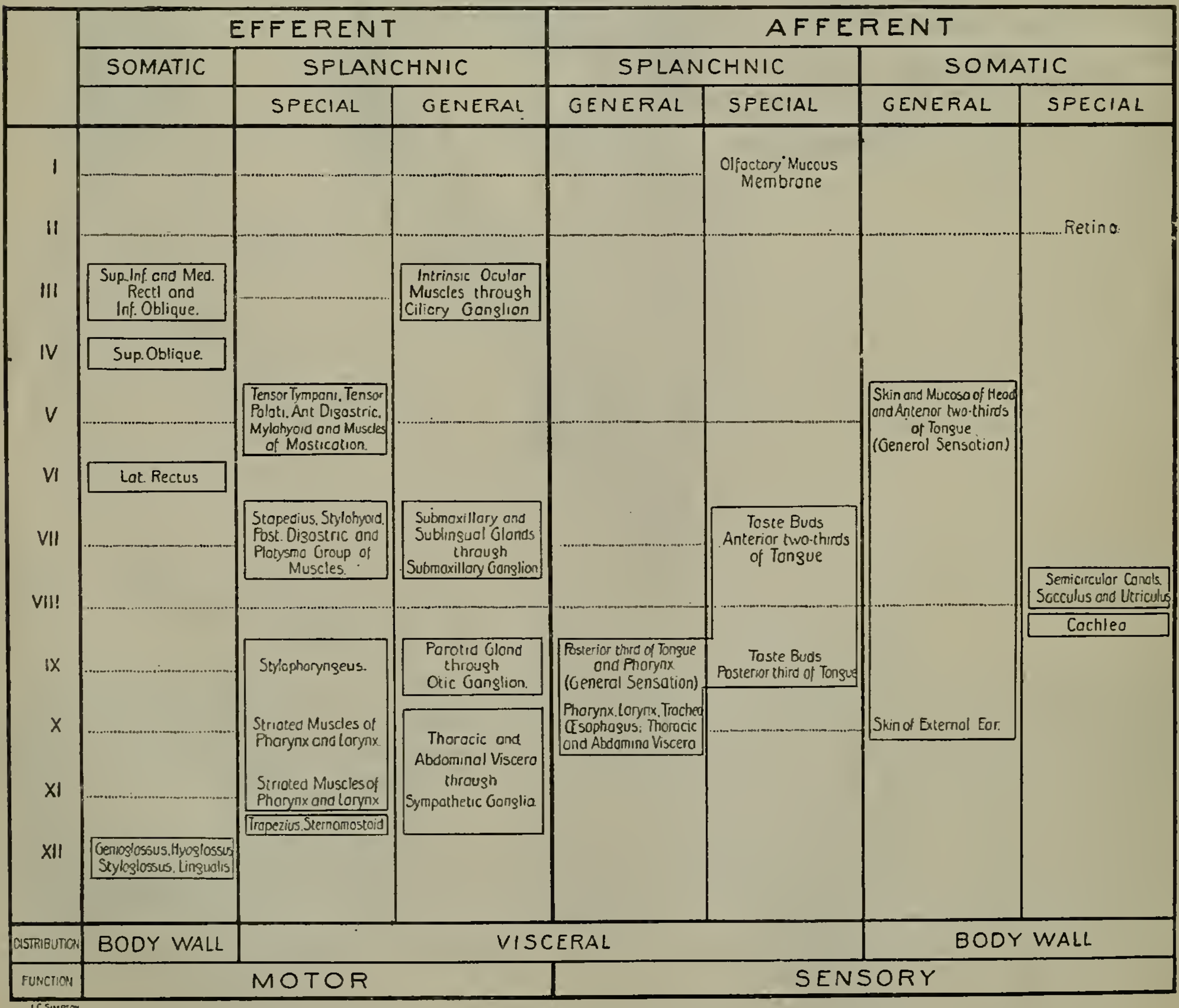
The lingual branches of the hypoglossal nerve are distributed to the hyoglossus, genio-hyoid, and genioglossus, and to all the intrinsic muscles of the tongue. The nerve to the genio-hyoid is said to be derived from the loop between the first and second cervical nerves. It is not known if these two cervical nerves are implicated in the innervation of the proper muscles of the tongue, but it appears certain that the muscles named—the genio-hyoid, thyreo-hyoid, sterno-hyoid, omo-hyoid, and sterno-thyreoid—are not supplied by the hypoglossal, but only by cervical nerves, the genio-hyoid and thyreo-hyoid by the first two, the other muscles by the first three cervical nerves.

COMPONENT FIBRES OF THE CEREBRAL NERVES.

The third, fourth, sixth, eleventh, and twelfth pairs are composed of large and small myelinated fibres; non-myelinated fibres have been found present in the fifth, sixth, ninth, eleventh, and twelfth, of which those in the sixth, eleventh, and twelfth are probably all derived from the sympathetic system (Koch). As regards the function of the fibres, although the cerebral nerves are usually broadly classified as motor and sensory, as well as mixed nerves, it is now recognised that few of them consist exclusively of one or the other order of fibres. The optic nerve itself is described as containing efferent fibres which may control the movements of the retinal elements in response to light. The third, fourth, and sixth nerves are not purely motor in function, as was formerly considered, but contain also some sensory (somatic afferent, proprioceptive) fibres, as well as fibres from the sympathetic system, and the same may prove true for the motor eleventh and twelfth nerves. Indeed the cerebral nerves vary greatly in their functional composition, and, moreover, no nerve, save the olfactory and auditory, is made up of one functional order of fibres.

The animal body is naturally divided into two different areas or regions, the **somatic** area, forming the body wall and limbs, and the **splanchnic** or visceral area, comprising the chief viscera contained within the body cavity. In the head and neck an additional factor has to be considered owing to the presence of the branchial system and its derivatives, for in connexion with this system there have been developed not only an additional set of visceral muscles, requiring motor innervation (*e.g.*, the muscles of mastication, and of the face, palate, and

Functional Composition of Cerebral Nerves.



	EFFERENT			AFFERENT			
	SOMATIC	SPLANCHNIC		SPLANCHNIC		SOMATIC	
		SPECIAL	GENERAL	GENERAL	SPECIAL	GENERAL	SPECIAL
I					Olfactory Mucous Membrane		
II							Retina
III	Sup. Inf. and Med. Recti and Inf. Oblique.		Intrinsic Ocular Muscles through Ciliary Ganglion				
IV	Sup. Oblique.						
V		Tensor Tympani, Tensor Palati, Ant. Digastric, Mylohyoid and Muscles of Mastication.				Skin and Mucosa of Head and Anterior two-thirds of Tongue (General Sensation)	
VI	Lat. Rectus						
VII		Stapedius, Stylohyoid, Post. Digastric and Platysma Group of Muscles.	Submaxillary and Sublingual Glands through Submaxillary Ganglion		Taste Buds Anterior two-thirds of Tongue		
VIII							Semicircular Canals, Sacculus and Utriculus Cochlea
IX		Stylopharyngeus.	Parotid Gland through Otic Ganglion.	Posterior third of Tongue and Pharynx (General Sensation)	Taste Buds Posterior third of Tongue		
X		Striated Muscles of Pharynx and Larynx	Thoracic and Abdominal Viscera through Sympathetic Ganglia	Pharynx, Larynx, Trachea, Œsophagus; Thoracic and Abdomina Viscera		Skin of External Ear	
XI		Striated Muscles of Pharynx and Larynx Trapezius, Sternomastoid					
XII	Genioglossus, Hyoglossus, Styloglossus, Lingualis						
DISTRIBUTION	BODY WALL	VISCERAL				BODY WALL	
FUNCTION	MOTOR			SENSORY			

J C Simpson

Note.—Fibres having a common nucleus of origin or termination are enclosed in a squared outline.

pharynx), but also visceral sense organs (taste buds). In a regional classification of the nerves on these lines those that supply the derivatives of the branchial system may be termed *special* in contrast with the *general* nerves supplying the rest of the visceral area; similarly in the somatic area the introduction of the ear as a specialised sensory area results in the presence of a special set of somatic afferent fibres. Combining the regional distribution with the function of the fibres, motor or *efferent* and sensory or *afferent*, the nerve fibres may be tabulated as follows (after Herrick):—

Sensory: General somatic afferent (sensory from the skin).
Special somatic afferent (the cochlear and vestibular nerves).
General splanchnic afferent (from the visceral mucous membrane).
Special splanchnic afferent (from organs of taste).
Motor: General splanchnic efferent (to the involuntary musculature).
Special splanchnic efferent (to the branchial muscles).
General somatic efferent (to the skeletal muscles).

It is worthy of note that such a classification serves rightly to emphasise the central connexion, practical continuity, and function of the peripheral nervous system as a whole, since many of the fibre paths designated under this nomenclature traverse both the usually demarked cerebro-spinal and sympathetic systems in reaching their destinations.

On such a basis the **functional composition** of the cerebral nerves is shown in the preceding table.

DEVELOPMENT AND MORPHOLOGY OF THE CEREBRAL NERVES.

In the early human embryo, when the neural plate is folded in to form the neural tube, the cells forming its lateral margins are left as a **neural crest** or ganglion ridge, lying above the tube and connecting it with the surface ectoderm. From the cells of this crest there are developed not only all of the cerebro-spinal and sympathetic ganglia, together with the chromaffin bodies, but all of the *sensory* fibres of the cerebro-spinal system (except those of the first and second cerebral nerves and a few fibres in connexion with the seventh, ninth, and tenth nerves to be mentioned later), whilst from the walls of the **neural tube** all of the *motor* fibres arise.

At a later stage the lateral walls of the neural tube become differentiated into three layers, the **ependymal, mantle**, and **marginal zones**; and the neural canal is somewhat rhomboidal in transverse section, its lateral angles marking the subdivision of the walls into a dorsal part, the **alar lamina**, and a ventral part, the **basal lamina**. Into the alar lamina grow the central processes of the cells situated in the cerebro-spinal ganglia, which have been derived from the neural crest, and it may, therefore, be considered sensory or *afferent* in function, whilst the basal lamina, from whose cells there grow out long peripheral fibres, may be termed motor or *efferent*. Furthermore, in the middle or mantle zone (gray matter) of each lamina the developing neuroblasts become arranged in two longitudinal columns, one having **somatic** (body wall) and the other **splanchnic** (visceral) peripheral connexions. Thus the gray matter of each lateral wall of the neural tube shows four longitudinal cell-columns, which, from their presence throughout the whole length of the neural tube, their peripheral connexions, and their functions may be called:—

1. General somatic afferent cell-column } in the Alar lamina,
2. General splanchnic afferent cell-column }
3. General splanchnic efferent cell-column } in the Basal lamina,
4. General somatic efferent cell-column }

corresponding to Gaskell's four primary functional divisions of the activities of the organism.

In the hind- and mid-brain regions, however, other cell columns are added, consequent upon the presence of (1) the great **special sense organs** (nose, eye, ear) which demand specialised somatic sensory (afferent) connexions, and (2) the **branchial system** and its derivatives which, as a specialised part of the visceral area, demand special splanchnic connexions, both sensory (afferent) and motor (efferent). In the developing brain-stem, therefore, three additional cell columns are to be found:—

1. Special somatic afferent cell column } in the Alar lamina,
2. Special splanchnic afferent cell column }
3. Special splanchnic efferent cell column in the Basal lamina.

As is pointed out above in the discussion of their components, few of the cerebral nerves are composed exclusively of fibres of one functional order; in most, however, there is such a preponderance of one type that we are justified in grouping them into three series:—

Somatic Afferent.	**Somatic Efferent.**	**Splanchnic Afferent and Efferent.**
I. Olfactory.	III. Oculo-motor.	V. Trigeminal.
II. Optic.	IV. Trochlear.	VII. Facial.
VIII. Acoustic.	VI. Abducens.	IX. Glossopharyngeal.
	XII. Hypoglossal.	X. Vagus.
		XI. Accessory.

Though this grouping is purely *functional*, it is, as we might expect, reflected anatomically in development, for the somatic afferent group of nerves (I., II., and VIII.) is connected with the alar lamina, corresponding in this respect to the dorsal roots of the spinal nerves, whilst the somatic efferent group (III., IV., VI., and XII.) arises from the medial part of the basal lamina in line with the ventral roots of the spinal nerves. The splanchnic group (V., VII., IX., X., and XI.), which is composed of sensory and motor nerves specialised in connexion with the branchial system, forms an intermediate series lying between the other two. It must be said, however, that though there is some degree of correspondence between cerebral and spinal nerves, any attempt to show a strict homology leads to insuperable difficulties.

Somatic Afferent Group.

Of the three cerebral nerves composing this group, the eighth only is developed from the neural crest, and is to that extent comparable to the dorsal root of a spinal nerve. It is quite probable, however, that some of its fibres come from cells developed from the ectoderm of the auditory vesicle, and, moreover, its distribution is limited to a specialised sensory area of the ectoderm. The first and second nerves are developed in connexion with outgrowths of the brain; indeed, as we shall see, neither of them is strictly comparable to any of the other nerves, cerebral or spinal.

I. Olfactory Nerve.—At the end of the fourth week an olfactory plate becomes differentiated in the ectoderm lying under the forebrain on each side. By the growth of the medial and lateral nasal processes around it, this plate comes to form the roof of the olfactory pit. The sensory cells of the plate now take on the character of true nerve cells, and send in basal fibres which arborise about the cells of the olfactory bulb. At first the olfactory plates are directly in contact with the bulb, which is developed from the forebrain, but later, by the development of the cribriform plate and meninges, they become pushed apart, and the fibres connecting them are lengthened to form the true olfactory nerves. These nerves are peculiar in that, though sensory, they have no ganglia; the cells giving rise to their fibres remain in the surface epithelium, and the fibres themselves are unmyelinated.

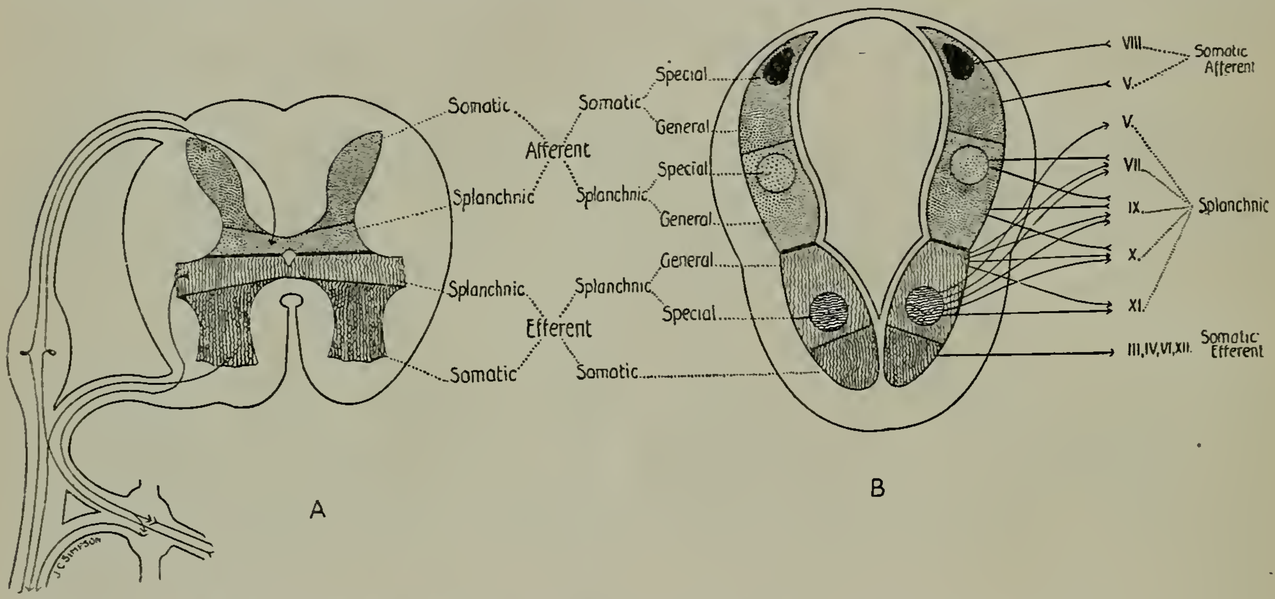


Fig. 593.—Scheme showing a Comparison of the Origins and Composition of the Nerve Roots from the Spinal Medulla and Hind-Brain.

A. Spinal medulla; B. Hind-brain.

II. Optic Nerve.—The optic nerve is developed in the stalk of the optic vesicle, an outgrowth from the forebrain, and, morphologically, is a part of the central nervous system. When the optic cup is formed (see under Development of the Eye) its inner, or retinal, layer becomes differentiated into the rods and cones (the true neuro-epithelial cells, corresponding to the olfactory cells) and nerve cells, the processes of which grow back along the optic stalk to form the optic nerve, chiasma, and tract. These nerve cells are true intermediate cells, corresponding to those of the gray matter of the central nervous system, and their fibres are largely supported by neuroglia.

VIII. Acoustic Nerve.—The internal ear first arises as an ectodermal plate lying dorsal to the first branchial cleft. This plate invaginates to form a flask-like auditory vesicle (otocyst) from the lining cells of which patches of neuro-epithelium are later differentiated. The vestibular and cochlear ganglia develop between the vesicle and the hind brain in close association with the genicular ganglion of the seventh nerve. Although the origin of the common mass is usually said to be from the neural crest, it is probable that some at least of the cells going to form the acoustic ganglia are derived from the neuro-epithelium of the auditory vesicle. The ganglia grow in direct proportion to the vestibular and cochlear outgrowth of this vesicle, and their central and peripheral fibres form the vestibular and cochlear nerves.

Somatic Efferent Group.

The hypoglossal nerve and the three nerves to the eye muscles all arise from the somatic efferent cell column in the basal lamina of the neural tube, and on this account, as well as by reason of the fact that they innervate somatic muscles, are usually considered as being in series with the ventral roots of the spinal nerves.

Though the primitive vertebrate head undoubtedly was segmental, little reliable evidence remains upon which to base a reconstruction of its segmentation, and various investigators have placed the number of the primitive cephalic segments between eight and nineteen. No distinct myotomes are visible in the head of the human embryo, but a study of the lower vertebrates leads to the conclusion that the pre-muscle mass from which the extrinsic ocular muscles are developed represents the first three cephalic myotomes. The first myotome forms the superior, inferior and medial recti and the inferior oblique, supplied by the oculo-motor nerve; the second myotome forms the superior oblique, supplied by the trochlear nerve; and the third forms the lateral rectus, supplied by the abducent (see Fig. 413, p. 496).

Similar studies tend to show that the intrinsic muscles of the tongue are derived from the last three cephalic myotomes. Between these two sets of persisting myotomes (ocular and lingual) there is a gap which probably represents three or more myotomes which have disappeared.

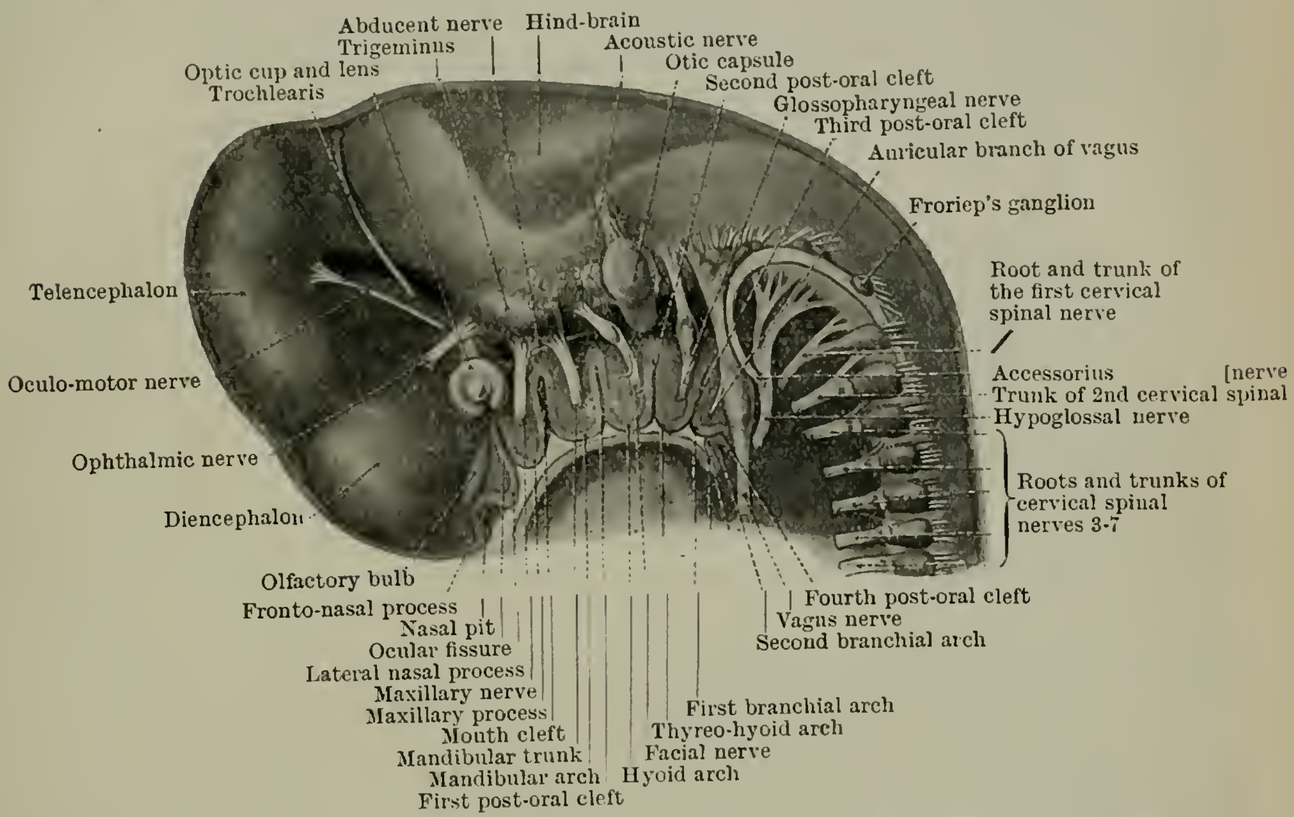


Fig. 594.—The Embryological Arrangement of the Cerebral Nerves. (Modified from Mall.)

III. Oculo-motor Nerve.—This nerve arises from neuroblasts in the basal lamina of the mid-brain. The fibres emerge in small bundles from the ventral surface of the lamina and converge to form the trunk of the nerve, which runs to the premuscle mass from which the extrinsic muscles of the eye (with the exception of the superior oblique and lateral rectus) are formed.

IV. Trochlear Nerve.—The neuroblasts from which this nerve arises lie just caudal to and in line with the nucleus of the third nerve. Instead of leaving the basal lamina by its ventral surface, however, the fibres grow dorsally, curve round the neural canal (aqueduct) and crossing above it, emerge on the opposite side at the junction of the mid- and hind-brain.

VI. Abducent Nerve.—The nucleus of origin lies in the basal lamina of the hind-brain under the floor of the fourth ventricle. The fibres emerge at a point caudal to the future pons and run to the rudiment of the lateral rectus muscle.

XII. Hypoglossal Nerve.—The twelfth is a compound nerve representing the fused motor nerves of three, or possibly more, precervical neural segments. Its fibres take origin from neuroblasts in the somatic efferent cell column and emerge from the walls of the basal lamina in several groups; they then converge ventrally to form the trunk of the nerve and grow upwards to end in the muscle rudiment of the tongue.

Splanchnic (Afferent and Efferent) Group.

The nerves of this group are essentially related to the **branchial arches**. In the embryo each of these arches contains a muscle plate which differs from the myotomes in that it is developed from splanchnic mesoderm. Associated with each arch is a nerve which contains both afferent and efferent fibres, and runs along the upper or cephalic border of the arch; this nerve sends a small branch (*pretrematic*) around the dorsal end of the gill cleft to run along the lower, or caudal, border of the arch in front of the one from which it arises. The nerve of the first or mandibular arch is the mandibular division of the trigeminal nerve; the nerve of the second arch is the facial, and that of the third is the glossopharyngeal; the nerves of the remaining arches are fused to form the vagus and accessory nerves.

The nerve of each arch has a ganglion developed on its root, and supplies (1) motor (special splanchnic efferent) fibres to the muscle plate, and (2) sensory (general splanchnic afferent) fibres to the pharyngeal mucosa covering the inner surface of the arch and of the branchial cleft in front of it.

Furthermore, in connexion with the branchial system there are in the human embryo vestiges of a series of sense organs which have been lost by the higher vertebrates. These are small areas of modified ectoderm which are found at the dorsal end of each branchial cleft and are known as epibranchial **placodes**. During the fifth week of embryonic development the placodes are in contact with the ganglia of the facial, glossopharyngeal, and vagus nerves, and contribute cells to the formation of their ganglia (genicular, petrous, and nodosum).

Whilst the nerves of the splanchnic group typically do not possess somatic afferent fibres, the trigeminal, in conformity with the large part taken by the first arch in the formation of the face, receives a preponderance of this type of fibre. In reality, however, the trigeminal is a double nerve, and the present tendency is to regard its branchial part as a separate nerve, the masticator; and the remainder as a somatic sensory nerve. The vagus nerve also contains a limited number of somatic afferent fibres which supply the skin around the persistent dorsal part of the first branchial cleft, that is, the external acoustic meatus.

V. Trigeminal Nerve.—The semilunar ganglion arises very early from the neural crest at the extreme cranial end of the hind-brain. Central processes from its cells form the large sensory root of the nerve, and, reaching the hind-brain at the level of the pontine flexure, divide to run up and down in the alar plate, where the descending fibres form the spinal tract of the fifth nerve. The peripheral fibres separate into three large divisions which grow out into the three processes taking part in the formation of the face (the fronto-nasal, maxillary, and mandibular processes) and form the three divisions of the adult nerve.

The motor fibres arise from the special splanchnic efferent column of the basal lamina, where the cell bodies form a dorsal nucleus lying opposite the point at which the sensory fibres enter the brain. The motor fibres emerge as a distinct trunk in the embryo, and, coursing along the medial side of the semilunar ganglion, run to the muscle plate of the first arch which later forms the muscles of mastication. It is this part of the nerve which forms the true branchial nerve.

VII. Facial Nerve.—The facial is composed mainly of motor fibres which arise from a nucleus in the special splanchnic efferent column of the basal lamina. Growing out from this nucleus they emerge from the hind-brain just medial to the acoustic ganglion and run to the muscle plate of the second or hyoid arch from which the platysma group of muscles is later developed. At first the fibres run directly from their nucleus of origin to the lateral surface of the hind-brain, passing above (rostal to) the nucleus of the abducent nerve. Later, however, the facial nucleus shifts downwards (caudally) and ventro-laterally towards the sensory nuclei of the solitary tract and the spinal tract of the trigeminal nerve, following the general law of neurobiotaxis that the chief dendrite and body of a neurone tend to move towards the source of the majority of their afferent impulses.

The sensory fibres are developed from the genicular ganglion, which is derived from the neural crest and lies in close association with the ganglia of the acoustic nerve. It is probable that certain cells are also contributed to this ganglion by the epibranchial placode of the first branchial cleft. The central fibres enter the alar plate and form, together with fibres from the glossopharyngeal nerve, the solitary tract. The peripheral fibres run in front of the branchial cleft and form the chorda tympani and great superficial petrosal nerves which represent the pretrematic branch of the facial nerve.

IX. Glossopharyngeal Nerve.—The motor fibres arise from the large nucleus ambiguus, which is a common nucleus of origin for the motor fibres of the glossopharyngeal, vagus, and accessory nerves and lies in the special splanchnic efferent column in line with the motor nuclei of the fifth and seventh nerves. Emerging from the hind brain they grow out ventrally to meet the muscle plate of the third arch, and eventually supply the pharyngeal muscles derived from this element.

The sensory fibres, which form the larger part of the nerve, are derived from two ganglia, the superior or root ganglion, developed from the neural crest, and the petrosal or trunk ganglion, formed in part from the neural crest, and in part from an epibranchial placode with which it is in contact. Centrally the fibres enter the alar lamina and join fibres from the facial and vagus to form the solitary tract. Most of the peripheral fibres from the ganglia run ventrally to enter the third arch, passing, as a lingual branch, to that part of the tongue which is later developed from it. Some of the peripheral fibres, however, form a pretrematic branch in front of the second branchial cleft, and, as the tympanic nerve, supply the structures derived from the dorsal extremity of the first branchial cleft (tympanum, etc.).

X. Vagus.—The vagus is a composite nerve representing, with the accessory, the union of the nerves of all the branchial arches behind the third. Its sensory fibres, therefore, grow out from several root ganglia developed from the neural crest. The jugular ganglion is the most cephalic of these; the others are vestigial and are called accessory ganglia. The trunk ganglion (ganglion nodosum), like the trunk ganglion of the glossopharyngeal, is developed in contact with an epibranchial placode, and in all probability receives cells from this source as well as from the neural crest. The central fibres grow towards the alar lamina, and, entering it, turn downward to form, in conjunction with fibres from the facial and glossopharyngeal nerves, the solitary tract. The peripheral fibres grow downward to form the bulk of the vagus nerve.

The motor fibres arise from two nuclei in the basal lamina, the nucleus ambiguus in the special splanchnic efferent column, and a dorsal motor nucleus, which lies in the general somatic efferent column. The fibres from these two sources emerge laterally in two separate bundles and join the sensory fibres to form the trunk of the nerve. Those from the nucleus ambiguus grow out to the muscle plates of the fourth and succeeding arches, from which the laryngeal and part of the pharyngeal muscles are developed. The fibres from the dorsal nucleus run to the sympathetic plexuses of the vagus.

XI. Accessory Nerve.—This nerve is closely associated with the vagus; both embryologically and morphologically it may be regarded as the caudal part of the vagus complex which has become specialised in connexion with the assumption of a new rôle by the branchial muscles which it supplies, these muscles (sternomastoid and trapezius) having been pressed into service as limb-girdle muscles.

The motor fibres, of which alone it is composed, arise from two sources. The larger number grow out from cell groups which are developed in the lateral horn of the upper four or more cervical segments of the spinal medulla (special splanchnic efferent column) in series with the nucleus ambiguus of the tenth. Emerging from the cord laterally, these fibres run upwards along the line of the neural crest as the spinal accessory trunk to join the vagus. Leaving this nerve after a short course, however, they run to their destination. A few fibres of the accessory nerve arise from cells in the dorsal motor nucleus of the vagus, and after pursuing a short course with the accessory proper rejoin the vagus and are distributed to its plexuses.

II. THE SPINAL NERVES.

The spinal nerves are characterised by being attached to the medulla spinalis and by passing from the vertebral canal through the intervertebral foramina. There are usually thirty-one pairs, which are grouped as cervical, thoracic, lumbar, sacral, and coccygeal, in relation to the vertebræ between which they emerge. There are eight cervical nerves, the first passing out of the vertebral canal between the occipital bone and the atlas, and the last appearing between the seventh cervical and first thoracic vertebræ; the other cervical nerves are numbered in correspondence with the vertebræ *above* which they emerge from the canal. There are twelve thoracic, five lumbar, five sacral nerves, and one coccygeal nerve, all appearing *below* the corresponding vertebræ.

The thirty-first nerve is occasionally absent; and there are sometimes one or two additional pairs of minute filaments below the thirty-first, which, however, do not emerge from the vertebral canal. These are rudimentary caudal nerves.

The size of the spinal nerves varies. The largest are those which take part in the formation of the great nerve trunks of the limbs (lower cervical and first thoracic, and lower lumbar and upper sacral nerves); and of these the nerves destined for the lower limbs are the larger. The coccygeal nerve is the smallest of the spinal nerves; the thoracic nerves (except the first) are more slender than the limb nerves; and the cervical nerves diminish in size from below upwards.

Origin of the Spinal Nerves.—Each nerve is attached to the spinal medulla by two roots, one of which is ganglionic and the other not; they are called respectively **posterior** (dorsal, sensory, or afferent) and **anterior** (ventral, motor, or efferent).

The **posterior root** is larger than the anterior root; it contains a larger number of radicular fibres, and the individual fibres are of larger size than in the anterior root. It has a vertical linear attachment to the postero-lateral sulcus of the spinal medulla. The fibres of contiguous posterior roots are in close relation, and, in some instances, overlap. The posterior root separates, as it passes away from the spinal medulla, into two bundles, both of which become connected with the proximal end of a **spinal ganglion**. From the distal end of this ganglion the posterior root proceeds to its junction with the anterior root in the intervertebral foramen.

The **spinal ganglia** are found on the posterior roots of all the spinal nerves. (In the case of the first cervical or sub-occipital nerve, the spinal ganglion may be rudimentary or absent; and the posterior root itself may be wanting, or derived from the accessory nerve.) They occupy the intervertebral foramina, except in the case of the sacral and coccygeal nerves, the ganglia of which lie *within* the vertebral canal; and the first and second cervical nerves, the ganglia of which lie upon the vertebral arches of the atlas and epistropheus respectively. With the exception of the coccygeal ganglia they are outside the cavity of the dura mater, but are invested by the membrane. The ganglia are of ovoid form, bifurcated in some cases at their proximal ends. They consist of unipolar nerve-cells, whose axons, after a very short course, divide into central (root) and peripheral (trunk) fibres. The central fibres form the portion of the root entering the spinal medulla; the peripheral fibres are continued in a lateral direction from the ganglion into the spinal nerve.

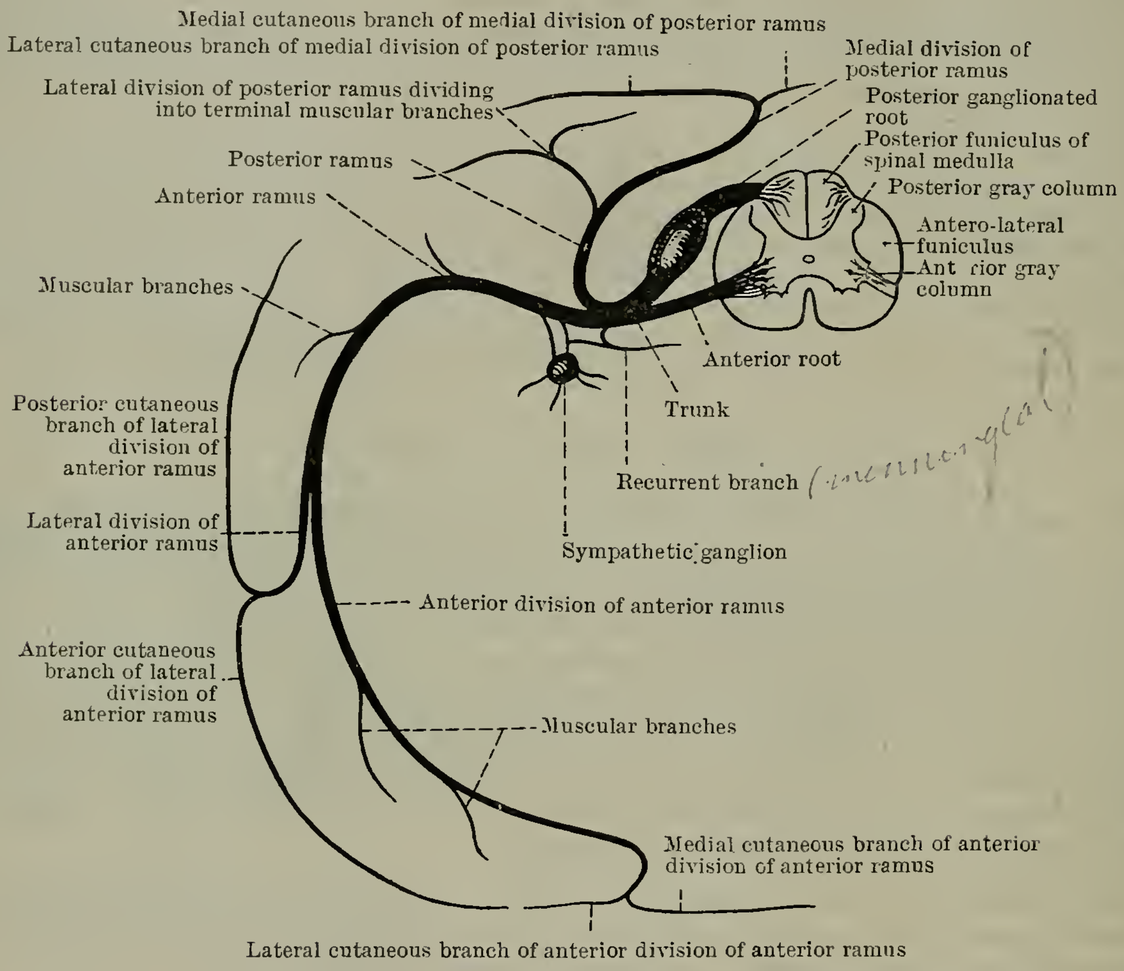

Medial cutaneous branch of medial division of posterior ramus
Lateral cutaneous branch of medial division of posterior ramus
Medial division of posterior ramus
Lateral division of posterior ramus dividing into terminal muscular branches
Posterior ganglionated root
Posterior funiculus of spinal medulla
Posterior ramus
Posterior gray column
Anterior ramus
Antero-lateral funiculus
Anterior gray column
Muscular branches
Anterior root
Posterior cutaneous branch of lateral division of anterior ramus
Trunk
Recurrent branch
(meningeal)
Lateral division of anterior ramus
Sympathetic ganglion
Anterior division of anterior ramus
Anterior cutaneous branch of lateral division of anterior ramus
Muscular branches
Medial cutaneous branch of anterior division of anterior ramus
Lateral cutaneous branch of anterior division of anterior ramus

FIG. 595.—DIAGRAM OF THE ORIGIN AND DISTRIBUTION OF A TYPICAL SPINAL NERVE.

Note that the medial division of the posterior ramus is represented as distributed to skin, whilst the lateral division terminates at a deeper level in muscle; in some situations the reverse condition occurs. The medial and lateral divisions of all posterior rami supply muscles.

Ganglia Aberrantia (aberrant spinal ganglia).—Between the spinal ganglion and the spinal medulla small collections of cells are occasionally found on the posterior roots, either as scattered cells or distinct ganglia. They are most frequently met with on the posterior roots of the lumbar and sacral nerves.

The **anterior root** is smaller than the posterior root. It arises from the anterior surface of the spinal medulla (*anterior root zone*) by means of scattered bundles of nerve-fibres, which occupy a greater horizontal area and are more irregular in their arrangement than the radicular fibres of the posterior root. It possesses no ganglion in its course. The rootlets sometimes overlap, and are not infrequently connected with neighbouring radicular fibres above and below.

The dorsal and ventral roots, from their attachment to the spinal medulla, proceed laterally in the vertebral canal towards the intervertebral foramina, where they unite to form the spinal nerve. The direction of the roots of the first two nerves is upwards and laterally; the roots of the remaining nerves course obliquely downwards and laterally, the obliquity gradually increasing until, in the case of the lower lumbar, the sacral and coccygeal nerve-roots, their course is vertically downwards in the vertebral canal. The collection of nerve-roots which occupies the lower part of the canal, below the first lumbar vertebra, and comprises all the nerve-roots below those of the first lumbar nerve, is designated the **cauda equina.**

They arise from the lumbar enlargement and conus medullaris, and surround the filum terminale of the spinal medulla.

Within the vertebral canal the nerve-roots are in relation with the meninges of the spinal medulla, and are separated from one another by the ligamentum denticulatum, and, in the neck, by the spinal part of the accessory nerve. Each receives a covering of pia mater, continuous with the neurilemma; the arachnoid invests each root as far as the point where it meets with the dura mater; and each root pierces the dura mater separately. The two roots are thereafter enclosed in a single tubular sheath of dura mater, in which is included the spinal ganglion of the posterior root. The spinal nerve thus ensheathed occupies the intervertebral foramen (except the first two cervical and the sacral and coccygeal nerves).

Divisions of a Spinal Nerve.—After emerging from the intervertebral foramen the nerve immediately divides into two primary divisions, named respectively the **posterior** and **anterior rami**. Just before its division each nerve gives off a minute **meningeal (recurrent) branch**, which re-enters the vertebral canal after effecting a junction with a branch from the sympathetic trunk, and is distributed to the spinal medulla and its membranes.

The **posterior** and **anterior rami** of the spinal nerves are mainly somatic in their distribution, and are responsible for the innervation of the skeletal muscles and of the skin covering the trunk and limbs.

The posterior and anterior rami of the nerves contain fibres from both posterior and anterior roots. Indeed, each root can be seen, on removal of its sheath, to divide into two portions, of which one portion enters into the formation of the posterior ramus, the other into the formation of the anterior ramus. The posterior rami, with the exception of the first two, are smaller than the anterior rami. They are responsible for the innervation of the skin and axial muscles of the back. They do not supply the muscles of the limbs, although in their cutaneous distribution they are prolonged on to the back of the head, the shoulder, and the buttock. They form two small plexuses—the **posterior cervical** and the **posterior sacral plexuses**. The anterior rami are, with the exception of the first two cervical nerves, much larger than the posterior rami. They supply the sides and anterior parts of the body, the limbs, and the perineum. For the most part they have a complicated arrangement. The thoracic or intercostal nerves alone have a simple mode of distribution; the other nerves give rise to the three great **plexuses—cervical, brachial,** and **lumbo-sacral.**

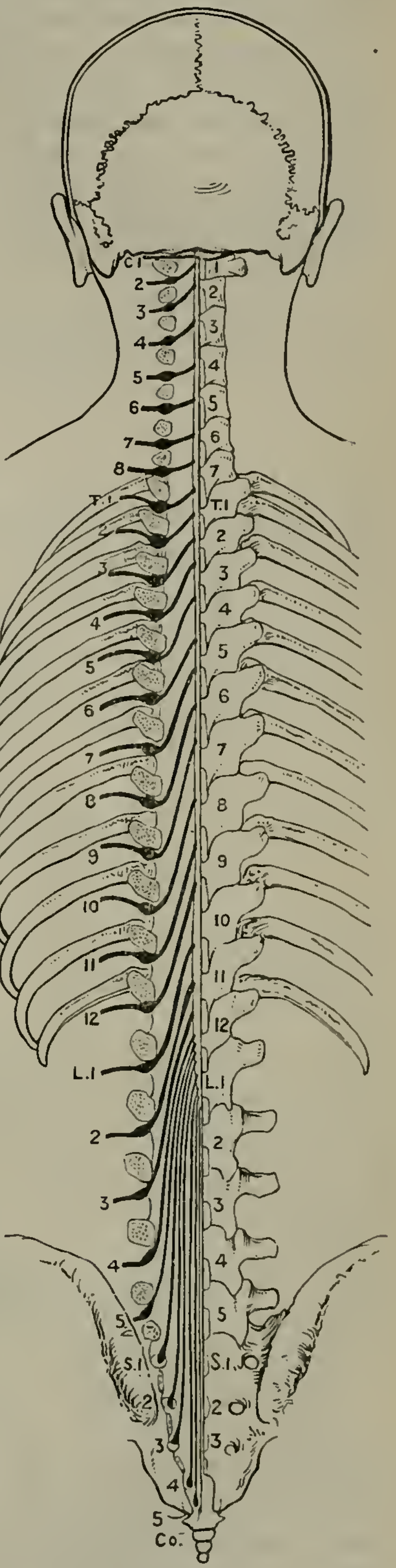


Fig. 596.—Diagrammatic Representation of the Origin of the Spinal Nerves, showing the position of their roots and ganglia respectively in relation to the vertebral column. The nerves are shown as thick black lines on the left side.

White Rami Communicantes.—From the anterior rami of certain nerves (first or second thoracic to second lumbar inclusive) a series of fine nerves arises, which serves to connect the spinal with the sympathetic system. These **visceral** or **splanchnic branches**, or **white rami communicantes**, through the medium of the gangliated trunk of the sympathetic, serve to innervate the vessels and viscera in the splanchnic area. A second stream of **pelvic splanchnic nerves**, associated with the second and third, or third and fourth sacral nerves, connects these spinal nerves with the pelvic sympathetic plexuses (p. 790).

Distribution of the Spinal Nerves.—Although the distribution, like the origin of the spinal nerves, presents primarily and essentially a segmental arrangement, this is masked, and in some instances obliterated, by developmental changes in the parts supplied. In no region can an isolated nerve be traced to a complete segment. The nearest approach to a complete girdle of innervation is found in the thoracic region, in such a nerve as the sixth thoracic nerve. Yet even such a nerve is not distributed to any part entirely alone. In its cutaneous distribution it supplies a complete belt of skin, a distinctly segmental area from the median plane posteriorly to the median plane anteriorly; yet at the same time the adjacent nerves overstep, so to speak, the boundaries of the area and assist in the cutaneous nerve supply. Its muscular distribution, also, is segmental; the anterior ramus supplies the intercostal muscles of the space in which it lies; but in this it forms communications with adjacent nerves. The posterior ramus supplies axial muscles of the back, not, however, in an obviously segmental manner, on account of the fusion of the segmental myotomes in the formation of complex longitudinal muscles, which are together supplied by the series of muscular branches derived from the posterior rami of contiguous nerves. In other regions still greater changes of structure are accompanied by deviations from a segmental type of distribution, causing the foundation of the nerve-plexuses by which the trunk and limbs are innervated.

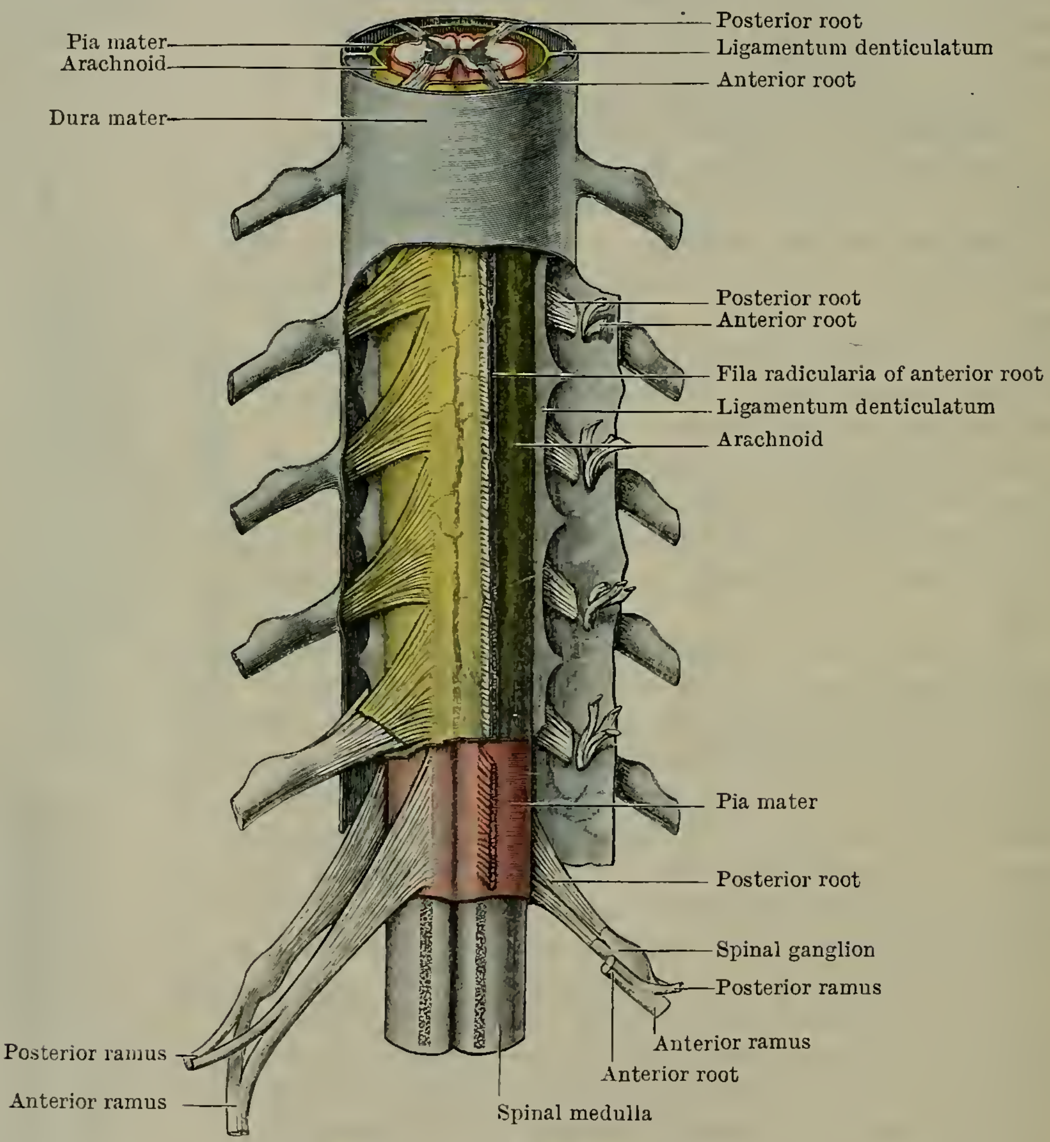


Fig. 597.—Scheme of the Arrangement of the Membranes of the Spinal Medulla and the Roots of the Spinal Nerves.

POSTERIOR RAMI OF THE SPINAL NERVES.

The **posterior rami** of the spinal nerves innervate both skin and muscles; the skin of the trunk posteriorly, the back of the head, the shoulder and the buttock, and the longitudinal muscles of the back, but not the muscles of the limbs.

Each posterior ramus divides as a rule into two parts, a **medial** and a **lateral trunk** (Fig. 595, p. 712). In the upper half of the body the medial trunks generally supply the cutaneous branches, while the lateral trunks are purely muscular nerves. In the lower part of the body the opposite is the case: the lateral trunks provide the cutaneous nerves and the medial trunks are distributed entirely to muscles. The cutaneous branches have a different course in the two cases. In the upper half of the back they course backwards beneath and among the muscles to within a short distance of the spinous processes of the vertebræ, close to which they become superficial. They then extend laterally in the superficial fascia. In the lower half of the back the cutaneous nerves are directed downwards and laterally among the muscles, and become superficial at a greater distance from the median plane. In both regions the nerves pursue a sinuous course to the surface, and the lower series emerge and become superficial a considerable distance below the level of their spinal origin. There are considerable individual differences in the origin, course, and distribution of the several nerves.

CERVICAL NERVES.

First Cervical Nerve (N. sub-occipitalis).—It has already been pointed out that the posterior root of this nerve may be very small, or even absent altogether. Its posterior ramus is larger than the anterior ramus; it does not divide into medial or lateral branches, and it does not directly supply any cutaneous branch.

Passing backwards, in the space between the occipital bone and the posterior arch of the atlas, the nerve occupies the sub-occipital triangle, and is placed below and behind the vertebral artery, and under cover of the semispinalis capitis muscle. It supplies the following branches:—

(*a*) **Muscular branches** to the semispinalis capitis (O.T. complexus), rectus capitis posterior major and minor, and obliqui capitis, superior and inferior.

(*b*) A **communicating branch** descends to join the second cervical nerve.

The communicating branch may arise in common with the nerve to the obliquus inferior, and reach the second cervical nerve by piercing or passing superficial or deep to that muscle; or it may accompany the nerve to the semispinalis capitis and communicate with the greater occipital nerve, under or over that muscle.

Second Cervical Nerve.—The posterior ramus of this nerve is larger than the corresponding anterior ramus. It passes backwards between the atlas and epistropheus, and in the interval between the obliquus inferior and the semispinalis cervicis muscles, under cover of the semispinalis capitis muscle. In this situation the nerve gives off several small muscular and communicating branches. The main trunk, after piercing the semispinalis capitis and trapezius muscles, accompanies the occipital artery to the scalp as the **greater occipital nerve.** This is the chief cutaneous nerve for the posterior part of the scalp. It enters the superficial fascia at the level of the superior nuchal line of the occipital bone and about an inch from the external occipital protuberance. Ramifying over the surface, it supplies the skin of the scalp as far as the vertex. It *communicates* on the scalp with the following nerves: great auricular, lesser occipital, posterior auricular, and third occipital.

The **muscular branches** of the second cervical nerve are destined for the semispinalis capitis, obliquus inferior, semispinalis cervicis, and multifidus.

Its **communicating branches** form the **posterior cervical plexus.** Descending over the posterior arch of the atlas is a branch from the sub-occipital nerve which forms a loop or network with a branch of the second nerve. From this loop twigs are supplied to the surrounding muscles. A similar loop is formed by a communication between branches of the second and third nerves, from which muscles are also supplied. Occasionally an additional loop is formed between branches of the third and fourth nerves.

Third Cervical Nerve.—This is much smaller than the second nerve. Near its origin it forms a loop of communication with the second, and it may give off a similar communicating branch to the fourth nerve. The main trunk divides into medial cutaneous and lateral muscular branches. The lateral muscular branch enters contiguous muscles; the medial cutaneous branch passes backwards and medially, and becomes superficial as the **third occipital nerve** (O.T. *n. occipitalis*

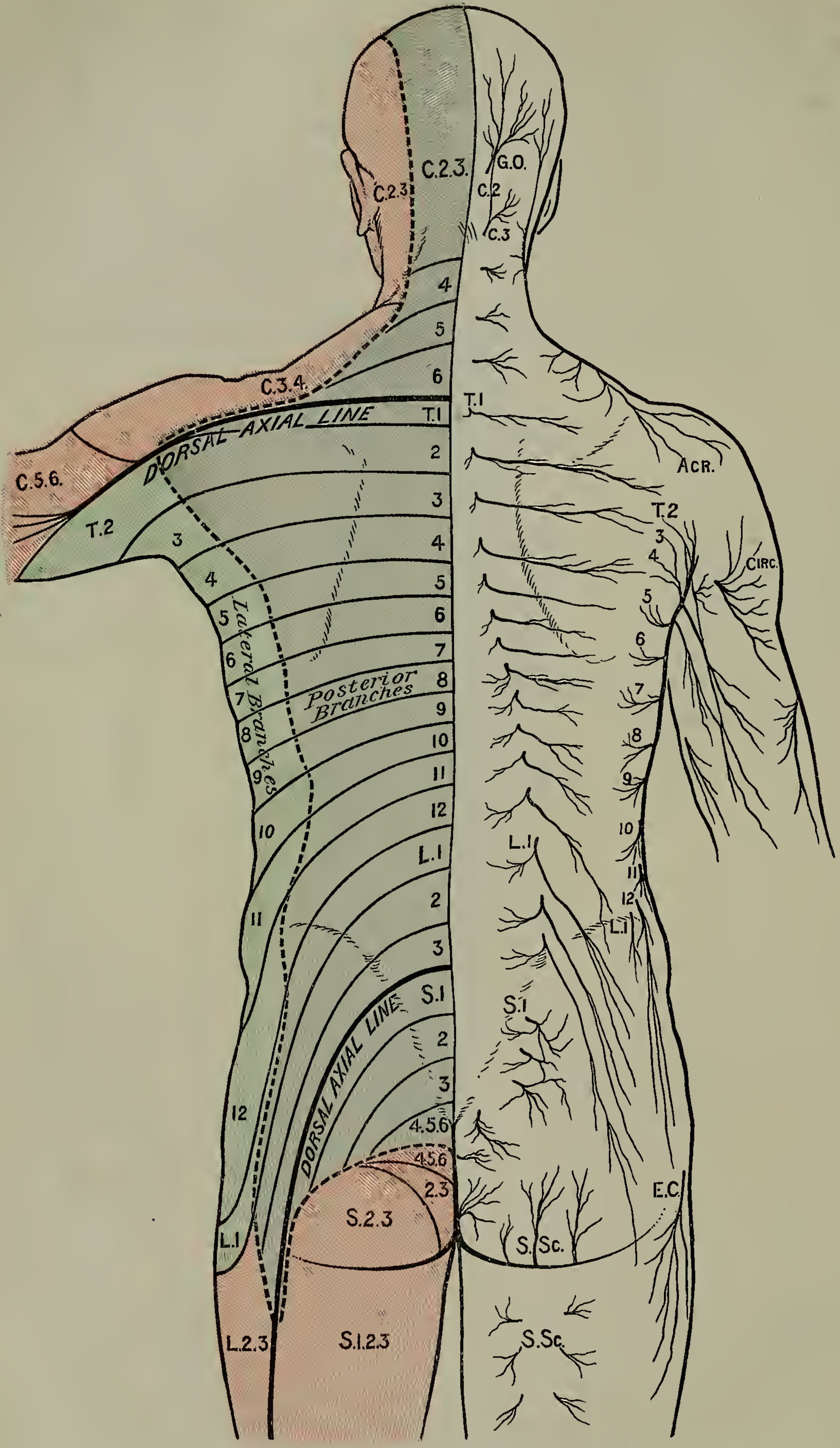


FIG. 598.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE BACK OF THE TRUNK.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.O. (C.2), Greater occipital; C.3, Third occipital; T.1 *et seq.*, Posterior rami of thoracic nerves; L.1 *et seq.*, Posterior rami of first three lumbar nerves; S.1 *et seq.*, Posterior rami of sacral nerves; Acr., Posterior supra-clavicular branches from cervical plexus; T.2-12, Lateral branches of thoracic nerves; Circ., Cutaneous branches of axillary nerve; L.1, Iliac or lateral cutaneous branch of ilio-hypogastric nerve; E.C., Lateral cutaneous nerve of thigh; S.Sc., Posterior cutaneous nerve of thigh.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

minimus), close to the median plane of the neck. It supplies fine branches to the neck and scalp, and communicates with the greater occipital nerve.

The **fourth, fifth, and sixth cervical nerves** are still smaller. Beneath the semispinalis capitis each divides into lateral muscular and medial cutaneous branches. The muscular branches supply neighbouring muscles; the cutaneous branches are small nerves, which, passing backwards, become superficial close to the median plane. They supply the skin of the back of the neck. The sixth is the smallest, and the cutaneous branches of the fifth and sixth nerves may be absent altogether. In certain cases the fourth nerve forms, with the third, a loop of communication from which muscles are supplied.

Seventh and Eighth Cervical Nerves.—These are the smallest of the posterior rami of the cervical nerves. They give off ordinarily no cutaneous branches, and end in the deep muscles of the back. There is occasionally a small cutaneous offset from the eighth nerve.

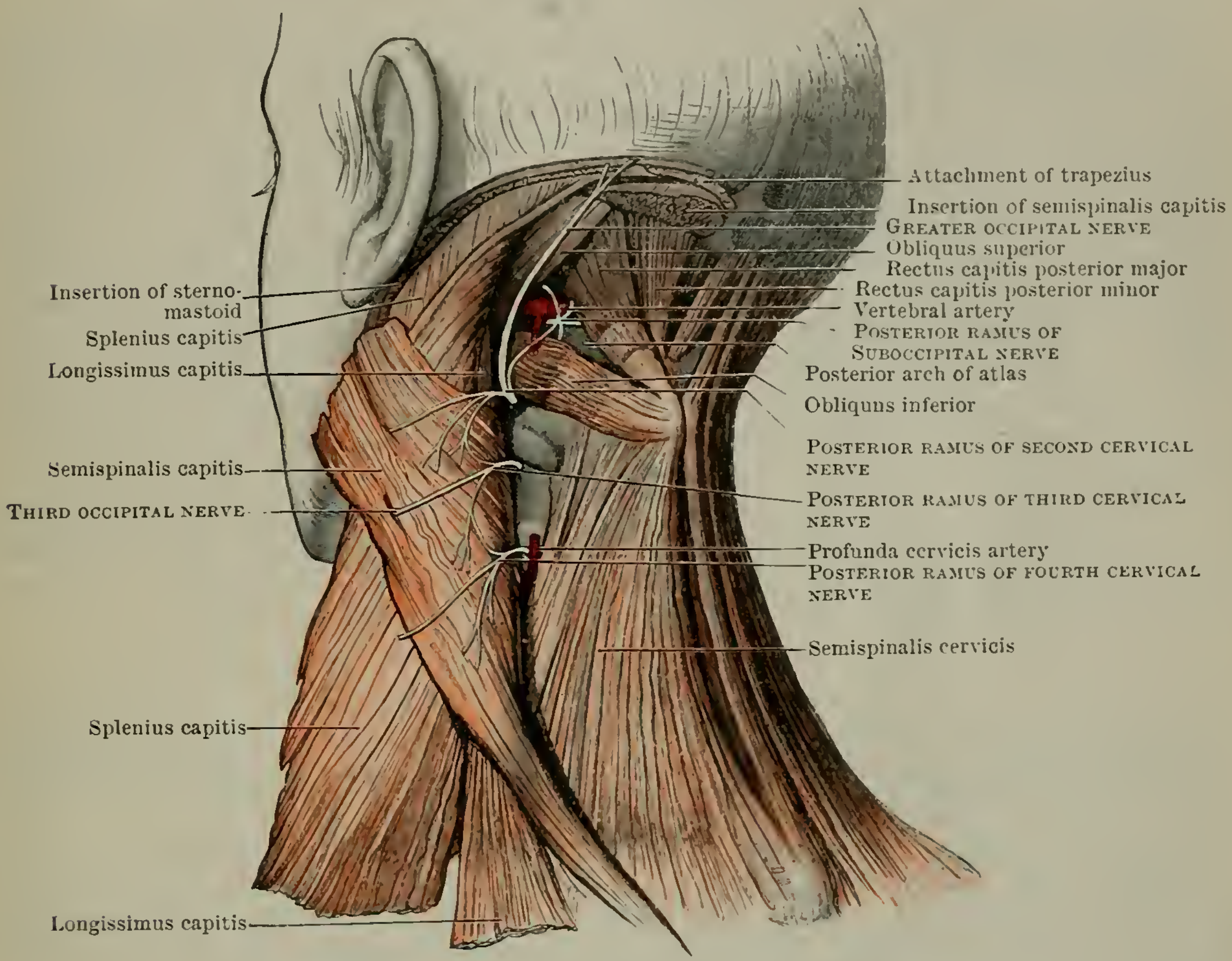

Attachment of trapezius
Insertion of semispinalis capitis
GREATER OCCIPITAL NERVE
Obliquus superior
Rectus capitis posterior major
Rectus capitis posterior minor
Vertebral artery
POSTERIOR RAMUS OF SUBOCCIPITAL NERVE
Posterior arch of atlas
Obliquus inferior
POSTERIOR RAMUS OF SECOND CERVICAL NERVE
POSTERIOR RAMUS OF THIRD CERVICAL NERVE
Profunda cervicis artery
POSTERIOR RAMUS OF FOURTH CERVICAL NERVE
Semispinalis cervicis
Insertion of sterno-mastoid
Splenius capitis
Longissimus capitis
Semispinalis capitis
THIRD OCCIPITAL NERVE
Splenius capitis
Longissimus capitis

FIG. 599.—POSTERIOR CERVICAL PLEXUS.

THORACIC NERVES.

The posterior ramus of each thoracic nerve divides into a **medial** and a **lateral branch**. In the case of the upper six or seven thoracic nerves the medial branches are distributed chiefly as *cutaneous* nerves—only giving off small muscular branches—while the lateral branches are wholly *muscular* in their distribution; in the case of the lower five or six thoracic nerves the opposite is the case. In all cases the muscular branches serve to innervate the longitudinal muscles of the back. The distribution of the cutaneous branches is therefore different in the upper and lower part of the back. The **medial cutaneous branches** of the *upper six* or *seven* thoracic nerves innervate the skin of the scapular region; after a sinuous backward course from their origin, among the dorsal muscles, they reach the surface near the spines of the vertebræ and are directed almost horizontally laterally over the trapezius muscle. The first is small; the second is very large and reaches to the acromion. The rest diminish in size, from above downwards, and become more and more oblique in direction. The **lateral cutaneous branches** of the *lower five* or *six* thoracic nerves are directed from their origin obliquely downwards and laterally among the parts of the sacro-spinalis muscle. Becoming cutaneous by piercing the latissimus dorsi at some distance from the median plane, they supply the skin of the back in the lower part of the chest and loin, the lowest nerves (eleventh and twelfth) reaching over the iliac crest on to the buttock. The lower nerves often subdivide into two branches before or after their emergence from the latissimus dorsi muscle. Owing to the obliquity of their course, each of these cutaneous branches supplies an area of skin which lies at a lower level than does the posterior ramus from which the branch arises.

LUMBAR NERVES.

First three Lumbar Nerves.—The posterior rami of the first three lumbar nerves subdivide into medial and lateral branches, in the same way as the lower thoracic nerves. The medial branches are muscular and innervate the deep muscles of the back. The lateral branches are chiefly cutaneous. They are directed obliquely downwards and laterally among the fibres of the sacro-spinalis and become superficial by piercing the lumbo-dorsal fascia, just above the iliac crest and a short distance in front of the posterior superior iliac spine. They are then directed downwards in the superficial fascia of the buttock, and supply a lengthy strip of skin, extending from the median plane above the iliac crest to a point distal to and behind the greater trochanter of the femur. There may be only two cutaneous branches, derived from the first two lumbar nerves; in other cases the three nerves are the branches of the twelfth thoracic and first two lumbar nerves.

The **fourth and fifth lumbar nerves** (like the last two cervical nerves) usually supply only muscular branches to the longitudinal muscles of the back. The fifth nerve in many cases sends a branch to form a loop of connexion with the posterior ramus of the first sacral nerve, contributing to the posterior sacral plexus.

SACRAL AND COCCYGEAL NERVES.

The posterior rami of the sacral nerves issue from the posterior sacral foramina. As in the case of the thoracic and lumbar nerves, the upper sacral nerves differ from the lower in their distribution.

The **first three sacral nerves** supply medial muscular branches for the multifidus, and lateral cutaneous branches which pierce the fibres of the sacro-tuberous ligament and the glutæus maximus muscle, and supply the skin over the back of the sacrum and contiguous part of the buttock, giving rise to the posterior sacral plexus.

The **posterior sacral plexus** consists, like the posterior cervical plexus, of loops or plexiform communications over the back of the sacrum between the posterior rami of the first three sacral nerves, to which are frequently joined branches of the last lumbar nerve and fourth and even the fifth sacral nerve. From these loops branches proceed to supply the multifidus muscle; others, piercing the sacro-tuberous ligament, form secondary loops beneath the glutæus maximus muscle. From the secondary loops, two or more cutaneous branches arise, which, after traversing the muscle, supply the skin over the sacrum and medial part of the buttock.

Posterior Ano-coccygeal Nerve.—The posterior rami of the fourth and fifth sacral nerves do not divide into medial and lateral branches. They unite together to form a loop which is joined by the minute posterior ramus of the coccygeal nerve. The union of the three nerves constitutes the **posterior ano-coccygeal nerve**, which, after perforating the sacro-tuberous ligament, is distributed to the skin in the neighbourhood of the coccyx. It supplies no muscles. This nerve is the representative of the **superior caudal trunk** of tailed animals.

Morphology of the Posterior Rami.

1. **Muscular Distribution.**—In their muscular distribution they are strictly limited to the longitudinal muscles of the back: namely, those associated with the axial skeleton alone.

2. Cutaneous Distribution.—Their cutaneous distribution presents two points of interest.

A. In the first place, while the skin of the back is supplied in a regularly segmental manner by the several nerves, certain of them fail to reach the surface at all. The absence of a cutaneous branch from the sub-occipital nerve may be due either to the absence of a perfect posterior root, or to its communication with the second nerve. The other nerves which do not usually supply the skin are the last two, three, or four cervical, and the fourth and fifth lumbar nerves. These nerves are placed in the centre of regions in which the upper and lower limbs are developed. They are minute nerves, while the corresponding anterior rami are among the largest of the spinal nerves. Thus, opposite the centre of each limb, posteriorly, there is a hiatus in the segmental distribution of the posterior rami of the spinal nerves to the skin of the shoulder and buttock, attributable to the formation of the limbs, and the extension into them of the greater part of the nerves of the region. This gap, in the case of the upper limb, commences at the level of the vertebra prominens; in the case of the lower limb it commences opposite the level of the posterior superior iliac spine. It can be continued on to each limb as a hypothetical area (the **dorsal axial line**), which indicates the area of contact (and overlapping) of cutaneous nerves not in strictly numerical sequence. Thus, in the region of the shoulder, the sixth (or fifth) cervical nerve innervates an area of skin adjoining that supplied by the eighth cervical or first thoracic nerve; in the region of the buttock the third lumbar nerve supplies an area contiguous with that supplied by the fifth lumbar or first sacral nerve.

B. The cutaneous branches of the posterior rami of the spinal nerves differ from the muscular branches in respect of their penetration into regions beyond those supplied by their motor roots. The cutaneous branches, in regions where outgrowths or extensions from the trunk have occurred, follow these extensions; and, in consequence, supply skin covering parts which do not belong to segments represented by the nerves in question. Thus, the second and third cervical nerves (greater and third occipital) are drawn upwards so as to supply the posterior part of the *scalp*; the upper thoracic nerves are drawn laterally over the *scapular region*; the upper lumbar and sacral nerves supply the skin of the *buttock*; and the ano-coccygeal nerve forms a rudimentary *caudal nerve*.

3. Plexuses.—The plexuses formed by the posterior rami of the upper cervical and upper sacral nerves are the simplest met with in the human body. The posterior cervical plexus is one from which muscular branches are supplied; the posterior sacral plexus is mainly concerned in producing cutaneous offsets.

ANTERIOR RAMI OF THE SPINAL NERVES.

The **anterior rami** of the spinal nerves are, with the exception of the first two cervical nerves, much larger than the corresponding posterior rami. Composed of elements of both posterior and anterior roots, each nerve separates from the posterior ramus on emerging from the intervertebral foramen, and, proceeding laterally, is distributed to structures on the lateral and anterior aspects of the body,—including the limbs.

Each nerve is joined near its origin by a **gray ramus communicans** from the corresponding sympathetic gangliated trunk; and in the case of certain thoracic, lumbar, and sacral nerves, the anterior ramus gives off a delicate bundle of fibres, which forms the **white ramus communicans** to the sympathetic trunk. That part of the spinal nerve which is distributed to the body wall and limbs may be termed **somatic**; the small white ramus communicans, innervating structures in the splanchnic area, may be termed the **visceral** or **splanchnic** part of the spinal nerve.

The anterior rami of the spinal nerves are distributed in a regular segmental manner only in certain cases. Except in the case of the thoracic nerves, the anterior rami combine to form the three great **plexuses**—cervical, brachial, and lumbo-sacral—and their arrangement and distribution is rendered exceedingly complex.

A **thoracic nerve,** such as the fifth or sixth, may be regarded as a type to illustrate the mode of distribution of the anterior rami of the spinal nerves (Fig. 595, p. 712). It occupies an intercostal space; near its origin it possesses *gray* and *white rami communicantes*; it courses through the interval between the intercostal muscles; it supplies branches to those muscles and gives off, when it reaches the side of the chest, a *lateral branch,* which, after supplying small muscular branches, pierces the external intercostal muscle, and is distributed to an area of skin over the lateral part of the trunk, contiguous dorsally with a similar area, innervated by the cutaneous branches of the posterior ramus of the same nerve. The lateral branch generally subdivides into a smaller *posterior* and a larger *anterior ramus,* as it pierces the muscles clothing the wall of the chest. The main trunk of the nerve, having given off its lateral branch, then pursues its course obliquely forwards to the side of the sternum, where, after piercing the pectoral muscles, it appears superficially as the *terminal anterior cutaneous branch.*

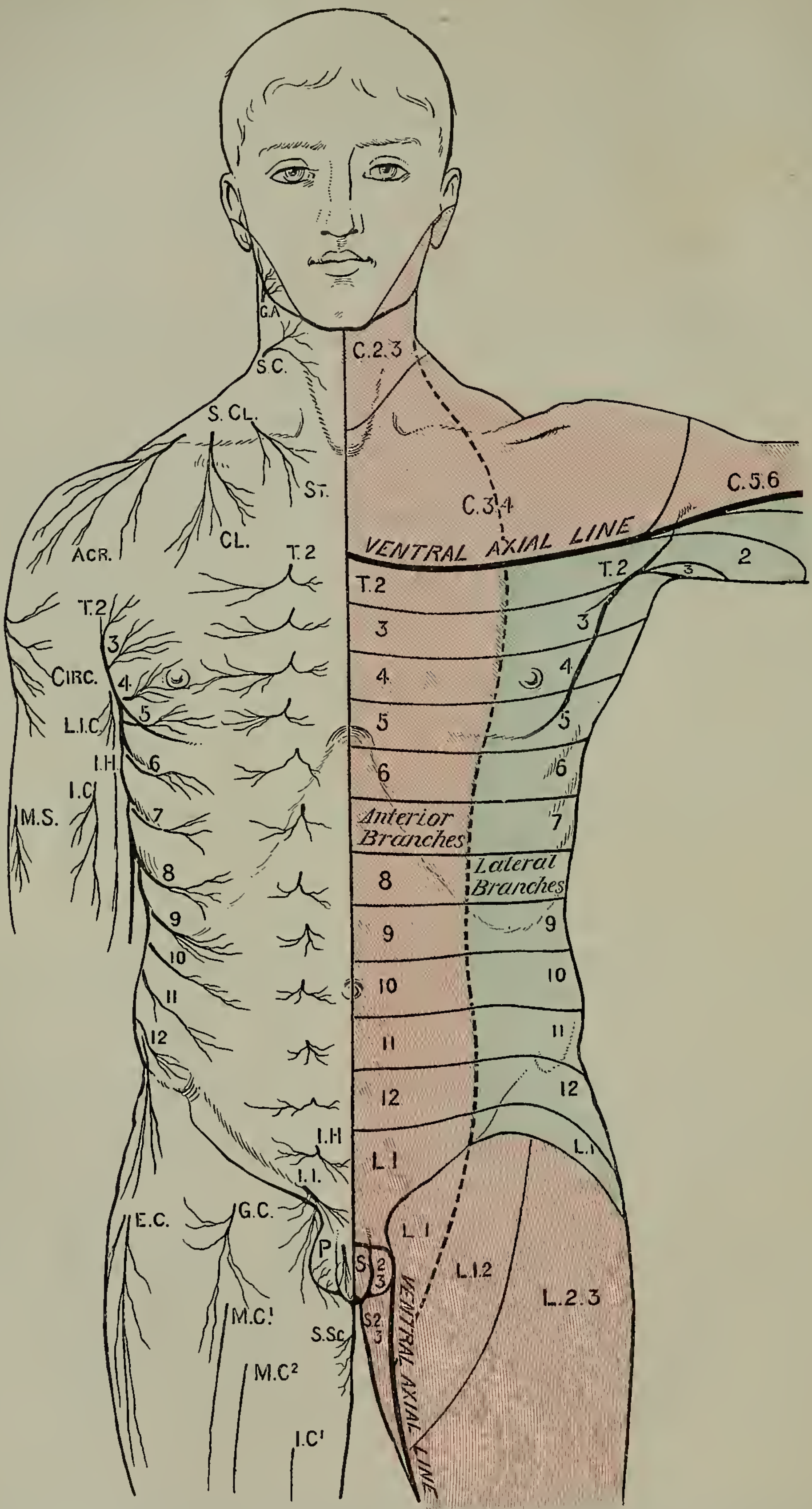


Fig. 600.—The Distribution of Cutaneous Nerves on the Front of the Trunk.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.A., Great auricular nerve ; S.C., N. cutaneus colli ; S.Cl., Supra-clavicular nerves ; Acr., Posterior ; Cl., Middle ; St., Anterior ; T.2-12, Lateral and anterior branches of thoracic nerves ; I.H. (below) Ilio-hypogastric nerve ; I.I., Ilio-inguinal nerve ; Circ., Cutaneous branch of axillary nerve ; L.I.C., Medial cutaneous nerve of the arm (lesser internal cutaneous nerve) ; I.H. (above) Intercosto-brachial ; I.C., Medial cutaneous nerve of the forearm (internal cutaneous) ; M.S., Cutaneous branch of radial nerve ; E.C., Lateral cutaneous nerves ; G.C., Lumbo-inguinal nerve ; M.C.$^{1\,2}$, Intermediate cutaneous nerves ; I.C.^{1}, Branch of medial cutaneous nerve ; P., Branches of pudendal nerve ; S.Sc., Branches of posterior cutaneous nerve of the thigh.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

This supplies an area of skin continuous with that supplied by the anterior part of the lateral branch of the same nerve. Such a nerve thus supplies, by means of its lateral and anterior branches, an area of skin which (with the area supplied by the cutaneous branch of its posterior ramus) forms a continuous and uninterrupted belt, extending from the median plane behind to the median plane in front. The lateral and anterior branches of the nerve innervate in their course the intercostal and other muscles, to be afterwards mentioned in detail.

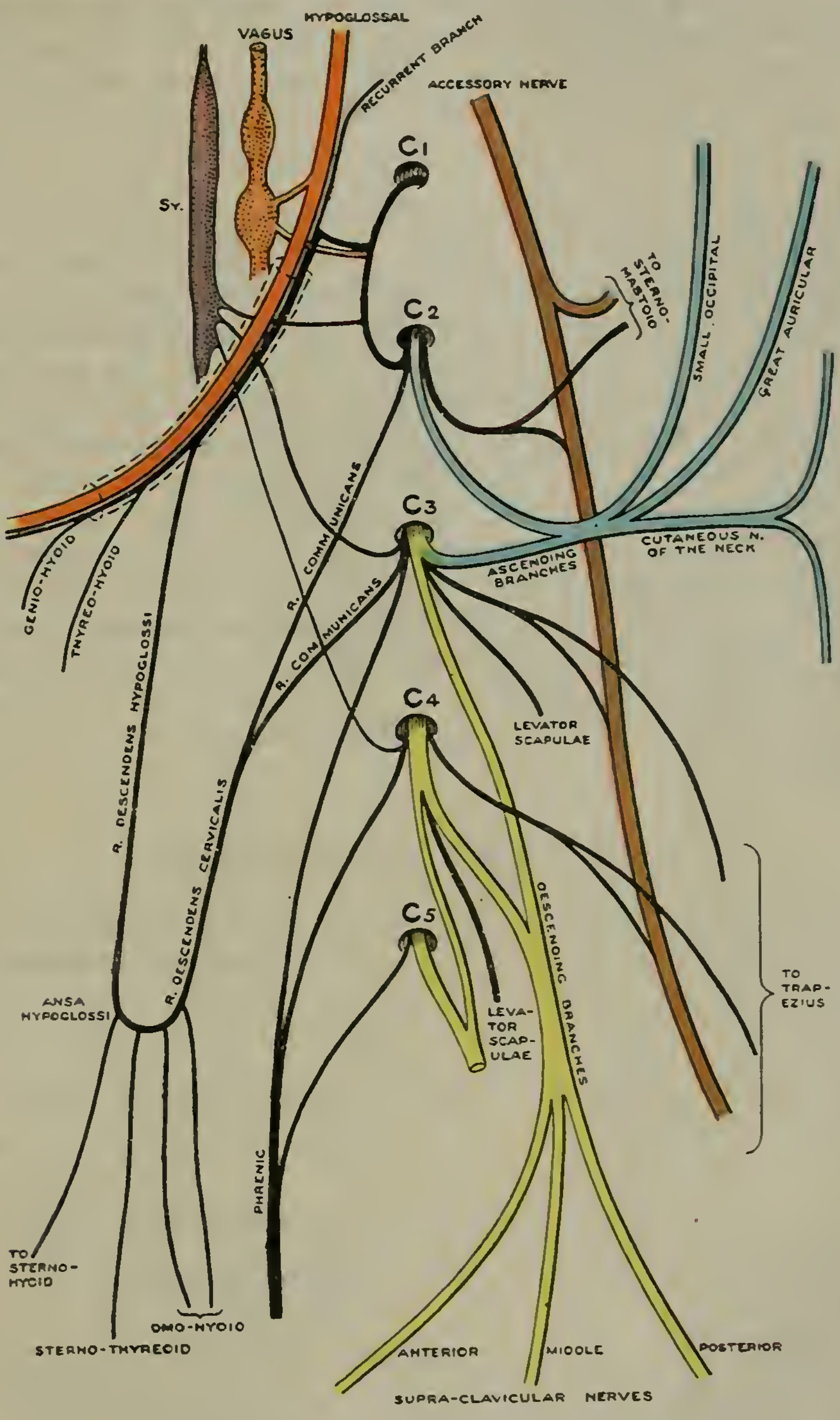


FIG. 601.—THE LEFT CERVICAL PLEXUS.

NERVI CERVICALES.

The anterior rami of the cervical nerves, together with parts of the first and second thoracic nerves, are distributed to the head, neck, and upper extremity. The first four cervical nerves, by means of the **cervical plexus**, innervate the neck; the last four cervical nerves, together with a large part of the first thoracic nerve, through the **brachial plexus**, supply the upper limb. The second thoracic nerve may contribute a trunk to this plexus, and always assists in the innervation of the arm.

The anterior ramus of the **first cervical (sub-occipital) nerve** emerges from the vertebral canal by passing over the posterior arch of the atlas; it curves forwards round the lateral side of the upper articular process of that vertebra, lying medial to the vertebral artery, and then descends to form a loop with the ascending branch of the second cervical nerve. A large part of its fibres joins the hypoglossal nerve (*vide infra*).

The anterior division of the **second cervical nerve** passes between the neural arches of the first two vertebræ, behind the upper articular process of the epistropheus; curving forwards on the lateral side of the vertebral artery, it divides into an ascending portion, which unites with the first cervical nerve and likewise contributes fibres to the hypoglossal nerve, and a descending part, which joins the third cervical nerve and takes part in the cervical plexus.

PLEXUS CERVICALIS.

The anterior rami of the first four cervical nerves are concerned in forming the **cervical plexus.** Each nerve emerges from the vertebral canal posterior to the vertebral artery. Each is joined on its emergence from the intervertebral foramen at the side of the vertebral column, by a **gray ramus communicans** from the superior cervical ganglion of the sympathetic. In the neck the cervical nerves are concealed at their origins by the sterno-mastoid muscle; in front lies the longus capitis muscle, and behind are the scalenus medius, and (behind the first or sub-occipital nerve) the rectus capitis lateralis. The cervical plexus is constituted by the combination of the four nerves in an irregular series of loops under cover of the sterno-mastoid muscle, and overlapped, in part, by the internal jugular vein.

From the loops of the plexus the branches of distribution arise, as (*a*) **cutaneous branches** to the head, neck, and shoulder; (*b*) **muscular branches** to muscles of the neck and to the diaphragm; and (*c*) **communicating branches** to the vagus, accessory, hypoglossal, and sympathetic nerves.

For convenience of description, the nerves derived from the plexus may be classified as follows:—

I. Superficial (cutaneous) Branches—

A. **Ascending Branches** (C. 2, 3).
- N. occipitalis minor (lesser occipital),
- N. auricularis magnus (great auricular),
- N. cutaneus colli (O.T. transverse superficial cervical).

B. **Descending (supra-clavicular) Branches** (C. 3, 4).
- Nn. supraclaviculares anteriores (O.T. suprasternal),
- Nn. supraclaviculares medii (O.T. supra-clavicular),
- Nn. supraclaviculares posteriores (O.T. supra-acromial).

II. Deep (muscular and communicating) Branches—

A. **Lateral Branches.**
1. Muscular branches to
    - Sterno-mastoid (C. 2),
    - Trapezius (C. 3, 4),
    - Levator scapulæ (C. 3, 4),
    - Scaleni (medius and posterior) (C. 3, 4).
2. Communicating branches to
    - Accessory nerve (C. 2, 3, 4).

B. **Medial Branches.**
1. Muscular to
    - Prevertebral muscles (C. 1, 2, 3, 4),
    - Infra-hyoid muscles (C. 1, 2, 3) (ansa hypoglossi),
    - Diaphragm (C. 3, 4, 5) (phrenic nerve).
2. Communicating branches to
    - Vagus nerve (C. 1, 2),
    - Hypoglossal nerve (C. 1, 2),
    - Ansa hypoglossi (C. 2, 3),
    - Sympathetic (C. 1, 2, 3, 4).

The second, third, and fourth cervical nerves are the chief nerves engaged in forming the plexus. The first cervical nerve only enters into the formation of a small part—the medial portion of the deep part of the plexus.

Superficial Cutaneous Branches.—These nerves, six in number, are entirely cutaneous. They radiate from the plexus, and appear in the posterior triangle of the neck a little above the mid-point of the posterior border of the sterno-mastoid muscle. They are divisible into two series—the one **ascending**: lesser occipital, great auricular, and nervus cutaneus colli; the other **descending** (supra-clavicular): posterior, middle, and anterior.

Ascending Branches.—The **lesser occipital nerve** is variable in size and is sometimes double. Its origin is from the second and third cervical nerves (more rarely from the second only). It extends backwards under cover of the sterno-mastoid, and then upwards along its posterior border. Piercing the deep fascia near the apex of the posterior triangle, it divides into **auricular, mastoid,** and **occipital branches,** and supplies small **cervical branches** to the upper part of the neck. The auricular branch supplies the skin of the cranial surface of the auricle; the mastoid and occipital branches supply the scalp. The nerve communicates on the scalp with the greater occipital and great auricular nerves, and with the posterior auricular branch of the facial nerve.

The **great auricular nerve** is the largest of the cutaneous branches. It arises from the second and third cervical nerves (or, more rarely, from the third alone). Winding round the posterior border of the sterno-mastoid muscle, it courses vertically upwards towards the ear. In this course it crosses the sterno-mastoid muscle obliquely and is covered by the platysma muscle. Before arriving at the ear it subdivides into mastoid, auricular, and facial branches. The **mastoid branches** ascend over the mastoid process and supply the skin of the scalp behind the ear, communicating with the lesser occipital and posterior auricular nerves. The **auricular branches** ascend to the ear and supply the lower part of the auricle on both aspects; they communicate with the same nerves. The **facial branches,** passing over the angle of the mandible and through the substance of the parotid gland, supply the skin of the cheek over the inferior part of the masseter muscle and the parotid gland. They communicate with branches of the facial nerve in the parotid gland.

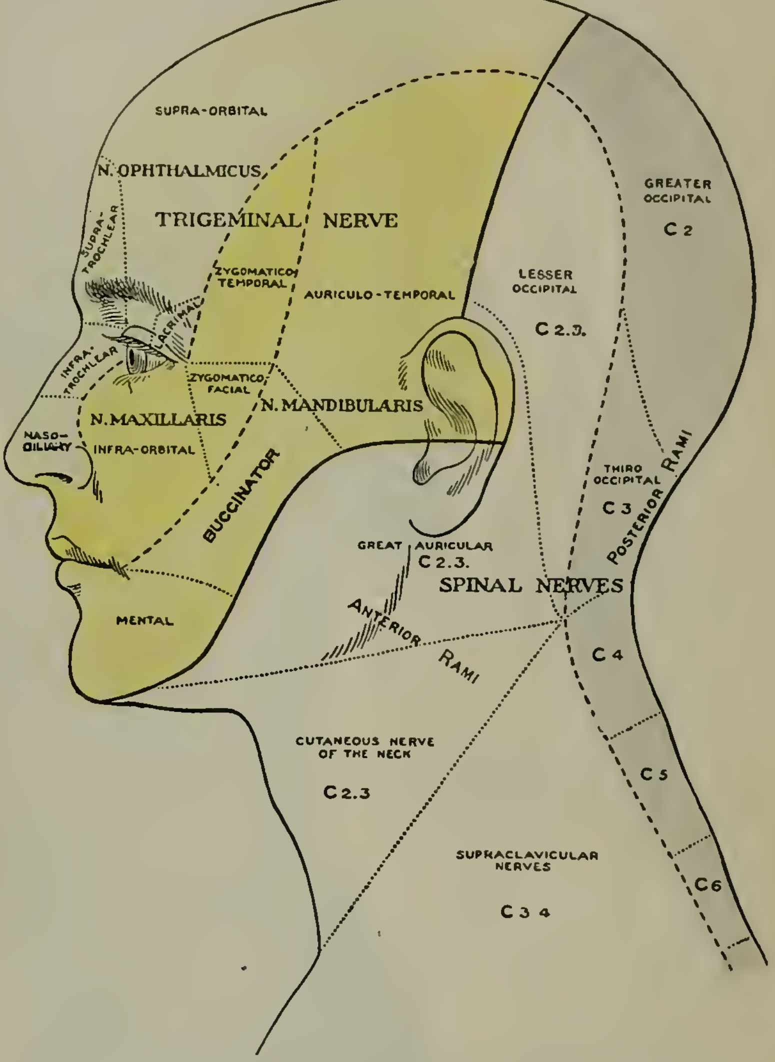


Fig. 602.—Distribution of Cutaneous Nerves to the Head and Neck.

The **nervus cutaneus colli** arises from the second and third cervical nerves. It winds round the posterior border of the sterno-mastoid muscle, and crosses the muscle to reach the anterior triangle, under cover of the platysma muscle and the external jugular vein. It divides near the anterior edge of the sterno-mastoid muscle into superior and inferior branches, which are distributed through the platysma to the skin covering the anterior triangle of the neck. The upper branches communicate freely beneath the platysma with the cervical branch of the facial nerve.

Descending (supra-clavicular) Branches.—By the union of two roots derived from the third and fourth cervical nerves a considerable trunk is formed, which emerges from under cover of the sterno-mastoid muscle and extends obliquely downwards through the inferior part of the posterior triangle of the neck. It subdivides into radiating branches—**anterior**, **middle**, and **posterior**—which pierce the deep fascia of the neck above the clavicle, and are distributed to the skin of the inferior part of the side of the neck, to the front of the chest, and the shoulder. The **anterior branches** are the smallest. Passing over the medial end of the clavicle, they supply the skin of the neck and chest as far down as the synchondrosis sternalis. The **middle branches** pass over the intermediate third of the clavicle, beneath the platysma, and can be traced as low as the third rib. The **posterior branches** pass over or through the insertion of the trapezius muscle, and over the lateral third of the clavicle, to the shoulder, where they supply the skin as far down as the distal third of the deltoid muscle.

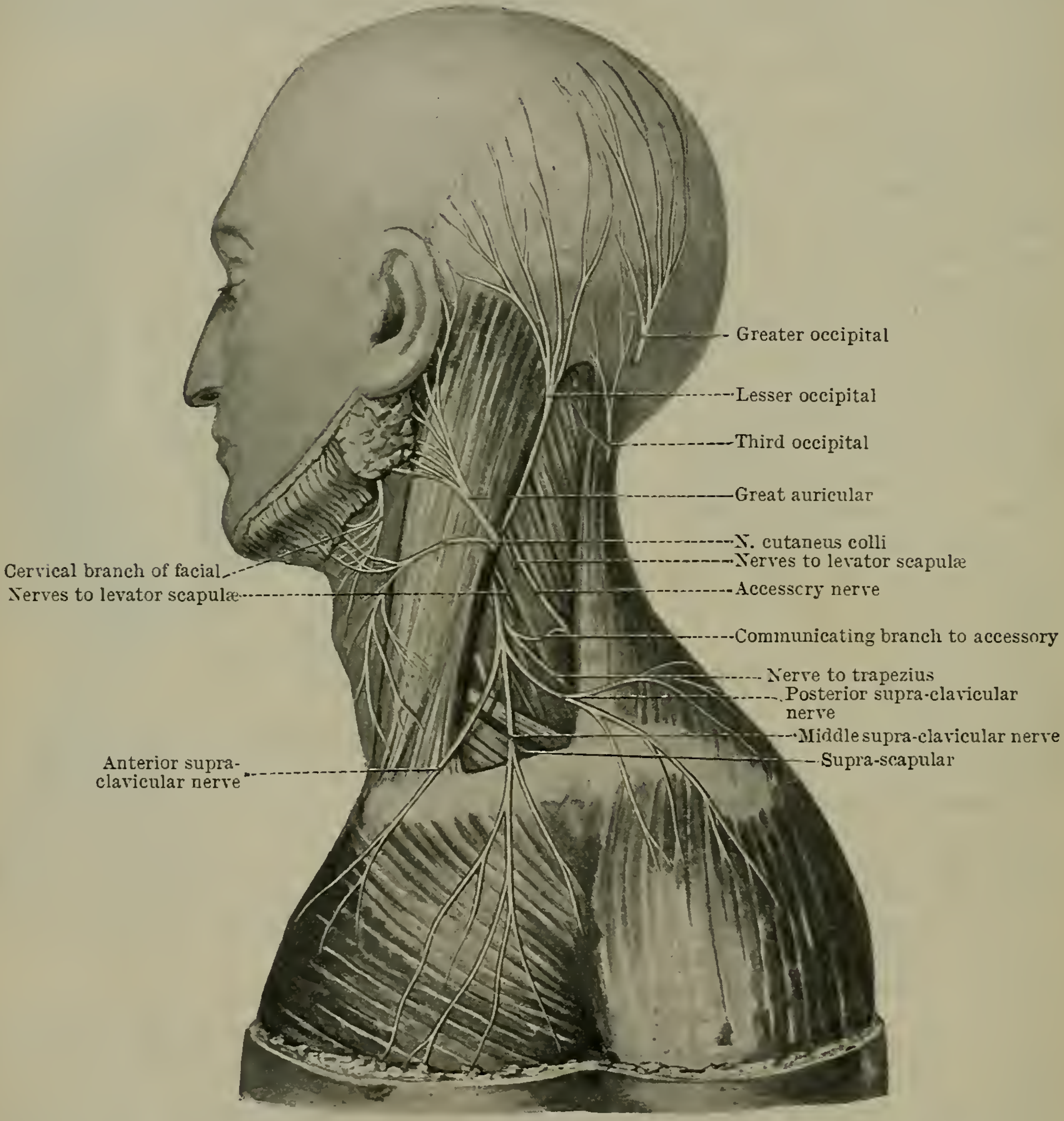

Greater occipital
Lesser occipital
Third occipital
Great auricular
N. cutaneus colli
Nerves to levator scapulæ
Accessory nerve
Communicating branch to accessory
Nerve to trapezius
Posterior supra-clavicular nerve
Middle supra-clavicular nerve
Supra-scapular
Cervical branch of facial
Nerves to levator scapulæ
Anterior supra-clavicular nerve

Fig. 603.—The Nerves of the Side of the Neck.

Deep Branches.—The deep branches of the cervical plexus are separated into a **lateral** and a **medial set** by their relation to the sterno-mastoid muscle. Beneath the muscle, the lateral branches are directed laterally towards the posterior triangle, and the medial branches pass medially towards the anterior triangle.

The **lateral branches** consist of muscular and communicating nerves, which for the most part occupy the posterior triangle.

The **muscular branches** are the following: (1) To the *sterno-mastoid*, from the second cervical nerve. This enters the muscle on its deep surface and communicates with the accessory nerve. (2) To the *trapezius*, from the third and fourth cervical nerves. These nerves cross the posterior triangle and end in the trapezius, after having communicated with the accessory nerve, both in the posterior triangle, and under cover of the muscle. (3) To the *levator scapulæ,* from the third and fourth cervical nerves. Two independent branches enter the lateral surface of the muscle in the posterior triangle. (4) To the *scaleni* (medius and posterior), from the third and fourth cervical nerves.

The **communicating branches** are three in number. They join the accessory nerve in three situations: (*a*) A branch from the second cervical nerve to the sterno-mastoid joins the accessory nerve *under cover of that muscle.* (*b*) Branches to the trapezius from the third and fourth nerves are connected with the accessory nerve *in the posterior triangle.* (*c*) Branches from the same nerves join the nerve *under cover of the trapezius muscle.*

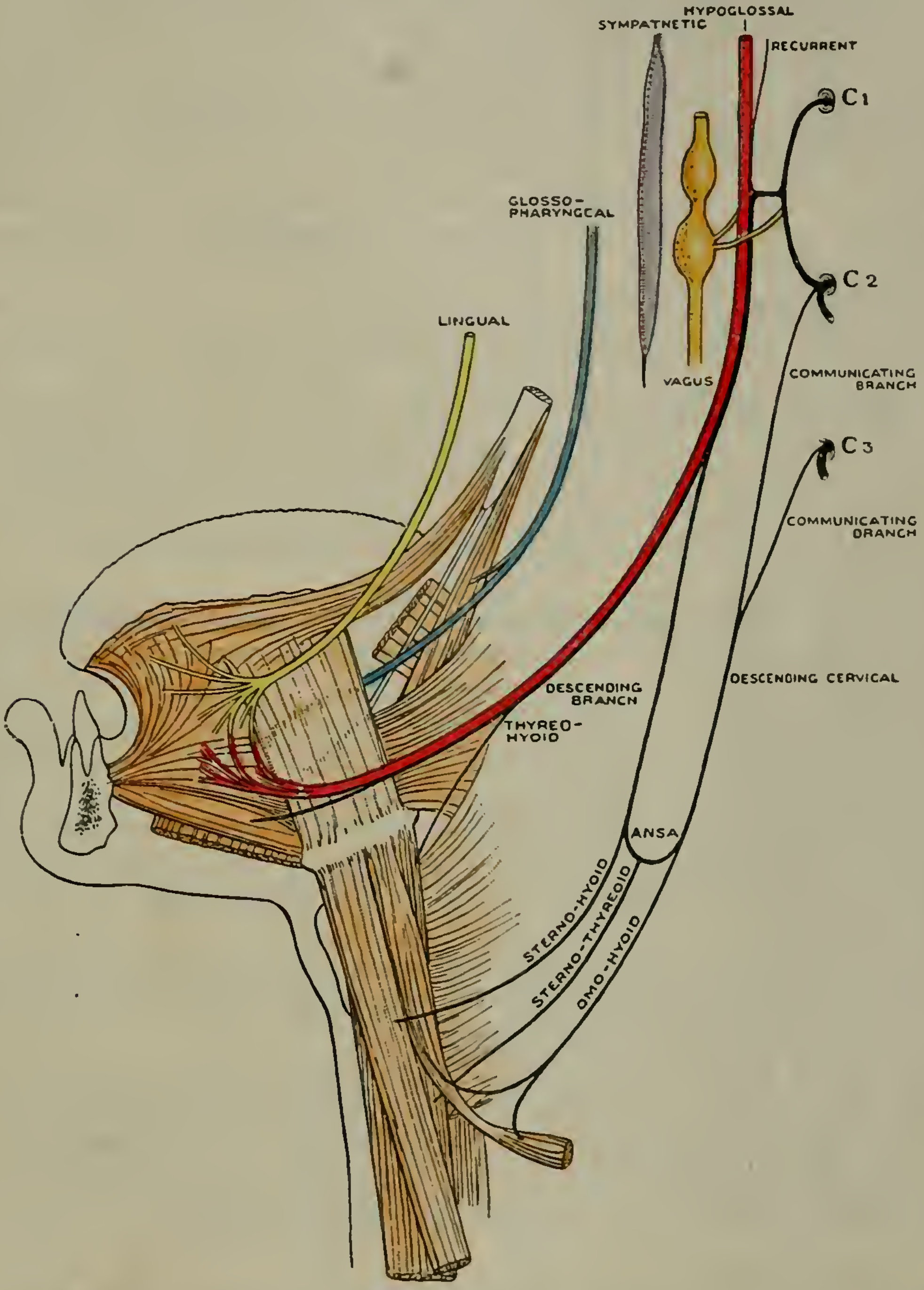


FIG. 601.—THE MUSCLES OF THE HYOID BONE AND STYLOID PROCESS, AND THE EXTRINSIC MUSCLES OF THE TONGUE, WITH THEIR NERVES.

The **medial branches** of the plexus also comprise muscular and communicating branches. The first cervical nerve assists in the formation of this series of nerves, forming a slender loop with part of the second nerve in front of the transverse process of the atlas.

Communicating Branches.—(*a*) *With the sympathetic.*—Gray rami communicantes pass to each of the first four cervical nerves, near their origins, from the superior cervical ganglion or from the trunk below the ganglion. (*b*) *With the* *vagus nerve.*—The ganglion nodosum of the vagus nerve may be connected by a slender nerve with the loop between the first two cervical nerves. This communication is not constant. (*c*) *With the hypoglossal.*—An important communication occurs between the hypoglossal nerve and the loop between the first and second cervical nerves (Fig. 601). A trunk from the loop joins the hypoglossal just beyond its exit from the skull. One fine branch from this trunk passes upwards along the hypoglossal nerve to the cranium (*meningeal branch*). The main part of the trunk accompanies the hypoglossal and separates from it to form successively three nerves—the **descendens hypoglossi,** and the **nerves to the thyreo-hyoid** and **genio-hyoid muscles.** The portion of the nerve which remains accompanies the hypoglossal to the muscles of the tongue. It is probable that no part of the hypoglossal nerve itself is concerned in the formation of these three branches. The descending branch of the hypoglossal descends in front of the internal and common carotid arteries, and is joined in the anterior triangle of the neck by the **descending cervical nerve,** to form the **ansa hypoglossi,** from which the infra-hyoid muscles are innervated. (The descending branch of the hypoglossal, in some cases, arises from the vagus nerve.)

Muscular Branches.—The muscles supplied by the medial branches of the plexus are the prevertebral muscles, the genio-hyoid and the infra-hyoid muscles, and the diaphragm.

(*a*) **Prevertebral Muscles.**—(1) From the loop between the first and second cervical nerves a small branch arises, for the supply of the rectus capitis lateralis, longus capitis, and the rectus capitis anterior. (2) From the second, third, and fourth nerves small branches supply the inter-transverse, longus colli, and longus capitis muscles. (3) From the fourth nerve a branch arises for the upper part of the scalenus anterior.

(*b*) **Genio-hyoid and Infra-hyoid Muscles.**—The **descending cervical nerve** is formed in front of the internal jugular vein by the union of two slender trunks from the second and third cervical nerves (communicantes hypoglossi). It forms a loop of communication in front of the carotid sheath with the descending branch of the hypoglossal nerve (derived ultimately from the first two cervical nerves). This loop of communication is called the **ansa hypoglossi.** It is often plexiform; and from it branches are given to the sterno-hyoid and sterno-thyreoid muscles, and both bellies of the omo-hyoid muscle. The nerve to the sterno-hyoid muscle is often continued behind the sternum, to join, in the thorax, with the phrenic nerve or the cardiac plexus.

The thyreo-hyoid and genio-hyoid muscles are supplied by branches of the hypoglossal nerve, which are also traceable back to the communication between the hypoglossal and the first two cervical nerves.

The anterior muscles in immediate relation to the median plane of the neck, between the chin and the sternum, are thus continuously supplied by the first three cervical nerves. The hypoglossal is the nerve of the muscles of the tongue, and it is not certain that it contributes any fibres to the above-named muscles.

(*c*) **Diaphragm.**—The phrenic nerve supplies the diaphragm.

Nervus Phrenicus.

The **phrenic nerve** is derived mainly from the fourth cervical nerve, reinforced by roots from the third (either directly or through the nerve to the sterno-hyoid) and fifth (either directly or through the nerve to the subclavius muscle). It runs downwards in the neck upon the scalenus anterior muscle; at the root of the neck it passes between the subclavian artery and vein, enters the thorax and traverses the mediastinum to reach the diaphragm, lying in the middle mediastinum between the pericardium and pleura, and anterior to the root of the lung. In its course it presents certain differences on the two sides. In the neck, on the left side, it crosses the first part of the subclavian artery; on the right side it crosses the second part. In the superior mediastinum, on the left side, it lies between the left subclavian and carotid arteries, and crosses the vagus nerve and the aortic arch. On the right side it accompanies the innominate vein and superior vena cava, and is entirely separate from the vagus nerve. The left nerve is longer than the right, owing to the position of the heart and the left half of the diaphragm. The right nerve sends fibres along the inferior vena cava through the foramen venæ cavæ. Reaching the diaphragm the nerve separates into numerous branches for the supply of the muscle; some enter its thoracic surface (sub-pleural branches), but most of the fibres supply it after piercing the muscle (sub-peritoneal branches). It appears possible, from clinical observations, that the nerve contains some sensory fibres as well as motor.

The **branches of the phrenic nerve** are: (1) Muscular (to the diaphragm); (2) pleural; (3) pericardiac; (4) inferior vena-caval; (5) suprarenal; and (6) hepatic.

The branches to the pleura and pericardium arise as the phrenic nerve traverses the mediastinum. The branches to the inferior vena cava, suprarenal gland, and liver arise after communication of the phrenic nerve with the diaphragmatic plexus of the sympathetic on the abdominal surface of the diaphragm.

Communications of the Phrenic Nerve.—(1) The phrenic nerve may communicate with the nerve to the subclavius muscle. (2) It may communicate with the *ansa hypoglossi*, or a branch from it (the nerve to the sterno-hyoid). (3) It frequently communicates with the cervical part of the sympathetic. (4) It communicates with the cœliac plexus by a junction upon the abdominal surface of the diaphragm with the *diaphragmatic plexus* on the inferior phrenic artery, in which a small *diaphragmatic ganglion* is found on the right side. From this junction branches are given off to the inferior vena cava, suprarenal gland, and hepatic plexus.

Morphology of the Cervical Plexus.

The characteristic feature of the cervical plexus is the combination of parts of adjacent nerves into compound nerve-trunks by the formation of series of loops. The result of the formation of these loops is that parts (particularly cutaneous areas) are supplied by branches of more than one spinal nerve.

A. **Cutaneous Distribution.**—By the combinations of the nerves into loops the discrimination of the elements in the upper cervical nerves, corresponding to the lateral and anterior rami of a typical thoracic nerve, is made a matter of some difficulty. The second, third, and fourth nerves, through the cervical plexus, supply an area of skin extending, laterally, from the side of the head to the shoulder; anteriorly, from the face to the level of the third rib. The higher nerves supply the upper region (second and third); the lower nerves supply the lower region (third and fourth). It is not possible to compare the individual nerves strictly with the lateral and anterior rami of a thoracic nerve. A line drawn from the ear to the middle of the clavicle separates, however, a lateral from an anterior cutaneous area; and certain of the cutaneous nerves fall naturally into one of these two categories. The nerves homologous with anterior rami of intercostal nerves are the n. cutaneus colli and the anterior branches of the supra-clavicular series; those homologous with lateral branches are the smaller occipital and posterior supra-clavicular branches. The great auricular and middle supra-clavicular branches are mixed nerves, comprising elements belonging to both sets.

B. **Muscular Distribution.**—The nerves from the cervical plexus supplying muscles are simpler in their arrangement. They are not generally in the form of loops, and they are easily separated into lateral and anterior series. The lateral nerves comprise the branches to the rectus capitis lateralis, sterno-mastoid, trapezius, levator scapulæ. The nerves in the anterior series are those to the longus capitis, rectus capitis anterior, the hyoid muscles, and the diaphragm.

It is noteworthy that the last-named muscles—genio-hyoid, thyreo-hyoid, sterno-hyoid, omo-hyoid, sterno-thyreoid, and diaphragm—are continuously supplied by branches from the first five cervical nerves: the higher muscles by the higher nerves; the lower muscles by the lower nerves.

PLEXUS BRACHIALIS.

The **Brachial Plexus** is formed by the anterior rami of the fifth, sixth, seventh, and eighth cervical nerves, along with the greater part of the first thoracic nerve. In over half the number of cases a slender branch of the fourth cervical nerve is also engaged; and the second thoracic nerve also, in all cases, contributes to the innervation of the arm, through the intercosto-brachial nerve. In many cases it contributes also directly to the plexus, by an intra-thoracic communication with the first thoracic nerve.

Position of the Plexus.—The nerves forming the brachial plexus appear in the posterior triangle of the neck between the scalenus anterior and scalenus medius muscles in series with the nerves forming the cervical plexus. Here the plexus is covered by the skin, platysma, supraclavicular nerves, and the deep fascia, and is crossed by the nerve to the subclavius muscle, external jugular vein, posterior belly of the omohyoid muscle, and the transverse cervical artery, which vessel sometimes passes between its branches. At the root of the neck the plexus passes behind the clavicle, subclavius muscle, and transverse scapular vessels; it lies above and behind the third part of the subclavian artery. In the axilla its branches surround the first part of the axillary artery.

Composition of the Brachial Plexus.—Whilst liable to some variation in the sequence of separation and junction of its individual parts, in a typical plexus four stages may always be identified:—

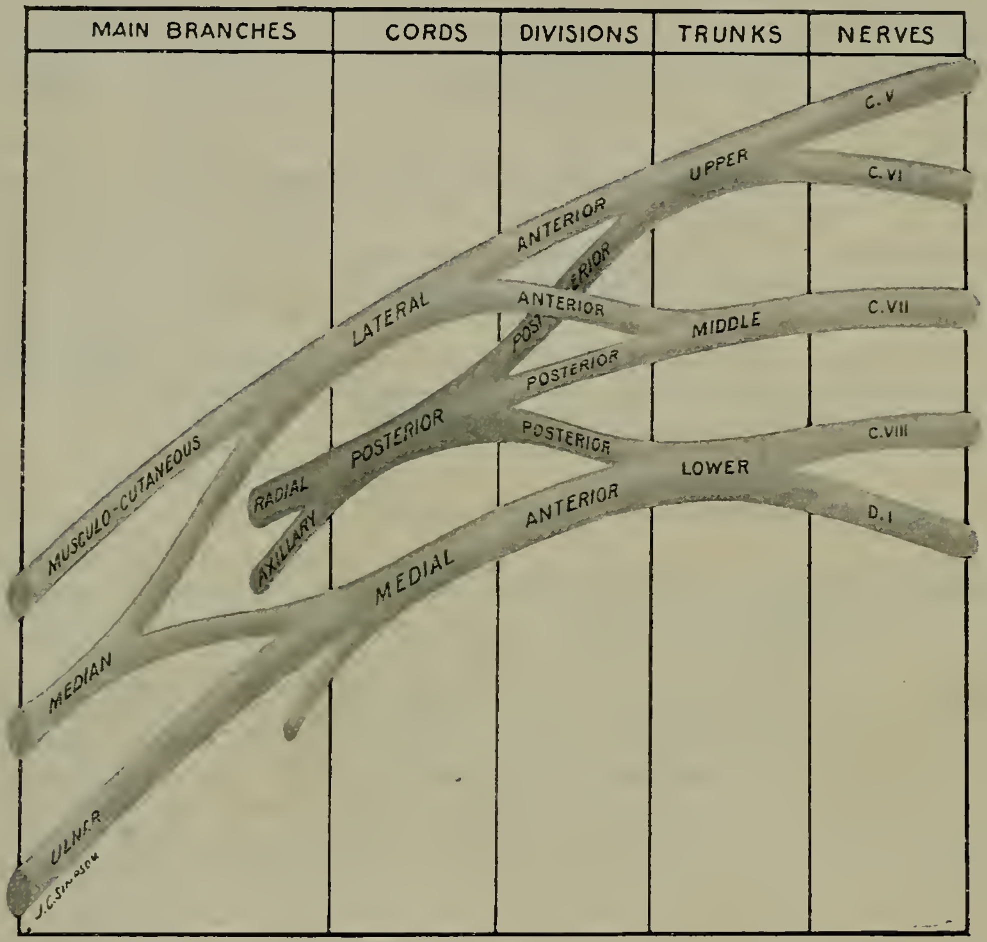


FIG. 605.—SCHEME TO SHOW THE STAGES OF FORMATION OF THE BRACHIAL PLEXUS.

(1) The undivided anterior rami of the nerves.
(2) The formation of three trunks.
(3) The separation of each trunk into an anterior and a posterior division.
(4) The union of the divisions to form three cords, from which the nerves of distribution originate.

(1) The undivided **nerves** have only a very short independent course at the side of the neck whilst passing between the scalene muscles.

(2) Immediately after entering the posterior triangle, there are formed three **trunks** in order from above downwards: the upper trunk is formed by the union of the fifth and sixth nerves together; the middle trunk is always formed by the seventh nerve alone; and the lower, by the union of the eighth cervical and first thoracic nerves. This lower trunk grooves the upper surface of the first rib and lies in the sulcus subclaviæ.

(3) Each trunk divides into anterior and posterior **divisions**, which represent corresponding separation of the nerves; sometimes the nerves themselves divide before or during the formation of the trunks, rendering identification of these two stages difficult. The anterior and posterior divisions of the fifth, sixth, and

seventh nerves are nearly equal in size; the posterior division of the eighth cervical nerve is much smaller; and that of the first thoracic nerve is minute and may not be present at all. This division is of morphological significance, since it indicates the separation of the nerve fibres destined for the supply of the ventral parts of the limb from those which supply the dorsal parts.

(4) The **cords** (fasciculi) of the plexus are formed by combinations of the anterior and posterior divisions. They are three in number, and lie in relation to the axillary artery. The lateral cord is formed by union of the anterior divisions of the upper and middle trunks, or of the fifth, sixth, and seventh nerves, and lies on the lateral side of the axillary artery. The medial cord is formed by the anterior division of the lower trunk, comprising the corresponding division of the eighth nerve with the part of the first thoracic nerve engaged in the formation of the plexus; it lies on the medial side of the axillary artery. The posterior cord is made up of the posterior divisions of all three trunks, that is, of the fifth, sixth, seventh, and eighth cervical and first thoracic nerves, and lies behind the axillary artery. The first thoracic nerve may not contribute to the posterior cord, and the branch, when present, is a very small nerve.

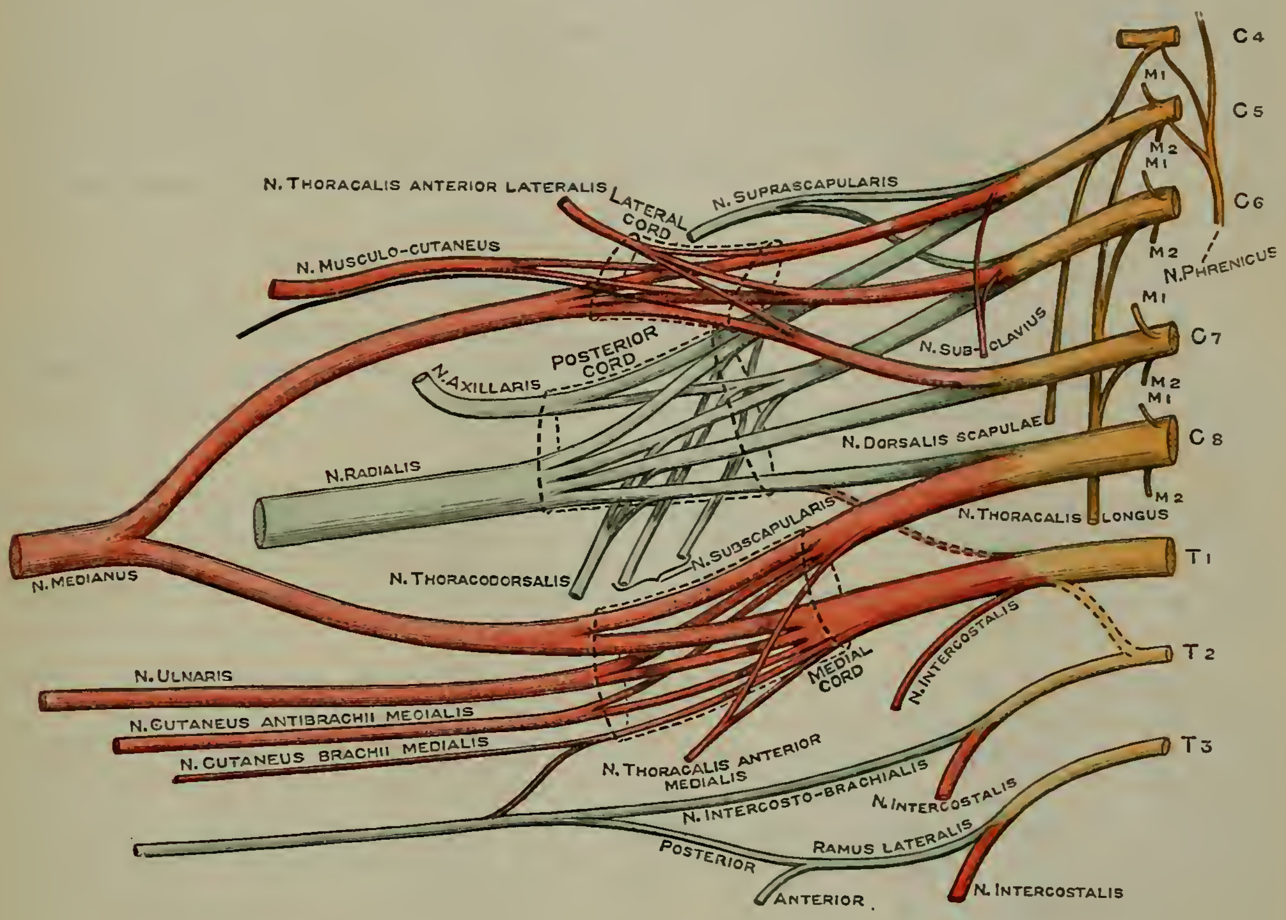


FIG. 606.—THE ORIGINS OF THE NERVES OF THE BRACHIAL PLEXUS.

The **nerves of distribution** for the shoulder and arm are derived from these cords, and receive in this way various contributions from the constituent spinal nerves. *From the lateral cord* arise the lateral anterior thoracic and musculo-cutaneous nerves, and the lateral head of the median nerve. *From the medial cord* arise the medial head of the median nerve, the ulnar nerve, medial cutaneous nerve of the forearm, medial cutaneous nerve of the arm, and the medial anterior thoracic nerve. *From the posterior cord* arise the axillary nerve, the two sub-scapular nerves, the thoraco-dorsal nerve, and the radial nerve.

It is to be remembered that, although derived from a cord formed by a certain set of spinal nerves, any given nerve does not necessarily contain fibres from all the constituent nerves; *e.g.*, both the musculo-cutaneous and axillary nerves, from the lateral and posterior cords respectively, are ultimately derived only from the fifth and sixth cervical nerves. In other words, the cords are merely collections of nerves of distribution bound together in a common sheath in their passage through the axilla. It may also be pointed out that it is impossible in nearly all cases to dissect out and trace the fibres of a given spinal nerve through the plexus to their ultimate distribution, owing to the complex manner in which the nerve bundles interlace and join one another.

Communications with the Sympathetic.—The lower four cervical nerves communicate with the cervical portion of the sympathetic by means of **gray rami communicantes.** Two branches arise from the middle cervical ganglion, and join the anterior rami of the fifth and sixth nerves. Two arising from the inferior cervical ganglion join the seventh and eighth nerves. They reach the nerves either by piercing the prevertebral muscles or by passing round the border of the scalenus anterior muscle.

Variations are found (1) in the number of nerves taking part in the formation of the plexus; and (2) in the pattern formed by the union and division of its constituent parts. (1) As regards the former, Kerr, on an examination of 175 plexuses, forms three groups: (*a*) a part of the fourth nerve joins the plexus in nearly two-thirds of cases; (*b*) no contribution is received from the fourth nerve, but all the fifth joins the plexus in one-third of cases; (*c*) a part only of the fifth enters the plexus in about 7 per cent. of cases. At the lower end of the plexus there is an intra-thoracic communication between the second and first thoracic nerves in one-third or more of cases. These figures indicate a higher or lower position of the plexus relative to the spinal column, though it is evidently subject to very slight variation. The presence of a cervical rib may coincide with little or no change in the relation of the nerves. (2) Variations in the pattern of the plexuses are due to (*a*) the stage of either trunk, divisional or even cord formation being absent in one or other part of the plexus, prior to a succeeding stage; in all such cases, however, there is no alteration in the typical nerve source of the ultimate terminal branches; (*b*) in very few cases the lateral or the medial cord may receive fibres from nerves below the seventh or above the eighth, respectively—that is, a new element is introduced into their composition.

THE BRANCHES OF THE BRACHIAL PLEXUS.

It is customary to separate artificially the nerves of distribution of the brachial plexus into two sets: (1) supra-clavicular and (2) infra-clavicular, a topographical division which is to some extent affected by the alteration in position of the bone in raising or lowering the shoulder.

The point of junction of the three posterior divisions of the trunks to form the posterior cord has been found fairly constantly situated 6·75 cm., or $2\frac{3}{4}$ inches, horizontally lateralwards, from the lateral border of the common carotid artery at the root of the neck, the arm being fully abducted; a vertical line passing through this point separates the trunks from the cords (Linell).

Clinically it is important to realise the position of origin of the nerves relative to the different stages of formation of the plexus. (*a*) The nerves to the prevertebral muscles, the communication with the phrenic, the dorsal scapular, and long thoracic nerves, arise from the *anterior rami* of the nerves involved in the plexus. (*b*) The supra-scapular and the nerve to the subclavius arise at the level of formation of the *trunks*. (*c*) The anterior thoracic, subscapular, and thoraco-dorsal nerves arise from the *cords*, prior to their ultimate subdivision into the nerves of distribution for the upper limb. (*d*) All the rest of the branches of the plexus arise from the *cords* subsequent to this last point.

Pars Supraclavicularis.—The nerves derived from the plexus above the level of the clavicle are, like the main trunks, divisible into two series: **anterior branches**, arising from the front of the plexus; **posterior branches**, arising from the back of the plexus (Fig. 606, p. 729).

(*a*) *Arising from the rami.*

Anterior Branches.	Posterior Branches.
1. Nerves to scalenus anterior and longus colli.	1. Nerves to scalenus medius and scalenus posterior.
2. Communicating nerve to join the phrenic nerve.	2. Dorsal (posterior) scapular nerve.
	3. Long thoracic nerve.

(*b*) *Arising from the trunks.*

3. Nerve to the subclavius muscle.	4. Supra-scapular nerve.

The **muscular twigs** to the anterior scalene and longus colli muscles arise from the lower four cervical nerves, as they emerge from the intervertebral foramina.

The **communicating branch to the phrenic nerve** arises usually from the fifth cervical nerve at the lateral border of the anterior scalene muscle. It is sometimes absent, and occasionally an additional root is present from the sixth cervical nerve. In some instances the nerve is replaced by a branch which springs from the nerve to the subclavius, and passes medially behind the sterno-mastoid muscle to join the phrenic at the inlet of the thorax.

N. Subclavius.—The **nerve to the subclavius** is a slender nerve, which arises from the front of the upper trunk, of the plexus, and usually receives fibres from the fourth, fifth, and sixth cervical nerves. It descends in the posterior triangle of the neck anterior to the third part of the subclavian artery. It often communicates with the phrenic nerve.

The **branches to the scalenus medius and scalenus posterior** are small trunks which arise from the lower four cervical nerves as they emerge from the intervertebral foramina.

N. Dorsalis Scapulæ. — The **dorsal scapular nerve** arises from the back of the fifth cervical nerve, as it emerges from the intervertebral foramen. It appears in the posterior triangle of the neck, after piercing the scalenus medius muscle. It is directed downwards, under cover of the levator scapulæ and rhomboid muscles, and along the vertebral margin of the scapula, to be distributed to the levator scapulæ, rhomboideus minor, and rhomboideus major muscles. It occasionally pierces the levator scapulæ.

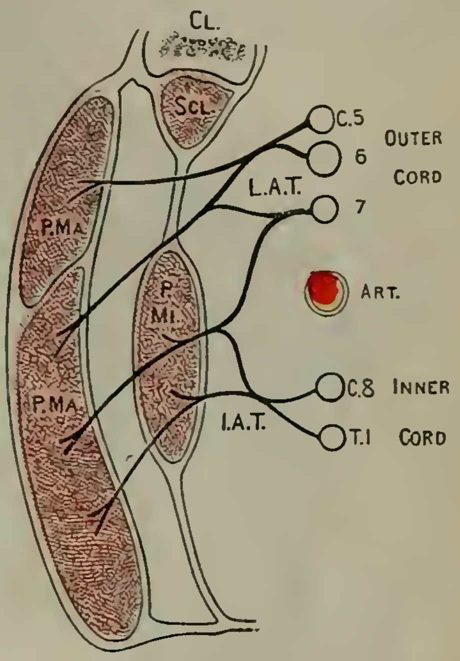


FIG. 607.—DIAGRAM OF THE ORIGIN AND DISTRIBUTION OF THE NERVES TO THE PECTORAL MUSCLES.

L.A.T., Lateral anterior thoracic nerve; I.A.T., Medial anterior thoracic nerve; C.5, 6, 7, C.8, T.1, Nerves of the brachial plexus; ART., Axillary artery; CL., Clavicle; SCL., Subclavius muscle; P.MI., Pectoralis minor, joined to subclavius by costo-coracoid membrane; P.MA., Pectoralis major.

N. Thoracalis Longus.—The **long thoracic nerve** arises by three roots, of which the middle one is usually the largest, from the back of the fifth, sixth, and seventh nerves, as they emerge from the intervertebral foramina. The nerve pierces the scalenus medius as two trunks, of which the lower represents the contribution from the seventh cervical nerve, and, descending along the side of the neck behind the cords of the brachial plexus, it enters the axilla between the superior edge of the serratus anterior muscle and the axillary artery. It continues its downward course over the axillary surface of the serratus, to the slips of which it is distributed.

There is a more or less definite relation between the roots of this nerve and the parts of the serratus muscle. The first part of the muscle is innervated by the fifth nerve alone; the second part by the fifth and sixth, or the sixth alone; the third part by the sixth and seventh, or the seventh nerve alone.

N. Suprascapularis.—The **supra-scapular nerve** arises from the back of the upper trunk of the plexus, receiving fibres from the fourth, fifth, and sixth cervical nerves. It occupies a position above the main cords of the brachial plexus, and courses downwards and laterally parallel to them towards the superior margin of the scapula. It passes through the scapular notch to reach the dorsum of the scapula. After supplying the supra-spinatus muscle it winds round the great scapular notch in company with the transverse scapular artery and terminates in the infra-spinatus muscle. It also supplies articular branches to the back of the shoulder-joint.

Pars Infraclavicularis.—The so-called infra-clavicular branches of the brachial plexus all arise from the *cords* of the plexus and are distributed to the chest, shoulder, arm and forearm. According to their origin they are divisible into two sets—an **anterior set**, derived from the lateral and medial cords, and a **posterior set**, derived from the posterior cord. In their distribution the same arrangement is maintained. The anterior nerves of distribution, springing from the lateral and medial cords, supply the chest and the front of the limb; the posterior nerves, springing from the posterior cord, supply the shoulder and the back of the limb.

(c) and (d) Arising from the cords.

Anterior Branches.

From the Lateral Cord.

Lateral anterior thoracic.
Median (lateral head).
Musculo-cutaneous.

From the Medial Cord.

Medial anterior thoracic.
Median (medial head).
Ulnar.
Medial cutaneous nerve of forearm (O.T. internal cutaneous).
Medial cutaneous nerve of arm (O.T. lesser internal cutaneous).

Posterior Branches.

Axillary nerve.
Radial nerve.
Two subscapular nerves.
Thoraco-dorsal nerve.

NERVI THORACALES ANTERIORES.

The **anterior thoracic nerves** are two in number, lateral and medial. The **lateral anterior thoracic nerve** arises from the anterior divisions of the fifth, sixth, and seventh cervical nerves just before they form the lateral cord of the plexus. The **medial anterior thoracic nerve** arises from the medial cord of the plexus, immediately after its formation, receiving fibres from the eighth cervical and first thoracic nerves. They course downwards and forwards, one on each side of the axillary artery, and a loop of communication is formed between them in front of the artery. They are finally distributed to the pectoralis major and minor muscles (Fig. 607).

The nerves are distributed to the pectoral muscles in the following way. Two sets of branches from the lateral anterior thoracic nerve pierce the costo-coracoid membrane. The superior branches supply the *clavicular part* of the pectoralis major; the inferior branches are distributed to the superior fibres of the *sternal portion* of the muscle. The superior branches come from the fifth and sixth cervical nerves; the inferior branches, from the fifth, sixth, and seventh nerves. The *pectoralis minor* is pierced by two sets of nerves—the superior set is derived from the loop of communication between the two anterior thoracic nerves over the axillary artery; the inferior set is derived from the medial anterior thoracic nerve alone. These nerves supply the *pectoralis minor* muscle, and, after piercing it, supply the *sternal part* of the pectoralis major. The inferior nerve, in many cases, sends its branches to the pectoralis major round the inferior border of the pectoralis minor, and on its way it may supply the *axillary arches*, if present. These two branches are derived—the superior from the seventh and eighth cervical, and first thoracic nerves; the inferior from the eighth cervical and first thoracic nerves. The pectoral muscles are thus both supplied by the two anterior thoracic nerves. The clavicular fibres of the pectoralis major are innervated by the fifth and sixth nerves; the sternal fibres, from above downwards, by the fifth, sixth, seventh, and eighth cervical, and first thoracic nerves; and the pectoralis minor is supplied by the seventh and eighth cervical, and first thoracic nerves.

NERVUS MUSCULOCUTANEUS.

The **musculo-cutaneous nerve** takes origin from the lateral cord of the plexus, from the fifth and sixth cervical nerves, and also from the fourth in over half the number of cases (Fig. 606). The **nerve to the coracobrachialis muscle**, arising from the seventh or sixth and seventh nerves, is usually associated with it. Separating from the lateral head of the median nerve, the musculo-cutaneous nerve lies at first between the coracobrachialis muscle and the axillary artery. It is then directed distally between the two parts of the coracobrachialis, and passes between the biceps and brachialis muscles, to the bend of the elbow. It pierces the deep fascia over the front of the elbow, between the biceps and brachioradialis, and terminates as the lateral cutaneous nerve for the supply of the lateral aspect of the forearm. In its course it may send a branch under the biceps to join the median nerve.

The branches of the nerve are muscular and cutaneous. The **muscular branches** are supplied to the two heads of the biceps and the brachialis, as the nerve lies between the muscles. The nerve to the coracobrachialis (usually incorporated with the trunk of the musculo-cutaneous nerve) has an independent origin from the seventh or sixth and seventh nerves (possibly the fifth also). It is usually double, one branch entering each portion of the muscle. The **lateral cutaneous nerve of the forearm** divides into volar and dorsal branches (Fig. 616, p. 733). The **volar branch** runs distally along the front of the lateral aspect of the forearm to the wrist, and supplies an area extending medially to the middle line of the forearm anteriorly, and distally so as to include the ball of the thumb. It usually communicates, proximal to the wrist, with the superficial ramus of the radial nerve, and supplies branches to the radial artery. The **dorsal branch** passes backwards and distally over the extensor muscles and supplies the skin on the lateral aspect of the forearm posteriorly in its proximal three-fourths, communicating with the cutaneous branches of the radial nerve. It sometimes extends on to the dorsum of the hand, supplying the skin over the first metacarpal bone.

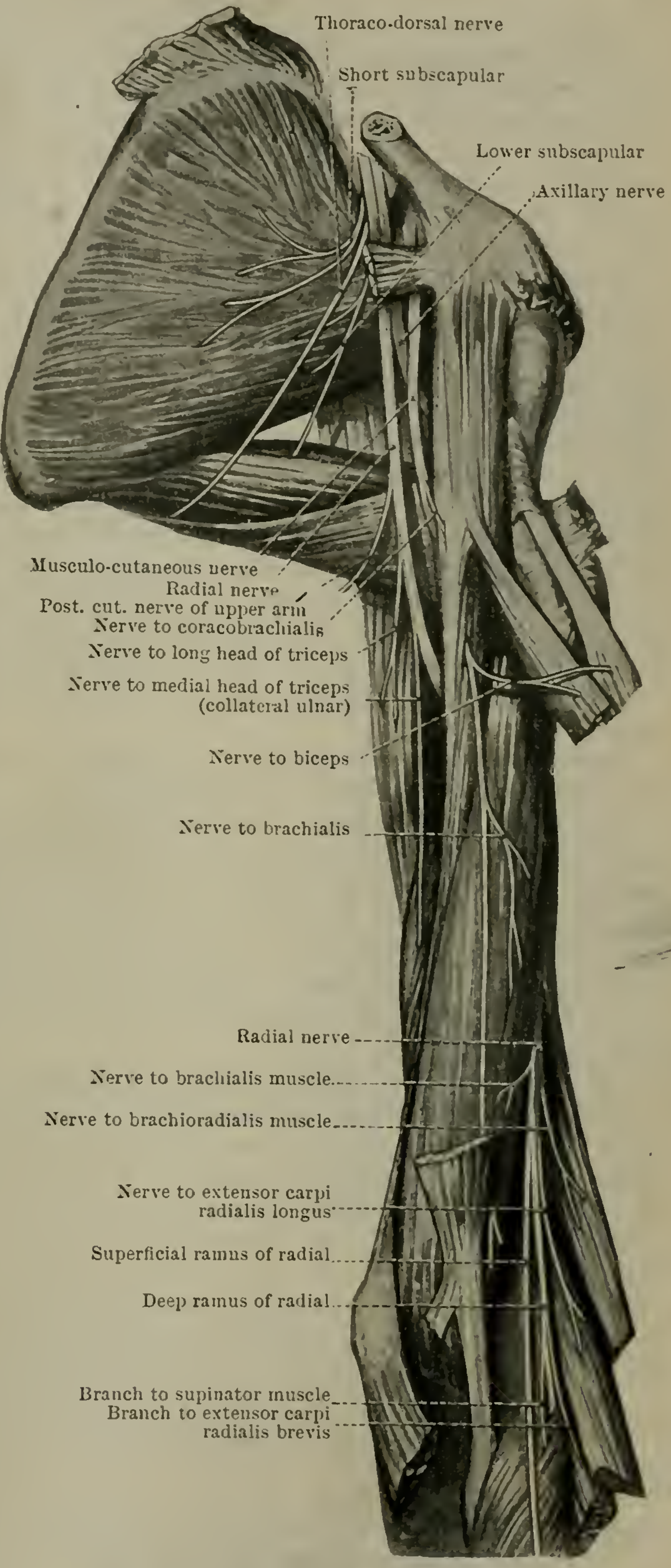

Thoraco-dorsal nerve
Short subscapular
Lower subscapular
Axillary nerve
Musculo-cutaneous nerve
Radial nerve
Post. cut. nerve of upper arm
Nerve to coracobrachialis
Nerve to long head of triceps
Nerve to medial head of triceps (collateral ulnar)
Nerve to biceps
Nerve to brachialis
Radial nerve
Nerve to brachialis muscle
Nerve to brachioradialis muscle
Nerve to extensor carpi radialis longus
Superficial ramus of radial
Deep ramus of radial
Branch to supinator muscle
Branch to extensor carpi radialis brevis

Fig. 608.—The Deeper Nerves of the Arm.

In addition to the above branches, the musculo-cutaneous nerve supplies in many cases the following small twigs in the arm: (1) a medullary branch to the humerus;

(2) a periosteal branch to the distal end of the humerus on its anterior surface; and (3) a branch to the brachial artery.

Nervus Medianus.

The **median nerve** arises by two heads—one from the lateral cord, the other from the medial cord of the brachial plexus. The lateral head, from the (fifth), sixth, and seventh nerves, descends along the lateral side of the axillary artery; the medial head, from the eighth cervical and first thoracic nerves, crosses the end of the axillary artery or the beginning of the brachial artery, to join the other head in the proximal part of the arm. It therefore receives fibres from all the main nerves forming the plexus. Descending along the lateral aspect of the brachial artery, the nerve crosses over it obliquely in the distal half of the arm. In the hollow of the elbow, it lies on the medial side of the brachial artery, behind the lacertus fibrosus and the median basilic vein. It passes into the forearm between the two heads of the pronator teres muscle, separated from the ulnar artery by the deep origin of that muscle. Extending distally along the middle of the forearm, between the superficial and deep muscles, to the wrist, it enters the palm of the hand on the lateral side of the flexor tendons of the fingers, and deep to the transverse carpal ligament. In the hand, it spreads out at the distal border of the transverse carpal ligament, under cover of the palmar aponeurosis and superficial volar arch, and separates into its six terminal branches. In the forearm a small artery accompanies it—the median branch of the volar interosseous artery. Immediately proximal to the wrist it is comparatively superficial, lying on the lateral side of the superficial flexor tendons and directly behind the tendon of the palmaris longus.

Branches.—The median nerve usually gives off no branches in the (upper) arm.

Branches in the Forearm.—(1) **Articular Branches.**—Minute articular filaments are distributed to the front of the elbow-joint.

(2) **Muscular Branches.**—Just below the elbow a bundle of nerves arises to be distributed to the following muscles: pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum sublimis. Nerves are also generally traceable from this bundle to the upper fibres of the flexor pollicis longus and flexor digitorum profundus. A separate branch to the index belly of the sublimis often arises in the lower half of the forearm. The nerve to the pronator teres, which is the first given off, often arises independently in the hollow of the elbow but seldom proximal to the joint.

(3) The **volar interosseous nerve of the forearm** (O.T. **anterior interosseous**) arises from the posterior surface of the median nerve in the forearm. It passes distally on the volar aspect of the interosseous membrane along with the volar interosseous artery, lies dorsal to the pronator quadratus muscle, and terminates by supplying articular filaments to the radio-carpal articulation. In its course the nerve supplies muscular branches to the flexor pollicis longus, the lateral half of the flexor digitorum profundus, and the pronator quadratus, minute medullary branches to the radius and ulna, and twigs to the periosteum and interosseous membrane.

(4) **Palmar Ramus.**—In the distal third of the forearm a small cutaneous branch arises, which pierces the deep fascia and crosses the transverse carpal ligament to reach the palm of the hand. It supplies the skin of the palm and communicates with a similar branch of the ulnar nerve. This branch is not always present.

Branches in the Hand.—In the hand the median nerve gives off its terminal branches. These are muscular and cutaneous.

The main **muscular branch** arises just distal to the transverse carpal ligament and passes to the base of the thenar eminence; entering the ball of the thumb superficially on the medial side, it supplies branches to the abductor pollicis brevis, opponens pollicis, and the flexor pollicis brevis.

The **cutaneous branches** are five in number. Three separate branches supply each side of the thumb and the lateral side of the index finger. The two remaining branches (*nn. digitales volares communes*) subdivide at the cleft between the second and third, and the third and fourth fingers respectively, into branches (*nn. digitales volares proprii*) which supply the adjacent sides of the second and third, and the third and fourth fingers. From the nerves which supply respectively the lateral side of the index finger, and the contiguous sides of the index and third fingers, fine muscular branches arise for the first two lumbrical muscles. The cutaneous branches of the median nerve are placed in the palm between the superficial palmar arch and the flexor tendons. They become superficial at the roots of the fingers between the slips of the palmar aponeurosis, or, in the case of the nerves to the thumb and lateral side of the index finger, at the lateral edge of the central portion of the palmar aponeurosis. In the fingers they are placed superficial to the digital arteries, and are distributed to the sides and volar aspects of the fingers. These volar branches, as in the case of the ulnar nerve, are beset with numerous Pacinian corpuscles. Each nerve supplies one or more *dorsal branches,* distributed to the skin on the dorsal aspect of the terminal phalanx of the thumb and the distal two phalanges of the first two and a half fingers, thus making up for the deficiency of the superficial branch of the radial nerve in those situations.

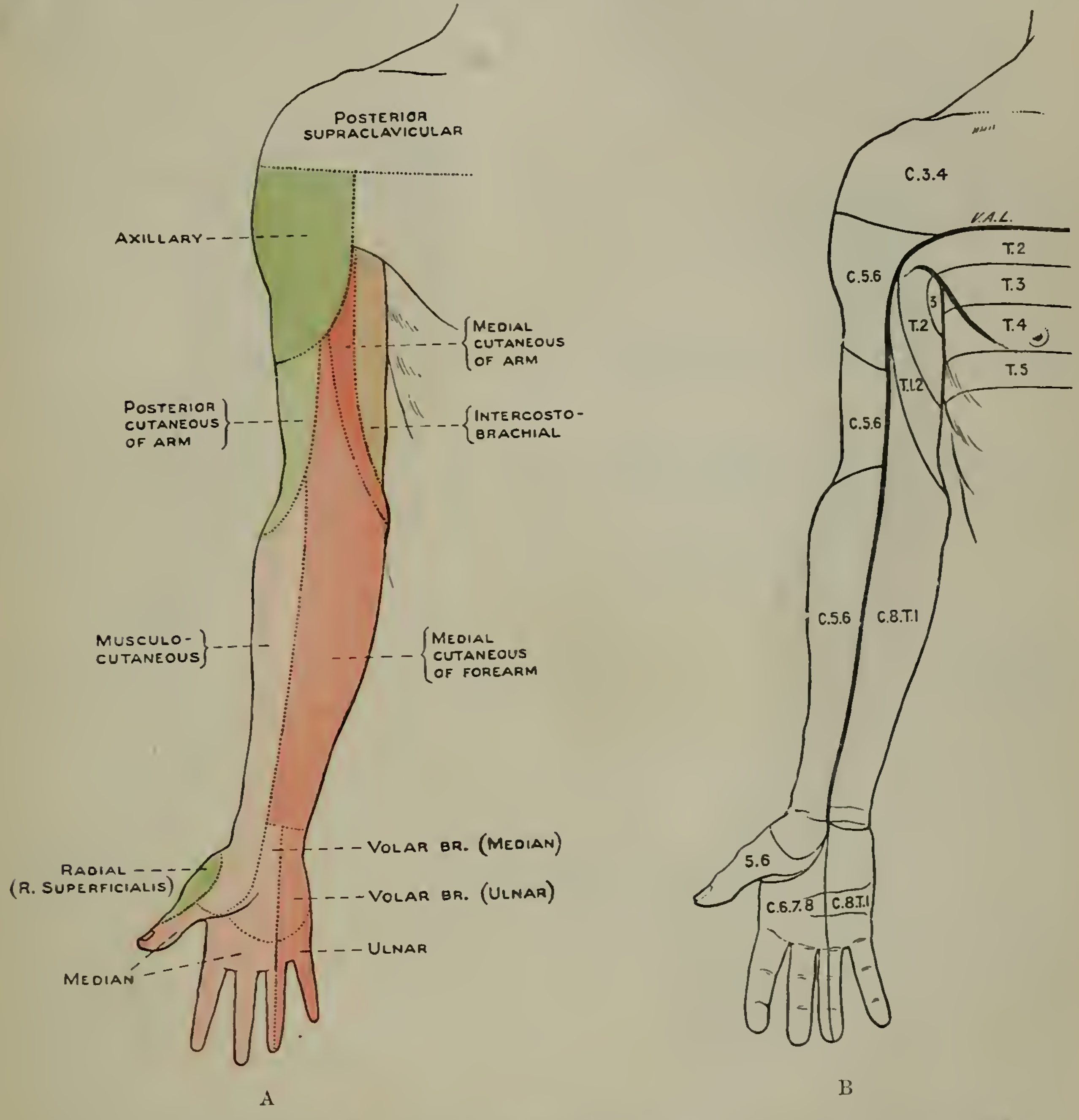


FIG. 609.—THE DISTRIBUTION OF CUTANEOUS NERVES ON THE FRONT OF THE ARM AND HAND.

B is a schematic representation of the areas supplied by the above nerves, the lettering indicating the spinal origin of the branches of distribution to each area. V.A.L., Ventral axial line.

Communications.—(1) The median nerve, in some cases, receives a communicating branch from the musculo-cutaneous nerve in the arm. (2) It communicates in some cases, in the proximal part of the forearm, with the ulnar nerve beneath the flexor muscles. (3) It communicates by means of its cutaneous branches with the ulnar nerve in the palm of the hand (*ramus anastomoticus cum nervo ulnari*).

Nervus Ulnaris.

The **ulnar nerve** arises from the medial cord of the brachial plexus, from the eighth cervical and first thoracic nerves. In over half the number of cases

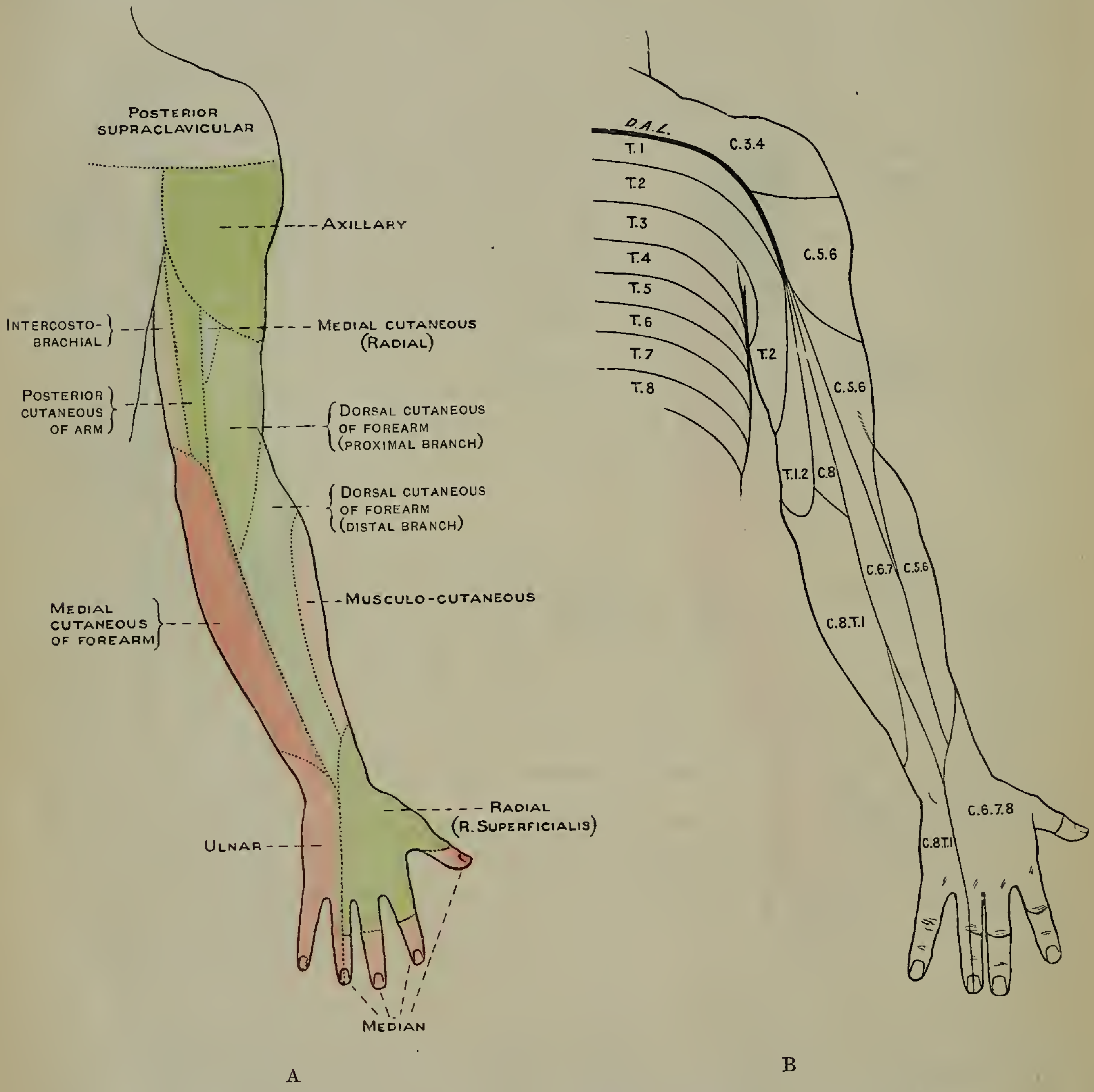

Posterior supraclavicular
Axillary
Intercosto-brachial
Medial cutaneous (Radial)
Posterior cutaneous of arm
Dorsal cutaneous of forearm (proximal branch)
Dorsal cutaneous of forearm (distal branch)
Musculo-cutaneous
Medial cutaneous of forearm
Radial (R. Superficialis)
Ulnar
Median
A
D.A.L.
T.1
C.3.4
T.2
T.3
C.5.6
T.4
T.5
T.6
T.7
T.8
T.2
C.5.6
T.1.2
C.8
C.6.7
C.5.6
C.8.T.1
C.6.7.8
C.8.T.1
B

Fig. 610.—The Distribution of Cutaneous Nerves on the back of the Arm and Hand.

B is a schematic representation of the areas supplied by the above nerves, the lettering indicating the spinal origin of the branches of distribution to each area. D.A.L., Dorsal axial line.

it has also a root from the lateral cord of the plexus or from the lateral head of the median nerve (seventh cervical nerve). This *caput laterale nervi ulnaris* is subject to great variation in size. In the axilla the ulnar nerve lies between the axillary artery and vein, and behind the medial cutaneous nerve of the forearm; in the proximal half of the arm it lies on the medial side of the brachial artery anterior to the triceps muscle. In the distal half of the arm it is separated from the brachial artery; and passing behind the intermuscular septum, and in front of the medial head of the triceps in company with the superior ulnar collateral artery, it reaches the interval between the medial epicondyle of the humerus and the olecranon. It is there protected by an arch of deep fascia stretching between the epicondyle and the olecranon. It enters the forearm between the humeral and ulnar origins of the flexor carpi ulnaris, and courses distally between the flexor carpi ulnaris and flexor digitorum profundus. In the distal half of the forearm it becomes comparatively superficial, lying on the medial side of the ulnar artery (to which it furnishes a supply) overlapped by the tendon of the flexor carpi ulnaris. Just proximal to the transverse carpal ligament, and lateral to the pisiform bone, it pierces the deep fascia, in company with the artery, and passes into the hand over the transverse carpal ligament. Reaching the palm it divides, under cover of the palmaris brevis muscle, into its two terminal branches, superficial and deep.

Branches.—The ulnar nerve gives off no branches till it reaches the forearm.

In **the forearm** it gives off articular, muscular, and cutaneous branches.

The **articular branch** is distributed to the elbow-joint and arises as the nerve passes behind the medial epicondyle of the humerus.

The **muscular branches** arise as soon as the nerve enters the forearm. They are distributed to the muscles between which the ulnar nerve lies—the flexor carpi ulnaris and the medial half of the flexor digitorum profundus. The flexor carpi ulnaris usually receives just below the elbow-joint two branches, one each to its olecranon and condylar heads; the latter may receive a secondary supply at a lower level, and even a fourth branch to the muscle may be found. Only in exceptional cases does one of these branches arise proximal to the elbow-joint (Linell).

The **cutaneous branches** are two in number, palmar and dorsal.

The **palmar cutaneous ramus** is variable in size and position. It pierces the deep fascia in the distal third of the forearm and passes to the hypothenar eminence and palm of the hand, to the skin over which it is distributed. It gives branches to the ulnar artery, and communicates often with the medial cutaneous nerve of the forearm and the palmar branch of the median nerve.

The **dorsal ramus of the hand** is much larger (Fig. 610). It arises from the ulnar nerve at a variable point in the middle third of the forearm; and, directed obliquely distally and backwards, beneath the tendon of the flexor carpi ulnaris, it becomes cutaneous on the medial side of the forearm in its distal fourth. It passes on to the back of the hand, and, after giving off branches to the skin of the wrist and hand which communicate with the superficial ramus of the radial nerve, it terminates in three *dorsal digital nerves,* to supply the little finger, the ring-finger, and half the middle finger in the following way: one branch courses along the medial side of the dorsum of the hand and supplies the little finger as far as the root of the nail; another branch subdivides at the cleft between the little and ring fingers to supply their adjacent sides to the same extent; a third branch bifurcates at the cleft between the ring and middle fingers, and supplies their adjacent sides, but only as far as the level of the proximal interphalangeal joints, the distal part of the surfaces being supplied by branches of the median overlapping from the palmar aspect. This last branch communicates with the superficial ramus of the radial nerve. The ulnar nerve in a less number of cases supplies only the little and half the ring fingers on their dorsal surfaces.

Ramus Volaris Manus.—*In the palm* the ulnar nerve supplies a small muscular branch to the palmaris brevis, and then subdivides into its terminal branches, which are named superficial and deep.

Ramus Superficialis.—The **superficial branch** is purely cutaneous; it passes distally deep to the palmar aponeurosis, and subdivides into a medial and a lateral branch. The medial branch courses along the medial border of the little finger, which it supplies on its palmar aspect. The lateral branch (*common volar digital nerve*) becomes superficial at the cleft between the fourth and fifth fingers, between the slips of the palmar aponeurosis, and subdivides into two branches (*proper volar digital nerves*) which supply the adjacent sides of these fingers on their palmar aspect. It communicates with the adjacent digital branch of the median nerve.

The ulnar nerve, therefore, usually supplies one and a half fingers on their palmar aspects and two and a half fingers on their dorsal aspects, the remaining fingers being supplied by the median nerve on the palmar, and the radial nerve on the dorsal surface. The median nerve further extends on to the dorsal aspect of the terminal phalanx of the thumb and the distal two phalanges of the first two and a half fingers, so making up for the deficiency of the radial nerve in these regions. Clinical observations show this to be a much more common arrangement than the classical description of the distribution of the ulnar nerve to one and a half fingers on both their surfaces.

Ramus Profundus.—The **deep branch** is purely muscular. It separates from the superficial branch, and passes deeply between the flexor brevis and abductor digiti quinti muscles; it supplies those muscles and the opponens digiti quinti, and, turning laterally along the line of the deep palmar arch and under cover of the deep flexor tendons, it supplies branches to the following muscles: interossei, third and fourth lumbricales (on their deep surfaces), the adductor pollicis (oblique and transverse parts), and the *interosseus primus volaris* (deep part of the flexor pollicis brevis).

Communications.—The ulnar nerve communicates (1), in some cases, with the median nerve in the forearm; (2) with the medial cutaneous nerve of the forearm, and sometimes with the median nerve, by its palmar branch; (3) with the cutaneous part of the median nerve in the palm, by means of its terminal cutaneous branches; (4) with the superficial ramus of the radial nerve on the dorsum of the hand, by means of its dorsal branch.

Nervus Cutaneus Antibrachii Medialis.

The **medial cutaneous nerve of the forearm** (O.T. **internal cutaneous nerve**) arises from the medial cord of the brachial plexus, from the eighth cervical and first thoracic nerves (Figs. 606 and 729). In the axilla and proximal half of the arm it lies superficial to the main artery. It becomes cutaneous by piercing the deep fascia about the middle of the arm on its medial side, and accompanying the basilic vein through the distal half of the arm, it divides at the front of the elbow into its two terminal branches.

Branches.—In the arm, as soon as it becomes superficial, the nerve gives off a branch which supplies the skin of the distal half of the anterior surface of the arm on its medial side. At the elbow it divides into two terminal branches—*volar* and *ulnar*, which, crossing superficial or deep to the median basilic vein, are distributed to the medial side of the forearm.

The **volar branch** can be followed to the wrist and supplies the whole of the volar surface of the forearm in the medial half; the **ulnar branch** is not so large, and, passing obliquely backwards and distally over the origins of the pronator and flexor muscles, it is distributed to the proximal two-thirds or three-fourths of the dorsal aspect of the forearm on the medial side.

Communication.—The medial cutaneous nerve of the forearm communicates with the volar branch of the ulnar nerve in the distal part of the forearm.

Nervus Cutaneus Brachii Medialis.

The **medial cutaneous nerve of the arm** arises from the medial cord of the brachial plexus, and ultimately from the first thoracic nerve (Fig. 606, p. 729). It lies at first between the axillary artery and vein; and after descending over, under, or even, in some cases, through the axillary vein, it perforates the deep fascia and is distributed to the skin of the arm for the proximal half or more on its medial side.

The nerve varies considerably in size. It may be absent, its place being taken by branches of the intercosto-brachial or by branches from the posterior cutaneous branch of the radial nerve. It generally bears a distinct relation in size to the intercosto-brachial, due to the fact that the size of the latter depends upon the size of the part of the second thoracic nerve connected with the first in the thorax. If an intra-thoracic connexion occurs between the first and second thoracic nerves, the intercosto-brachial may be deprived of a certain number of its fibres, which in that case reach the upper limb through the medial cutaneous nerve of the arm. When traced up to the plexus the medial cutaneous nerve of the arm is found to have an origin from the posterior part of the cord formed by the eighth cervical and first thoracic nerves, and usually receives fibres from the first thoracic nerve only. In cases where "*axillary arches*" are present they may be supplied by this nerve.

NERVUS AXILLARIS.

The **axillary nerve** (O.T. **circumflex**) at its origin is just below the suprascapular and comes from the same spinal nerves—the fifth and sixth cervical nerves (Fig. 606, p. 729). Extending distally and laterally behind the axillary artery, it leaves the axilla by passing round the lateral border of the subscapularis muscle, in company with the posterior circumflex artery of the humerus, in a quadrilateral space bounded by the humerus, subscapularis, triceps (long head), and teres major. Winding round the surgical neck of the humerus from medial to lateral side, it terminates by supplying the deltoid muscle (Fig. 611, p. 739).

Branches. — **Muscular branches** are supplied to the teres minor and deltoid muscles. It often gives off the lower subscapular nerve. The nerve to the teres minor enters the lateral aspect of the muscle; it possesses a pseudoganglion, a thickening of fibrous tissue, on its trunk.

Articular branches enter the posterior part of the capsule of the shoulder-joint.

A **cutaneous branch** of considerable size — *the lateral cutaneous nerve of the arm*—passes obliquely distally and forwards from beneath the deltoid muscle, becoming superficial at its posterior border. Sometimes branches pierce the muscle. It supplies the skin over the insertion of the deltoid and the proximal half of the arm on its lateral aspect (Figs. 609, p. 735, and 610, p. 736).

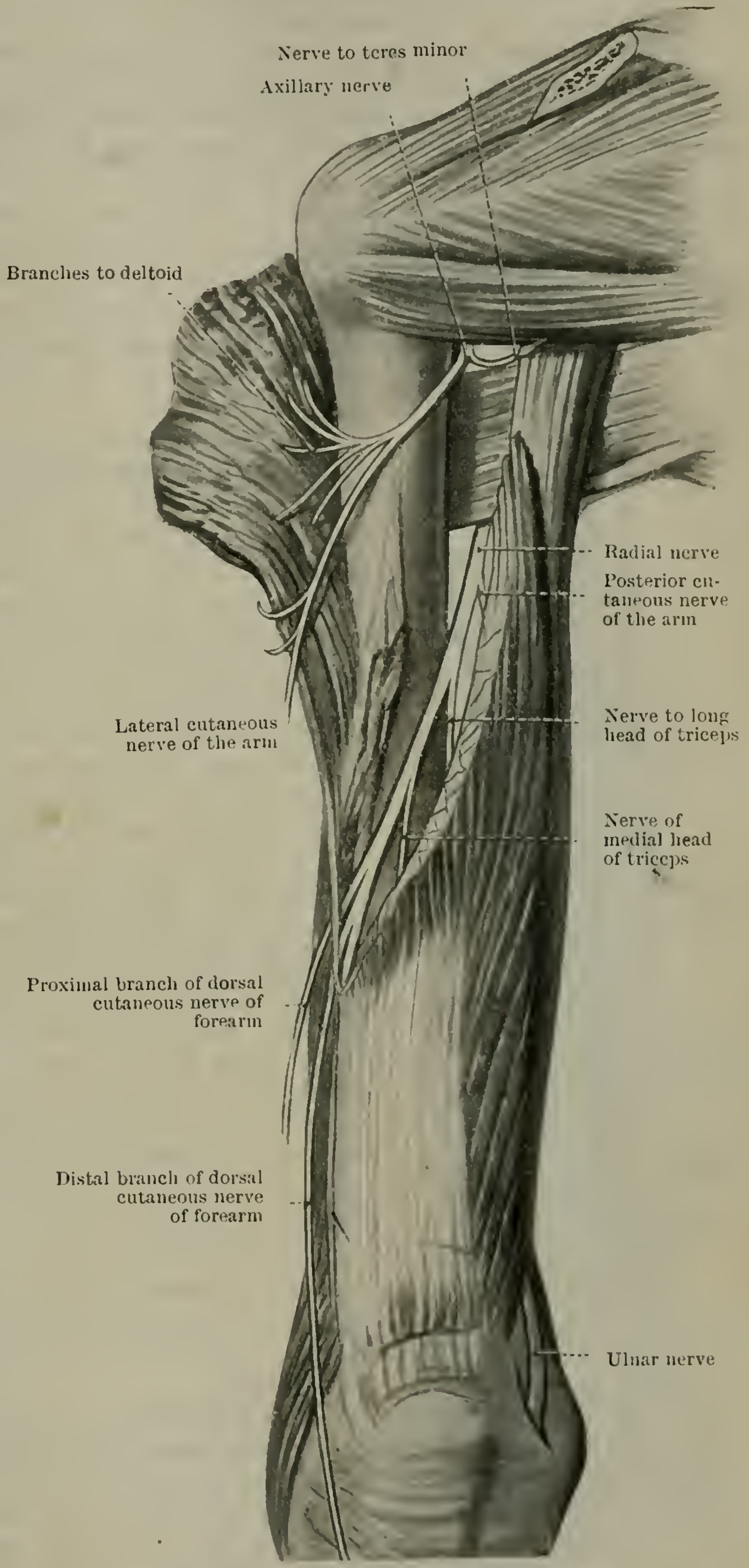

Nerve to teres minor
Axillary nerve
Branches to deltoid
Radial nerve
Posterior cutaneous nerve of the arm
Lateral cutaneous nerve of the arm
Nerve to long head of triceps
Nerve of medial head of triceps
Proximal branch of dorsal cutaneous nerve of forearm
Distal branch of dorsal cutaneous nerve of forearm
Ulnar nerve

FIG. 611.—THE AXILLARY AND RADIAL NERVES.

NERVUS RADIALIS.

The **radial nerve** (O.T. **musculo-spiral**) appears to be the continuation into the upper limb of the posterior cord of the brachial plexus. It usually takes origin from all the nerves which form the posterior cord —the fifth, sixth, seventh, and eighth cervical and first thoracic nerves (Fig. 606,

p. 729). In some cases the first thoracic contributes no fibres, and often the fifth cervical nerve is excluded from it. It extends from the axilla, round the back of the humerus, to the bend of the elbow, where it ends by dividing into its *superficial* and *deep* terminal branches.

In the axilla it lies behind the axillary artery, and in front of the subscapularis, teres major, and latissimus dorsi muscles.

In the arm, in the proximal third, it lies to the medial side of the humerus, behind the brachial artery, and upon the long head of the triceps. In the middle third of the arm it courses obliquely laterally and distally in the radial groove of the humerus, along with the profunda brachii artery, separating the long, lateral, and medial heads of the triceps muscle (Fig. 611, p. 739). In the distal third of the arm, piercing the proximal part of the intermuscular septum at the lateral border of the triceps muscle, it passes to the bend of the elbow in front of the lateral epicondyle of the humerus, in the interval between the brachio-radialis and brachialis muscles. Under cover of the former muscle, usually at the level of the lateral epicondyle of the humerus, it divides into its two terminal branches, the superficial and deep rami.

The **collateral branches** are in three sets, arising (*a*) on the medial side, (*b*) on the back, and (*c*) on the lateral side of the humerus (Fig. 612).

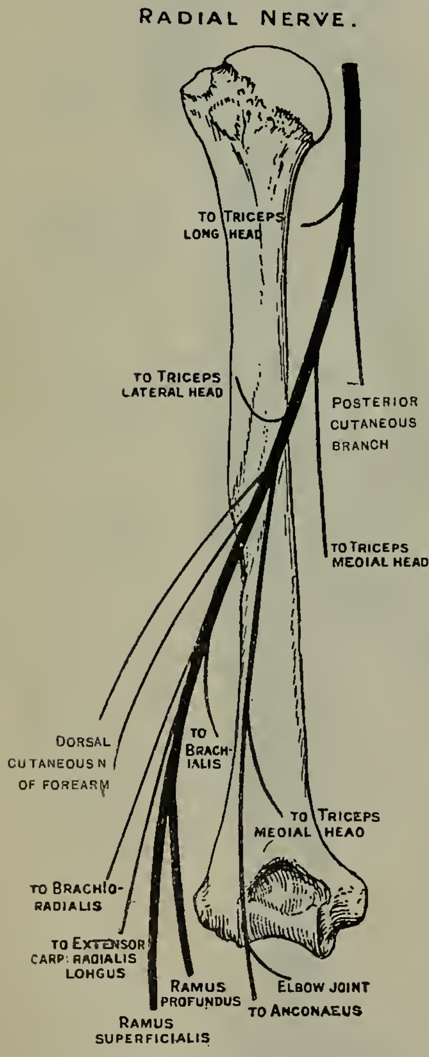


FIG. 612.—DIAGRAMMATIC REPRESENTATION OF THE BRANCHES OF THE RADIAL NERVE.

I. Branches arising medial to the Humerus.—1. **N. cutaneus brachii posterior.**—The posterior cutaneous nerve of the arm, arising in common with one of the following, or independently, pierces the fascia on the medial side of the arm near the axilla. It supplies the skin of the posterior surface of the arm in the proximal third, proximal and posterior to the area supplied by the medial nerve of the arm (Fig. 610, p. 736). This nerve varies in size, according to the bulk of the last named and the intercosto-brachial nerves.

2. **Rami Musculares.** — The muscular branches supply the triceps and anconæus. The triceps receives four distinct nerve supplies in the following order: (i.) to the long head, arising from the nerve in the axilla; (ii.) to the distal part of the medial head, arising near the lower border of the teres major, and termed the ulnar collateral nerve since it accompanies the ulnar nerve in the middle third of the arm; (iii.) to the lateral head, arising just distal to the last-mentioned branch; and (iv.) the main supply to the medial head, arising from the nerve just prior to its entry into the radial groove of the humerus. This last branch, after supplying the medial head of the triceps, passes through the muscle and behind the lateral epicondyle of the humerus to terminate in the anconæus muscle. All these branches, therefore, arise from the nerve above or just as it enters the radial groove; the only branch of any consequence arising from it in the groove is the dorsal cutaneous nerve of the forearm.

II. Branches arising on the Posterior Surface of the Humerus.—The dorsal cutaneous nerve of the forearm consists of two branches, proximal and distal. Arising from the radial nerve before it pierces the lateral intermuscular septum, these branches pierce the deep fascia close together on the lateral side of the arm in its distal half. Passing distally over the back of the lateral epicondyle, the *proximal branch* supplies the skin of the lateral side and posterior surface of the arm in its distal third, and the dorsal surface of the forearm in its proximal half. The *distal branch* supplies an area of skin on the dorsal surface of the forearm in the proximal two-thirds, medial to the area innervated by the musculo-cutaneous nerve (Fig. 610, p. 736).

III. **Branches arising at the Lateral Side of the Humerus.**—**Muscular Branches.**—The radial nerve, as it lies in the interval between the brachialis and brachio-radialis muscles, supplies nerves to the brachio-radialis (often double) and extensor carpi radialis longus. It may also provide the nerve to the extensor carpi radialis brevis; an inconstant branch is given to the brachialis, which would appear from electrical observations to be an afferent path.

RAMUS SUPERFICIALIS NERVI RADIALIS.

The **superficial ramus** (O.T. **radial nerve**) is entirely cutaneous in its distribution. Arising in the hollow of the elbow beneath the brachio-radialis, it courses distally under cover of that muscle through the proximal two-thirds of the forearm, and accompanies and supplies the radial artery in the middle third of the forearm. It then passes backwards, under cover of the tendon of the brachio-radialis, and pierces the deep fascia on the lateral aspect of the forearm in the distal third. It is distributed to the skin of the dorsum of the wrist, the lateral side and the dorsum of the hand, and the dorsum of the thumb and lateral two and a half fingers (Fig. 610, p. 736). Its branches communicate, on the ball of the thumb, with the musculo-cutaneous nerve, and, on the dorsum of the hand, with the dorsal branch of the ulnar nerve (*ramus anastomoticus ulnaris*). The **digital nerves** are small, and are five in number. They supply a very variable extent of the dorsum of the hand and fingers. Two pass to the back of the thumb and reach the level of the interphalangeal articulation. One supplies the lateral side of the index finger as far as the second phalanx. The remaining two branches divide at the clefts between the second and third, and third and fourth fingers respectively, and innervate the adjacent sides of those fingers as far as the second phalanx. The rest of the skin of those digits to the tips is supplied by digital branches of the median nerve. The nerve may only supply the thumb and one and a half fingers, being replaced by branches from the ulnar nerve. From

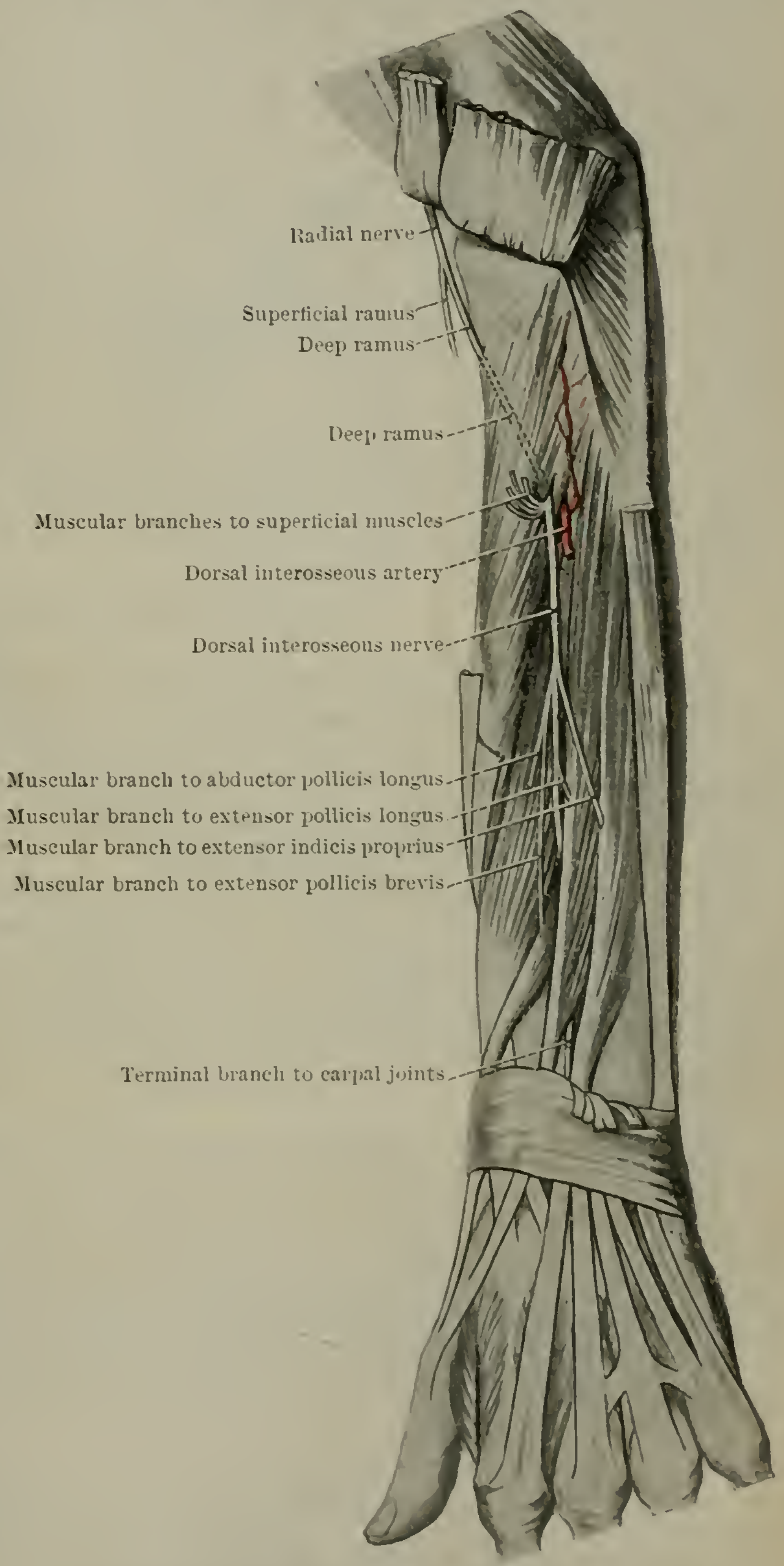

Radial nerve
Superficial ramus
Deep ramus
Deep ramus
Muscular branches to superficial muscles
Dorsal interosseous artery
Dorsal interosseous nerve
Muscular branch to abductor pollicis longus
Muscular branch to extensor pollicis longus
Muscular branch to extensor indicis proprius
Muscular branch to extensor pollicis brevis
Terminal branch to carpal joints

FIG. 613.—DISTRIBUTION OF THE DEEP BRANCH OF THE RADIAL NERVE.

clinical observations this last distribution would appear to be the more common, since in about 70 per cent. of cases the radial has been found not to extend medially beyond the second metacarpal bone (Stopford).

RAMUS PROFUNDUS NERVI RADIALIS.

The **deep ramus** (O.T. **posterior interosseous nerve**) is entirely muscular and articular in its distribution. It arises, like the superficial ramus, under cover of the brachio-radialis muscle. Directed obliquely distally and backwards, it reaches the back of the forearm, after passing round the lateral aspect of the radius, by piercing the fibres of the supinator muscle (Fig. 613). On the dorsal surface of the forearm it is called the **dorsal interosseous nerve**, and is placed in the proximal part of its course beneath the superficial extensor muscles, and upon the supinator and abductor pollicis longus, along with the dorsal interosseous artery, to which it furnishes twigs. In the distal half of the forearm it passes under cover of the extensor pollicis longus, and lies upon the interosseous membrane. At the wrist it passes deep to the extensor tendons, on to the back of the carpus, where it terminates in a gangliform enlargement of small size, from which branches pass to the inter-carpal articulations. The nerve supplies the following branches:—

(1) Terminal **articular branches** to the carpal joints.

(2) **Muscular branches**, in its course through the forearm. Thus, on the lateral side of the radius, it supplies the extensor carpi radialis brevis and the supinator muscles before it enters the fibres of the last-named muscle. After emerging from the supinator it supplies a large bundle of nerves which enter the extensor digitorum communis, extensor digiti quinti proprius, and extensor carpi ulnaris, near their origins. At a more distal level the nerve gives off branches to the abductor pollicis longus, extensor pollicis longus and extensor pollicis brevis, and extensor indicis proprius.

NERVI SUBSCAPULARES.

There are two subscapular nerves (Figs. 606 and 608).

The **first or short subscapular nerve** is often double, and there may be three trunks present. It arises from the posterior cord of the plexus behind the axillary nerve, and comes from the fifth and sixth cervical nerves (often from the fourth and seventh in addition). It passes downwards behind the axillary artery and enters the subscapularis muscle.

The **second, lower, or axillary subscapular nerve** also arises behind the axillary nerve from the posterior cord of the plexus (from the fifth and sixth cervical nerves). Its origin is distal and lateral to that of the first nerve; and it often arises in common with the axillary nerve. It courses downwards behind the axillary artery and the axillary and radial nerves, to the teres major muscle. It supplies branches to the lateral part of the subscapularis muscle and ends in the teres major.

NERVUS THORACODORSALIS.

The **thoraco-dorsal nerve** arises from the back of the posterior cord of the plexus, behind the radial nerve, and from the sixth, seventh, and eighth cervical nerves, or from the seventh and eighth nerves only. It is directed distally and laterally between the two preceding nerves, behind the axillary artery and over the posterior wall of the axilla, in company with the subscapular artery, to the latissimus dorsi muscle, which it supplies on its anterior (deep) surface.

NERVI THORACALES.

The anterior rami of the **thoracic nerves** are twelve in number, each nerve emerging below the corresponding vertebra and rib. Eleven of the series are intercostal, the twelfth lying below the last rib. The first, second, third, and twelfth nerves present peculiarities in their course and distribution. The other thoracic nerves, as already stated, are simple, and may be regarded as types both in course and distribution.

The anterior ramus of the **first thoracic nerve** is the largest of the series. It emerges from the vertebral canal below the neck of the first rib, and divides in the first intercostal space into two very unequal, superior and inferior parts. The *superior* and larger part ascends obliquely over the neck of the first rib, lying lateral to the arteria intercostalis suprema, and enters the neck behind the subclavian artery and the pleura. It proceeds laterally upon the scalenus medius muscle and enters into the formation of the brachial plexus, as already described.

The *inferior, intercostal part* of the nerve is much smaller in size. It courses forwards in the first intercostal space and supplies the intercostal muscles. It usually gives off no anterior branch to the skin of the chest and no lateral cutaneous branch.

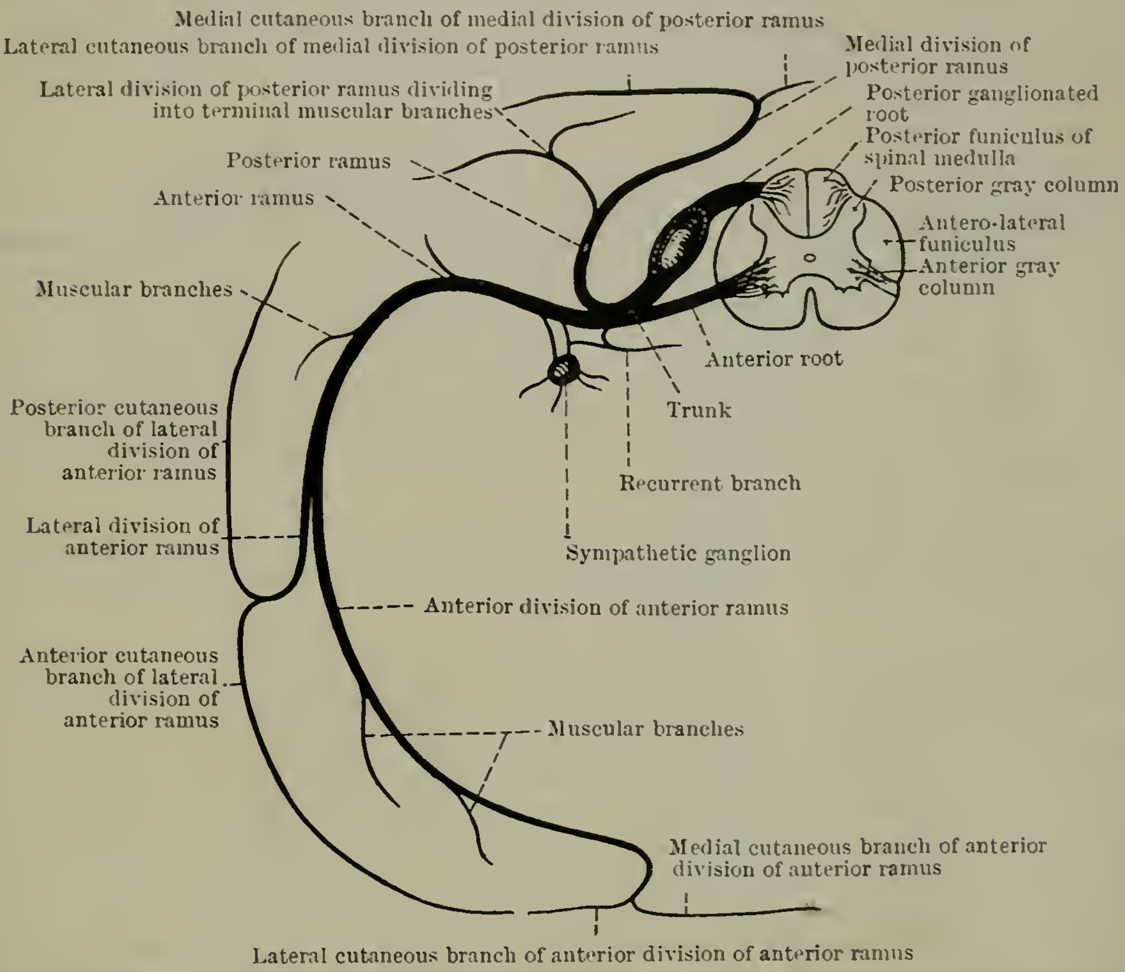

Medial cutaneous branch of medial division of posterior ramus
Lateral cutaneous branch of medial division of posterior ramus
Medial division of posterior ramus
Lateral division of posterior ramus dividing into terminal muscular branches
Posterior ganglionated root
Posterior funiculus of spinal medulla
Posterior ramus
Posterior gray column
Anterior ramus
Antero-lateral funiculus
Anterior gray column
Muscular branches
Anterior root
Trunk
Posterior cutaneous branch of lateral division of anterior ramus
Recurrent branch
Lateral division of anterior ramus
Sympathetic ganglion
Anterior division of anterior ramus
Anterior cutaneous branch of lateral division of anterior ramus
Muscular branches
Medial cutaneous branch of anterior division of anterior ramus
Lateral cutaneous branch of anterior division of anterior ramus

FIG. 614.—DIAGRAM OF THE ORIGIN AND DISTRIBUTION OF A TYPICAL SPINAL NERVE.

Note that the medial division of the posterior ramus is represented as distributed to skin, whilst the lateral division terminates at a deeper level in muscle; in some situations the reverse condition occurs. The medial and lateral divisions of all posterior rami supply muscles.

In some cases a lateral cutaneous branch emerges from the side of the first intercostal space. This may be derived from the first nerve, or it may be the **intercosto-brachial nerve**, *i.e.* the lateral branch of the second thoracic nerve. In many cases an anterior cutaneous branch perforates the first intercostal space and supplies the skin on the front of the chest. This branch, similarly, is sometimes traceable to the second thoracic nerve.

Communications.—Besides its junction with the eighth cervical to form the brachial plexus, the first thoracic nerve effects the following communications: (*a*) The last cervical or first thoracic ganglion of the sympathetic sends a *gray ramus communicans* to join the nerve on its appearance in the thorax. (*b*) The second thoracic nerve in a majority of cases communicates with the first. This communication varies considerably in size and distribution. It may reinforce the intercostal branch of the nerve, it may send one branch to the intercostal portion and another to the part of the nerve joining the brachial plexus, or it may consist of a nerve proceeding solely to join the brachial plexus by a junction in the first intercostal space with the part of the first thoracic nerve, which is engaged in forming the plexus. (*c*) The first *white ramus communicans* in the thoracic region connects the first thoracic nerve with, as a rule, the stellate ganglion of the sympathetic trunk.

The anterior ramus of the **second thoracic nerve** is of large size, though much smaller than the first. It passes forwards in the second intercostal space, lying at first in the costal groove, between the external and internal intercostal muscles. At the level of the mid-axillary line it gives off a large lateral branch; continuing its course, it pierces the internal intercostal muscle and lies upon the pleura; finally, at the lateral border of the sternum, it passes forwards in front of the internal mammary artery and through the internal intercostal muscle, and the aponeurosis of the external intercostal muscle and pectoralis major, and ends by supplying the skin of the front of the chest over the second intercostal space.

The nerve supplies the following branches:—

1. **Muscular branches** to the muscles of the second intercostal space.
2. **Cutaneous branches.** (*a*) **Anterior terminal branches** to the skin over the second intercostal space (Fig. 615). (*b*) A large lateral cutaneous branch, the **intercosto-brachial (O.T. intercosto-humeral) nerve** (Fig. 609, p. 735). This nerve pierces the intercostal and serratus anterior muscles, and, crossing the axilla, extends to the arm. It pierces the deep fascia just beyond the posterior fold of the axilla, and can be traced as far as the interval between the medial epicondyle of the humerus and the olecranon. It supplies an area of skin stretching across the axilla and along the posterior surface of the arm on the medial side as far as the elbow (Fig. 609, p. 735). It may supply the axillary arches, when present.

The intercosto-brachial nerve varies in size. It may pierce the first intercostal space, and it is often divisible into anterior and posterior branches, like the lateral branch of an ordinary intercostal nerve.

Communications.—(1) The intercosto-brachial nerve communicates with two adjacent nerves. Either before or after piercing the fascia of the axilla it is joined by the medial cutaneous nerve of the arm. It also communicates with the posterior part of the lateral branch of the third intercostal nerve by means of the branches distributed to the floor and boundaries of the axilla. (2) Besides the branches referred to, the second thoracic nerve in many cases transmits a nerve to the brachial plexus, which becomes incorporated with the first thoracic nerve after passing over the neck of the second rib. This branch is inconstant. As already mentioned, it may join only the intercostal part of the first thoracic nerve, it may join the brachial plexus only, or it may send branches to both parts of the first thoracic nerve. (3) Besides the communications effected by branches of the second thoracic nerve in its course, it also receives a *gray ramus communicans* from the second thoracic ganglion of the sympathetic trunk in the thorax. It also sends to the sympathetic a *white ramus communicans*, probably the first, though this is not known with certainty.

The anterior ramus of the **third thoracic nerve** differs from a typical thoracic nerve only in one respect. Its **lateral branch** divides in the usual way into anterior and posterior parts, of which the latter is carried to the arm and supplies an area of skin on the medial side near the root of the limb. It effects a junction with the intercosto-brachial nerve (Fig. 615, p. 745).

The anterior rami of the **fourth, fifth, and sixth thoracic nerves** have a course and distribution which are simple and typical. Except for the peculiarities above mentioned, the second and third thoracic nerves have a similar distribution.

The nerves lie on the posterior wall of the thorax, in the costal groove of the corresponding rib. They extend forwards between the intercostal muscles as far as the middle of the chest wall, lying at a lower level than the intercostal vessels. At the side of the chest each nerve passes obliquely through the internal intercostal muscle, and comes to lie upon the pleura, transversus thoracis muscle, and internal mammary artery. Thereafter, piercing the fibres of the internal intercostal muscle, the aponeurosis of the external muscle, and the pectoralis major, each nerve ends by supplying the skin of the front of the chest, over an area corresponding to the medial or anterior part of the intercostal space to which it belongs.

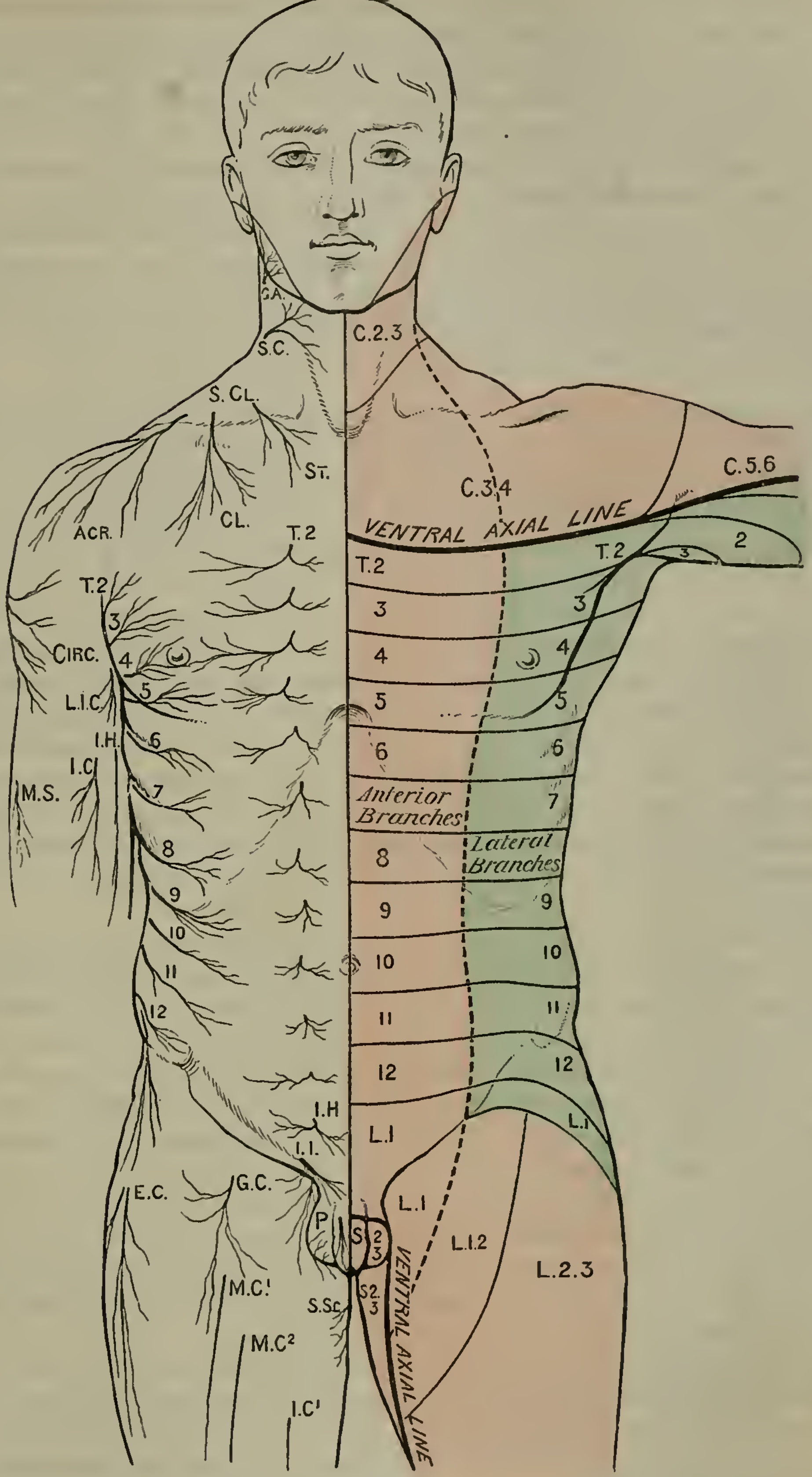


Fig. 615.—The Distribution of Cutaneous Nerves on the front of the Trunk.

On one side the distribution of the several nerves is represented, the letters indicating their nomenclature.

G.A., Great auricular nerve; S.C., N. cutaneus colli; S.Cl., Supra-clavicular nerves; Acr., Posterior; Cl., Middle; St., Anterior; T.2-12, Lateral and anterior branches of thoracic nerves; I.H., (below) Ilio-hypogastric nerve; I.I., Ilio-inguinal nerve; Circ., Cutaneous branch of axillary nerve; L.I.C., Medial cutaneous nerve of the arm (O.T. lesser internal cutaneous nerve); I.H., (above) Intercosto-brachial; I.C., Medial cutaneous nerve of the forearm (O.T. internal cutaneous); M.S., Cutaneous branch of radial nerve; E.C., Lateral cutaneous nerves; G.C., Lumbo-inguinal nerve; M.C.¹ ², Intermediate cutaneous nerves; I.C.¹, Branch of medial cutaneous nerve; P., Branches of pudendal nerve; S.Sc., Branches of posterior cutaneous nerve of the thigh.

On the other side a schematic representation is given of the areas supplied by the above nerves, the numerals indicating the spinal origin of the branches of distribution to each area.

Branches.—Each intercostal nerve supplies, in addition to the anterior terminal cutaneous branches, *muscular branches* to the intercostal muscles and a **lateral cutaneous ramus**, which, piercing the intercostal and serratus anterior muscles, divides into anterior and posterior branches for the innervation of the skin over the side of the chest. Each area of skin thus innervated is continuous anteriorly with the area innervated by the anterior rami of the same nerves, and posteriorly with the areas supplied by their posterior rami.

The upper six intercostal nerves supply the muscles of the first six intercostal spaces and the transversus thoracis (3, 4, 5, 6). The second, third, fourth, fifth, and sixth nerves supply the skin of the front of the chest: the second, opposite the sternal synchondrosis; the sixth, opposite the base of the xiphoid process. Their lateral branches supply branches to the intercostal muscles and the skin of the side of the chest, the second (intercosto-brachial) and the third, in part, being drawn out to the arm. The fourth supplies the nipple (Fig. 615).

Communications.—Each of these intercostal nerves communicates with the sympathetic trunk and ganglia by two branches—a *white ramus communicans* to the corresponding sympathetic ganglion or the adjacent part of the sympathetic trunk; and a *gray ramus communicans*, which passes to each nerve from the corresponding ganglion.

The anterior rami of the **seventh, eighth, ninth, tenth, and eleventh thoracic nerves** differ from the preceding nerves only in regard to a part of their course and distribution. Each has the same course and communications as the preceding nerves in the thoracic wall. In addition, these nerves have a further course and distribution in the abdominal wall. Each nerve traverses an intercostal space in the way described. At the anterior end of the space, the nerve passes between the attachments of the diaphragm and the transversus abdominis muscle to the costal cartilages, and courses forwards in the abdominal wall between the transversus and obliquus internus muscles. The nerve then passes between the rectus abdominis muscle and the posterior layer of its sheath, and eventually reaches the anterior abdominal wall and becomes cutaneous by piercing the rectus abdominis itself and the anterior layer of its sheath.

Muscular Branches.—The lower intercostal nerves supply the intercostal muscles of the spaces in which they lie; and in the abdominal wall they innervate the transversus, obliquus externus and internus, and rectus abdominis. The branches arise from the main trunk as well as from its lateral and anterior branches. (The ninth, tenth, and eleventh nerves are described as assisting in the innervation of the diaphragm by communications with the phrenic nerve.)

Cutaneous Branches.—These are lateral and anterior. The **lateral branches** divide into anterior and posterior parts, and, becoming superficial along the line of inter-digitation of the obliquus externus muscle with the serratus anterior and latissimus dorsi, they are directed more obliquely downwards than the lateral branches of the higher intercostal nerves, and are distributed to the skin of the loin as low down as the buttock. The lateral branch of the eleventh nerve can be traced over the iliac crest.

The **anterior branches** are small. That of the seventh nerve innervates the skin at the level of the xiphoid process. The eighth and ninth appear between the xiphoid process and the umbilicus; the tenth nerve supplies the region of the umbilicus; and the eleventh, the area immediately below the umbilicus.

The cutaneous branches of these nerves, including those of the posterior rami, thus supply continuous belts of skin, which can be mapped out on the body from the vertebral column behind to the median plane in front. These areas are not placed horizontally, but tend to be drawn more downwards anteriorly as the series is followed from the upper to the lower nerves.

The anterior ramus of the **twelfth thoracic nerve** is peculiar in its course and distribution. It emerges below the last rib (Fig. 617), and passes laterally and downwards in the posterior abdominal wall under cover of the psoas muscle; it appears in the abdomen beneath the lateral lumbo-costal arch, and crosses over the quadratus lumborum muscle, lying behind the kidney and colon. It then pierces the transversus abdominis muscle, and courses forwards in the interval between it and the obliquus internus as far as the sheath of the rectus muscle.

After piercing the posterior layer of the sheath, the rectus muscle, and the anterior layer of the sheath, it terminates by supplying the skin of the anterior abdominal wall midway between the umbilicus and the os pubis. The branches of the nerve are **muscular** to the transversus, obliqui, rectus, and pyramidalis muscles of the abdominal wall; and **cutaneous branches**, two in number—an *anterior terminal branch*, which supplies the skin of the anterior abdominal wall midway between the umbilicus and the pubis, and a large *lateral cutaneous branch*, which, passing obliquely downwards through the lateral muscles of the abdominal wall, becomes superficial above the iliac crest, a couple of inches behind the anterior superior spine. It supplies the skin of the buttock as far down as a point below and anterior to the greater trochanter of the femur (Fig. 615, p. 745).

The twelfth thoracic nerve, in many cases, receives a **communicating branch** from the eleventh, near its origin, and still more frequently sends a fine branch to join the origin of the first lumbar nerve in the psoas muscle. It may communicate also with the ilio-hypogastric nerve, as they lie together in the abdominal wall.

Intercommunications of the Thoracic Nerves.—It has been noted already that the belts or areas of skin supplied by the branches of the thoracic nerves are also innervated by adjacent nerves on either side which invade the area supplied by a given nerve. Communications also take place between the branches of the nerves supplying the intercostal muscles, whereby the muscles of a given space derive their innervation from more than one intercostal nerve.

PLEXUS LUMBOSACRALIS.

The **lumbo-sacral plexus** is formed by the union of the anterior rami of the remaining spinal nerves—five lumbar, five sacral, and one coccygeal. Frequently a fine communicating branch of the twelfth thoracic nerve joins the first lumbar nerve near its origin.

Of the nerves in question the first sacral is generally the largest in size, the nerves diminishing gradually above and rapidly below this nerve. The plexus, for the most part, forms the nerves destined for the supply of the lower limb. In addition, however, nerves arise at its superior limit which are distributed to the trunk above the level of the limb, and at the inferior end of the plexus nerves arise for the supply of the perineum.

Partly for convenience of description, and partly on account of the differences in position and course of some of the nerves emanating from it, the plexus is subdivided into three subordinate parts—lumbar, sacral, and pudendal plexuses. There is, however, no strict line of demarcation between the three parts.

Plexus Lumbalis.—The **lumbar plexus** is formed by the first four lumbar nerves, and is often joined by a branch from the twelfth thoracic nerve as well. It is limited below by the fourth lumbar nerve (*n. furcalis*), which enters also into the composition of the sacral plexus. The nerves of the lumbar plexus are formed in the loin, and supply that region as well as part of the lower limb. They are separated from the nerves of the sacral portion of the plexus by the articulation of the hip bone with the sacrum.

Plexus Sacralis.—The **sacral plexus** is formed by the fourth and fifth lumbar, and the first two or three sacral nerves. It is generally limited below by the third sacral nerve (*n. bigeminus*), which assists also in forming the pudendal plexus. The nerves of the sacral plexus are placed on the posterior wall of the pelvis, and are destined almost entirely for the lower limb.

Plexus Pudendus.—The **pudendal plexus** is formed by the second, third, fourth, and fifth sacral nerves, and the minute coccygeal nerve. It is placed on the posterior wall of the pelvis and supplies branches mainly to the perineum.

Communications with the Sympathetic.—Each of these nerves has communications with the gangliated trunk of the sympathetic in the abdomen and pelvis by means of **rami communicantes.**

From the lumbar and sacral ganglia long slender *gray rami communicantes* are directed backwards and laterally over the bodies of the vertebræ, and (in the lumbar region) beneath the origins of the psoas muscle, to reach the spinal nerves. These branches are irregular in their arrangement. A given nerve may receive branches from two ganglia, or one ganglion may send branches to two nerves. The rami are longer in the loin than in the pelvis, owing to the projection of the lumbar portion of the vertebral column.

Certain lumbar and sacral nerves are also connected with the sympathetic by means of *white rami communicantes.* From the first two, and possibly in some cases also the third and fourth lumbar nerves, white rami are directed forwards, either independently or incorporated with the corresponding gray rami, to join the upper part of the lumbar sympathetic trunk. The fifth lumbar nerve and the first sacral nerves are unprovided with white rami. From the anterior rami of the second and third, or third and fourth sacral nerves, white rami (visceral or splanchnic branches) pass medially, and, crossing over (without joining) the sympathetic trunk, enter the pelvic plexus of the sympathetic. The fifth sacral and coccygeal nerves possess no white rami communicantes.

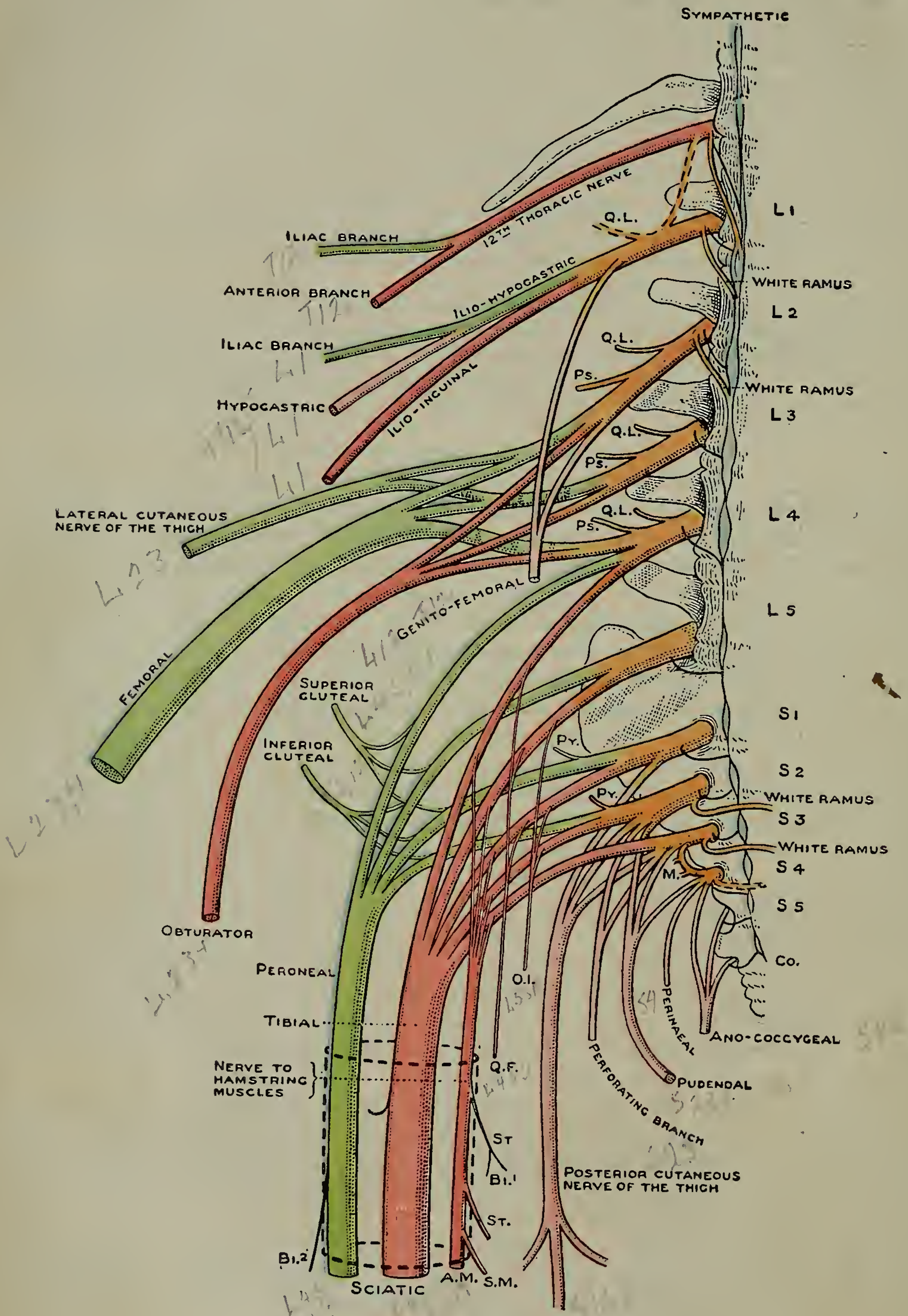


FIG. 616.—NERVES OF THE LUMBO-SACRAL PLEXUS.

VARIATIONS IN THE POSITION OF THE LUMBO-SACRAL PLEXUS.

The **lumbo-sacral plexus** shows a very considerable variability in position and constitution. Eisler records concomitant variations in the plexus in 18 per cent. of the cases examined by him. The variations occur within wide limits. The plexus may begin at the eleventh or twelfth thoracic or first lumbar nerve. The last nerve in the sciatic cord may be the second, third, or fourth sacral nerve. The position of the n. furcalis is a guide to the arrangement of the plexus. It may be formed by the third, third and fourth, fourth, fourth and fifth, or fifth lumbar nerves. The resulting variations are illustrated by the following extreme cases:—

	(1) *Prefixed Variety.*	(2) *Normal.*	(3) *Postfixed Variety.*
Nervus furcalis	L. 3 and 4 (double).	L. 4.	L. 5.
Obturator	L. 1, 2, 3.	L. 2, 3, 4.	L. 2, 3, 4, 5.
Femoral	T. 12, L. 1, 2, 3, 4.	L. 2, 3, 4.	L. 2, 3, 4, 5.
Tibial	L. 3, 4, 5, S. 1, 2.	L. 4, 5, S. 1, 2, 3.	L. 5, S. 1, 2, 3, 4.
Common peroneal	L. 3, 4, 5, S. 1.	L. 4, 5, S. 1, 2.	L. 5, S. 1, 2, 3.

Those variations in the constitution of the lumbo-sacral plexus are most numerous which are due to the inclusion of nerves more caudally placed. Thus, out of twenty-two variations in the position of the *n. furcalis*, in nineteen Eisler found it formed by the fifth lumbar nerve; in two cases only, by the third lumbar nerve. There is further evidence that variations in the position of the plexus are accompanied by variations in the vertebral column itself. Out of the twenty-two abnormal plexuses examined by Eisler, sixteen were coincident with abnormal arrangement of the associated vertebræ.

PLEXUS LUMBALIS.

The **lumbar plexus** is formed by the anterior rami of the first three and a part of the fourth lumbar nerves, with the addition, in half the number of cases, of a small branch from the twelfth thoracic nerve. The nerves increase in size from above downwards (Fig. 616).

Position and Constitution.—The plexus is formed in the substance of the psoas muscle, in front of the transverse processes of the lumbar vertebræ. The nerves, on emerging from the intervertebral foramina, are connected as above described with the sympathetic system, and then divide in the following manner in the substance of the psoas major muscle. The first and second nerves divide into superior and inferior branches. The superior branch of the first nerve (which may be joined by the branch from the twelfth thoracic nerve) forms two nerves, the **ilio-hypogastric** and **ilio-inguinal**. The inferior branch of the first joins the superior branch of the second nerve, to produce the **genito-femoral nerve**. The inferior branch of the second nerve, the whole of the third, and that part of the fourth nerve engaged in the constitution of the plexus divide each into two unequal parts—smaller *anterior* and larger *posterior parts*. The smaller anterior portions combine together to form the **obturator nerve**, which is thus formed by the second, third, and fourth lumbar nerves. The root from the second nerve is not always present. The larger posterior portions of the same nerves combine together to form the **femoral nerve**. From the posterior aspect of the posterior parts of the second and third nerves the **lateral cutaneous nerve of the thigh** arises. The nerves also provide, near their origins, irregular **muscular branches** for the psoas and quadratus lumborum muscles. The following is a list of the nerves which spring from the lumbar plexus together with their origins.

(1) Muscular branches to the quadratus lumborum (L. 1-4) and psoas muscles (L. 2, 3).
(2) Ilio-hypogastric (?T. 12, L. 1).
(3) Ilio-inguinal (?T. 12, L. 1).
(4) Genito-femoral (L. 1, 2).
(5) Lateral cutaneous (L. 2, 3).
(6) Obturator (L. 2, 3, 4).
(7) Femoral (L. 2, 3, 4).

Muscular Branches.—The nerves to the **quadratus lumborum muscle** arise independently from the first three or four lumbar nerves (and sometimes also from the twelfth thoracic nerve). The nerves to the **psoas muscles** arise from the second and third lumbar nerves, with additions, in some cases, from the first or fourth. They are often associated in their origin with the nerve to the iliacus from the femoral nerve. The **psoas minor**, when present, is innervated by the first or second lumbar nerve.

The ilio-hypogastric and ilio-inguinal nerves closely resemble, in their course and distribution, the lower thoracic nerves, with which they are in series.

The **ilio-hypogastric nerve** is the highest branch of the first lumbar nerve.

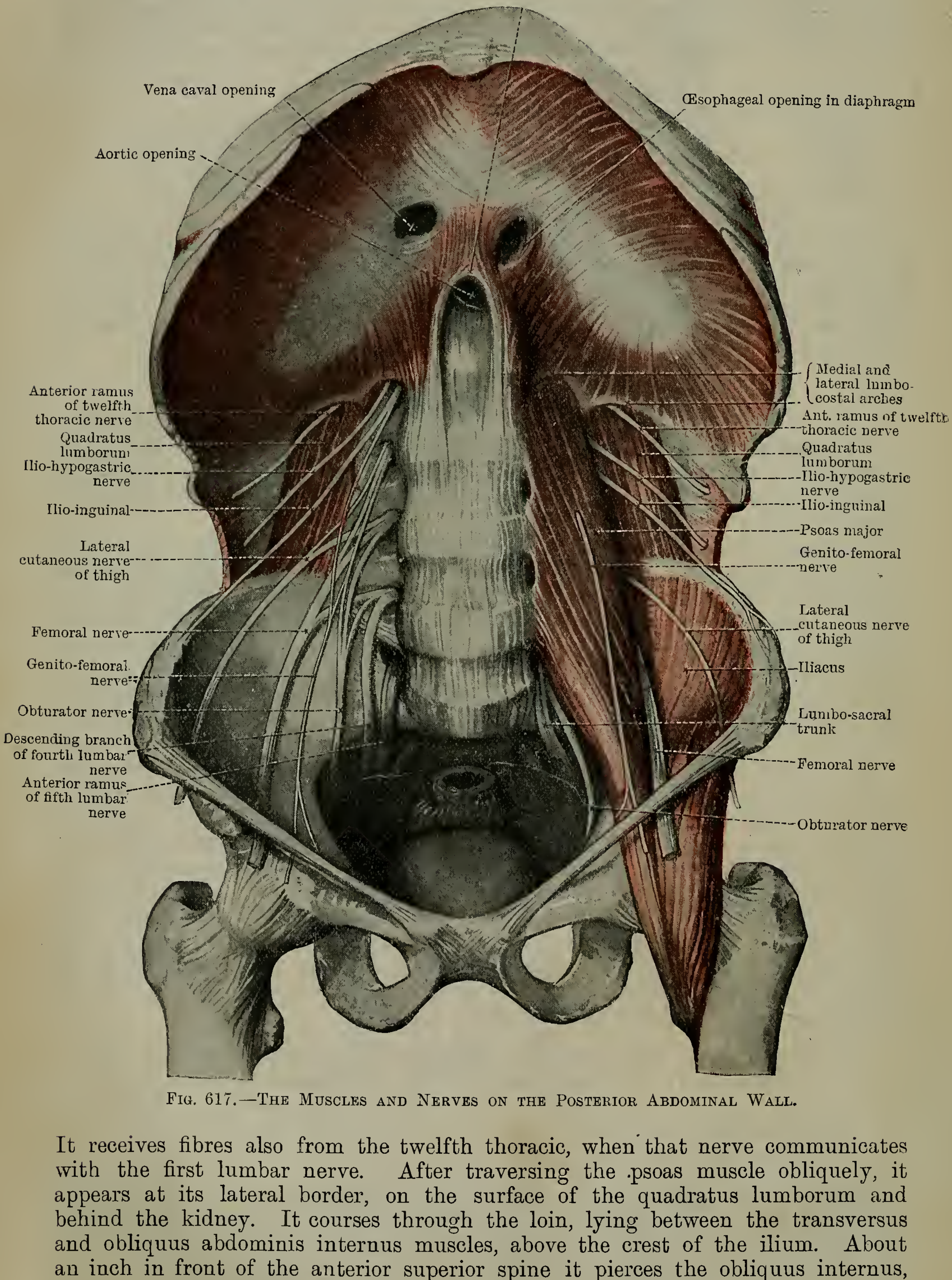

Vena caval opening
Aortic opening
Œsophageal opening in diaphragm
Anterior ramus of twelfth thoracic nerve
Quadratus lumborum
Ilio-hypogastric nerve
Ilio-inguinal
Lateral cutaneous nerve of thigh
Femoral nerve
Genito-femoral nerve
Obturator nerve
Descending branch of fourth lumbar nerve
Anterior ramus of fifth lumbar nerve
Medial and lateral lumbo-costal arches
Ant. ramus of twelfth thoracic nerve
Quadratus lumborum
Ilio-hypogastric nerve
Ilio-inguinal
Psoas major
Genito-femoral nerve
Lateral cutaneous nerve of thigh
Iliacus
Lumbo-sacral trunk
Femoral nerve
Obturator nerve

Fig. 617.—The Muscles and Nerves on the Posterior Abdominal Wall.

It receives fibres also from the twelfth thoracic, when that nerve communicates with the first lumbar nerve. After traversing the psoas muscle obliquely, it appears at its lateral border, on the surface of the quadratus lumborum and behind the kidney. It courses through the loin, lying between the transversus and obliquus abdominis internus muscles, above the crest of the ilium. About an inch in front of the anterior superior spine it pierces the obliquus internus, and continues its course in the groin beneath the aponeurosis of the obliquus externus. It finally becomes cutaneous in the anterior abdominal wall, by piercing the aponeurosis of the obliquus externus about an inch and a half above the subcutaneous inguinal ring (Fig. 615, p. 745).

Its **branches** are—(1) *muscular* to the muscles of the abdominal wall; and (2) *cutaneous branches*, two in number. The **lateral cutaneous branch** corresponds with the lateral branch of an intercostal nerve, and, after piercing the obliquus internus and obliquus externus, becomes cutaneous just above the iliac crest, below and behind the iliac branch of the last thoracic nerve. It is small, and may be absent. It is distributed to the skin over the superior part of the lateral side of the buttock, in continuity with the cutaneous branch of the posterior ramus of the first lumbar nerve. The **anterior cutaneous branch** is the anterior terminal branch of the nerve. It supplies the skin of the anterior abdominal wall below the level of the last thoracic nerve and above the os pubis.

The **ilio-inguinal nerve** is the second branch given off from the first lumbar nerve. It also may receive fibres from the last thoracic nerve. Not infrequently the ilio-hypogastric and ilio-inguinal nerves are represented for a longer or shorter part of their course by a single trunk. When separate the nerve takes a course similar to that of the ilio-hypogastric nerve, but at a lower level, as far as the anterior abdominal wall. It then pierces the obliquus internus farther forward and lower down than the ilio-hypogastric; and coursing forwards beneath the aponeurosis of the obliquus externus, just above the inguinal ligament, it becomes superficial after passing through the subcutaneous inguinal ring and external spermatic fascia (Fig. 615, p. 745).

Its branches are *muscular* to the muscles of the abdominal wall, among which it passes, and *cutaneous branches* (*anterior scrotal*, or *labial* nerves), which innervate the skin (1) of the anterior abdominal wall over the symphysis pubis, (2) of the thigh over the proximal and medial part of the femoral triangle, and (3) of the superior part of the scrotum, and root and dorsum of the penis (of the mons Veneris and labium majus in the female). These last-named branches are contiguous to branches of the perineal and pudendal nerves. No lateral cutaneous branch arises from the ilio-inguinal nerve. It thus corresponds, like the anterior cutaneous part of the ilio-hypogastric nerve, to the anterior trunk of a typical thoracic nerve.

The **genito-femoral nerve** usually arises by two independent roots from the front of the first and second lumbar nerves, which unite in the substance of the psoas major to form a slender trunk. It appears on the posterior abdominal wall, lying on the psoas major, medial to the psoas minor, and, piercing the psoas fascia, it extends downwards on the lateral aspect of the common and external iliac vessels and behind the ureter, to the inguinal ligament (Fig. 617, p. 750). At a variable point above that ligament it divides into two branches. 1. The **external spermatic branch** is a small nerve. It crosses the terminations of the external iliac vessels, and, along with the ductus deferens and testicular and external spermatic vessels, enters the inguinal canal through the abdominal inguinal ring. It terminates by supplying small branches to the skin of the scrotum and adjacent part of the thigh. In the female it accompanies the round ligament to the labium majus. This nerve gives off in its course the following small branches: (1) to the external iliac artery; (2) to the cremaster muscle; (3) to communicate with the spermatic plexus of the sympathetic. 2. The **lumbo-inguinal branch** continues the course of the parent nerve into the thigh, lying on the lateral aspect of the femoral artery. It becomes cutaneous by passing through the fossa ovalis or through the iliac portion of the fascia lata, and supplies an area of skin over the femoral triangle, lateral to that supplied by the ilio-inguinal nerve (Fig. 615, p. 745). It communicates in the thigh with the intermediate cutaneous branch of the femoral nerve. Before piercing the deep fascia it gives a minute branch to the femoral artery.

The **lateral cutaneous nerve of the thigh** is distributed only to the skin (Fig. 615). It arises from the back of the lumbar plexus, and usually from the second and third lumbar nerves. Emerging from the lateral border of the psoas major muscle, the nerve crosses the iliacus muscle, beneath the fascia iliaca, to reach the anterior superior iliac spine. It enters the thigh beneath the lateral end of the inguinal ligament, and either over, under, or through the origin of the sartorius muscle. It extends distally along the front of the thigh for a few inches, lying at first beneath the fascia lata, and afterwards in a tubular investment of the fascia. It gives off small branches in this part of its course, and finally, piercing the fascia about four inches distal to the anterior superior iliac spine, it separates into anterior and posterior terminal branches. The **anterior branch** is the larger, and is distributed on the lateral aspect of the front of the thigh almost to the knee. The smaller **posterior branch** supplies the skin of the lateral side of the buttock, distal to the greater trochanter, and the skin of the proximal two-thirds of the lateral aspect of the thigh (Fig. 619, p. 755).

NERVUS OBTURATORIUS.

The **obturator nerve** supplies the muscles and skin on the medial side of the thigh. It arises in the substance of the psoas major muscle by three roots placed in front of those of the femoral nerve, and derived from the second, third, and fourth lumbar nerves (Fig. 616, p. 748). Sometimes the root from the second nerve is absent. Passing vertically downwards, the nerve emerges from the psoas major at its medial border, behind the common iliac, and on the lateral side of the hypogastric vessels. It passes forwards below the pelvic brim in company with the obturator artery to the obturator groove of the obturator foramen, through which it reaches the thigh. While in the obturator groove it separates into its two main branches, named anterior and posterior (Fig. 618).

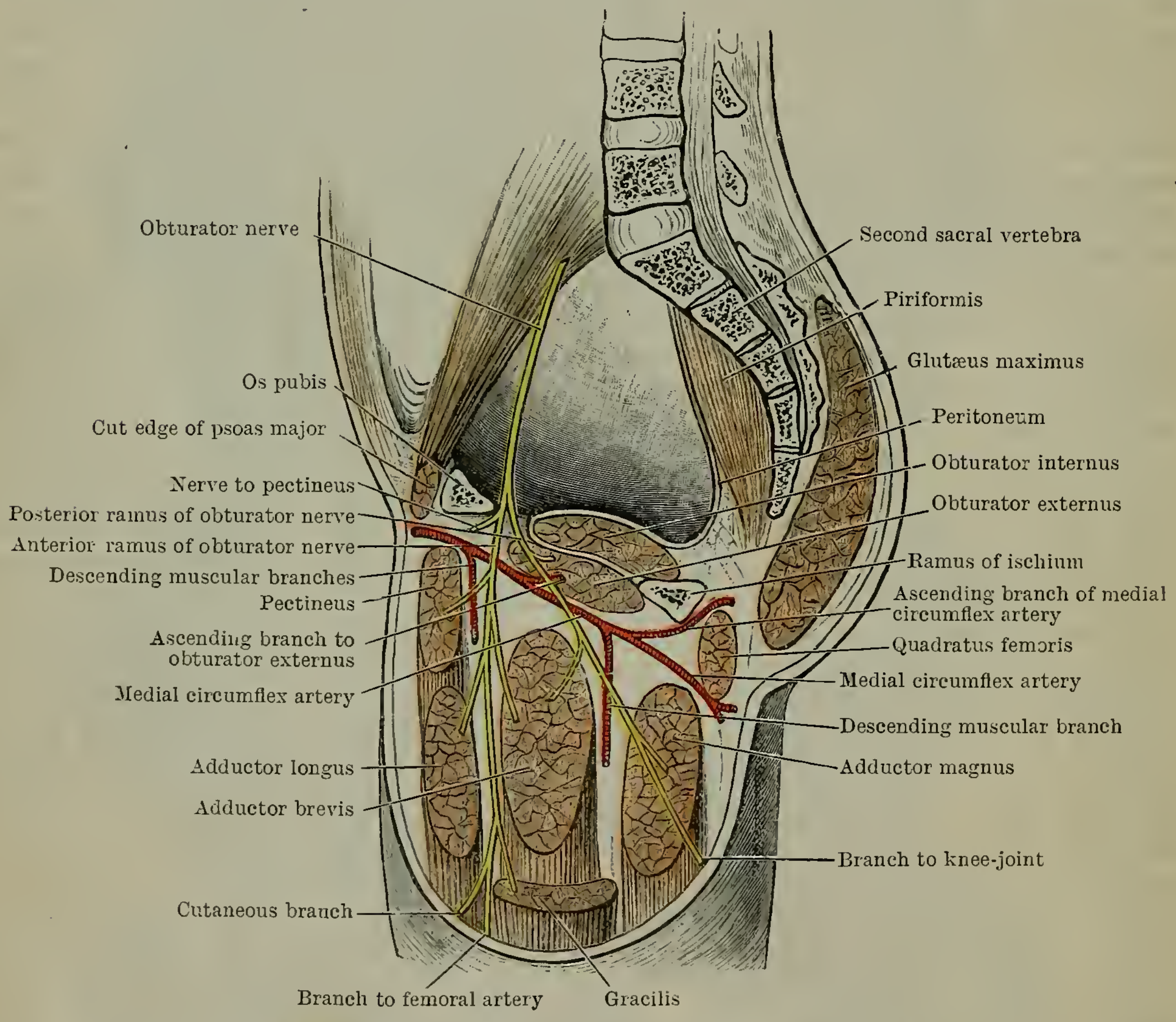


FIG. 618.—SCHEME OF THE COURSE AND DISTRIBUTION OF THE OBTURATOR NERVE.

The **anterior branch** enters the thigh in front of the obturator externus and adductor brevis muscles, and behind the pectineus and adductor longus. In the middle third of the thigh it is found coursing along the medial border of the adductor longus anterior to the gracilis; and it finally divides into two slender terminal filaments, of which one enters the adductor canal and ends on the femoral artery, while the other supplies the skin for a variable distance on the medial side of the thigh and joins in the obturator plexus.

The branches of the anterior part of the nerve are:—

1. An **articular branch** to the hip-joint, which arises from the nerve as soon as it enters the thigh, and supplies the joint through the acetabular notch.

2. **Muscular branches** to the adductor longus, gracilis, adductor brevis (usually), pectineus (occasionally). The last-named muscle is not usually supplied from the obturator nerve.

3. A **cutaneous branch** of very variable size forms one of the terminal branches (Fig. 618). It becomes superficial between the gracilis and adductor longus, in the middle third of the thigh, and may supply the skin of the distal two-thirds of the thigh on its medial side. It is generally of small size, and is connected with branches of the medial cutaneous and saphenous nerves behind the sartorius muscle to form the **obturator** (O.T. **sub-sartorial**) **plexus.** The branch from the saphenous nerve to the plexus passes medially behind the sartorius after piercing the aponeurotic covering of the adductor canal. The branch from the medial cutaneous nerve is generally superficial at the point of formation of the plexus.

4. The **branch to the femoral artery** is the other terminal branch of the nerve. It enters the adductor canal along the medial border of the adductor longus, and ramifies over the distal part of the artery.

5. A fine **communicating branch** sometimes joins the femoral nerve in front of the hip-joint.

The **posterior branch of the obturator nerve** reaches the thigh by piercing the obturator externus muscle. It passes distally between the adductor brevis and adductor magnus muscles. After passing obliquely through the adductor magnus, it appears in the popliteal fossa on the popliteal artery, to which it furnishes twigs, and terminates by piercing the oblique ligament of the knee and supplying the knee-joint.

Its branches are: (1) **muscular branches** to the obturator externus, adductor magnus, and (when the muscle is not supplied by the superficial part of the nerve) the adductor brevis. The branch to the obturator externus arises before the nerve enters the muscle, in the obturator groove. The nerve to the adductor magnus is given off as the obturator nerve passes through the substance of the muscle. (2) An **articular terminal branch** is supplied to the posterior aspect of the knee-joint.

Nervus Femoralis.

The **femoral nerve** is the large nerve for the muscles and skin of the front of the thigh. It arises in the substance of the psoas major muscle, from the back of the second, third, and fourth lumbar nerves, posterior to the obturator nerve. Passing obliquely through the psoas major muscle, it emerges from its lateral border in the pelvis major (Fig. 617, p. 750). Passing downwards in the groove between the psoas and iliacus, it enters the thigh beneath the inguinal ligament, lateral to the femoral sheath and femoral vessels. In the femoral triangle it breaks up into a large number of branches, among which the lateral circumflex artery of the thigh passes in a lateral direction.

The **branches** of the femoral nerve, which are (1) muscular, (2) articular, (3) cutaneous, and (4) vascular, arise in the following way:—

In the abdomen a muscular branch arises from the lateral aspect of the nerve and enters the iliacus muscle, and a vascular branch descends to supply the femoral artery, which vessel also receives branches lower down in the thigh.

In the femoral triangle the terminal muscular, articular, and cutaneous branches arise in the form of a large bundle of nerves.

1. The **muscular branches** supply the pectineus, sartorius, and quadriceps. The nerve to the *pectineus* arises close to the inguinal ligament, and, coursing obliquely distally and medially behind the femoral vessels, enters the muscle at its lateral border. It is not infrequently double. It sometimes gives off a fine communicating branch to the anterior part of the obturator nerve. The nerves to the *sartorius* are in two sets: a lateral, short set of nerves, associated with the

lateral part of the intermediate cutaneous nerve, which supply the proximal part of the muscle; and a medial, longer set, which are associated with the medial part of the intermediate cutaneous nerve, and enter the middle of the muscle. The parts of the *quadriceps* are supplied by several branches. The vastus lateralis and rectus femoris are supplied on their deep surface by separate nerves which are accompanied by branches of the lateral circumflex artery of the thigh. The vastus intermedius muscle is supplied superficially by a nerve which passes through the muscle, and innervates also the muscle of the knee-joint (subcrureus). It also receives fibres from one of the nerves to the vastus medialis. The vastus medialis muscle is supplied by two nerves: a proximal trunk, which supplies the proximal part of the muscle, and sends fibres to the vastus intermedius as well; and a distal trunk, which descends on the lateral side of the femoral artery along with the saphenous nerve, and passing beneath the sartorius, over or under the aponeurotic covering of the adductor canal, enters the medial side of the muscle. This nerve gives off a small branch which enters the medullary canal of the femur.

2. The **articular branches** supply the hip and knee-joints. The articular branch to the hip-joint arises from the nerve to the rectus femoris, and is accompanied by branches from the lateral circumflex artery of the thigh. The articular branches to the knee-joint are four in number. Three of them arise from the nerves to the vastus lateralis, vastus intermedius, and vastus medialis, which, after the muscular nerves are given off, are continued downwards to the knee-joint along the front of the femur. A fourth articular branch arises (sometimes) from the saphenous nerve.

3. The **cutaneous branches** are the intermediate and medial cutaneous, and the saphenous nerves (Fig. 619).

The **intermediate cutaneous nerve** arises in two parts, a *lateral* and a *medial branch,* in the proximal part of the femoral triangle. The two branches descend vertically and become cutaneous by piercing the fascia lata over the proximal third of the sartorius muscle. They carry muscular branches to the sartorius, and the lateral branch in many cases pierces the muscle. These two nerves supply the skin of the distal three-fourths of the front of the thigh, between the lateral cutaneous nerve of the thigh laterally and the medial cutaneous on the medial side. They reach to the front of the patella, and there assist in the formation of the patellar plexus. The lateral branch communicates, in the proximal third of the thigh, with twigs from the lumbo-inguinal branch of the genito-femoral nerve.

The **medial cutaneous nerve** lies at first in the femoral triangle on the lateral side of the femoral vessels. At the apex of the triangle it crosses over the femoral vessels, and is directed distally over or through the sartorius muscle, and beneath the fascia lata, to the distal third of the thigh. It is distributed to the skin of the distal two-thirds of the thigh on the medial side by means of three branches—proximal, middle, and distal.

The *proximal branch* may be represented by two or more twigs. It arises from the main nerve near its origin, and pierces the fascia lata near the apex of the femoral triangle. It is distributed to the skin of the proximal part of the thigh, along the line of the great saphenous vein. The *middle or anterior branch* is a larger nerve. It separates from the distal branch at the apex of the femoral triangle, and passing over the sartorius muscle becomes cutaneous in the middle third of the thigh on the medial side. It supplies the skin of the distal half of the thigh, extending as far as the knee, where it joins in the formation of the patellar plexus.

The *distal branch* represents the termination of the nerve. It passes along the medial side of the thigh over the sartorius muscle, and communicates in the middle third of the thigh with the saphenous and obturator nerves to form the obturator plexus. Piercing the fascia lata on the medial side of the thigh in the distal third, it ramifies over the side of the knee, and assists in the formation of the patellar plexus.

The size of the medial cutaneous nerve varies with the size of the cutaneous part of the obturator, and of the saphenous nerve.

The **saphenous nerve** may be regarded as the terminal branch of the femoral nerve. It is destined for the skin of the leg and foot. From its origin in the femoral triangle it extends distally alongside the femoral vessels to the adductor canal. In the canal it crosses obliquely over the femoral sheath from lateral to medial side. At the distal end of the canal, accompanied by the saphenous branch of the arteria genu suprema, it passes over the tendon of the adductor magnus, and opposite the medial side of the knee-joint becomes cutaneous by passing between the sartorius and gracilis muscles. The nerve then extends distally in the leg along with the great saphenous vein, and coursing over the front of the medial malleolus it terminates at the middle of the medial border of the foot.

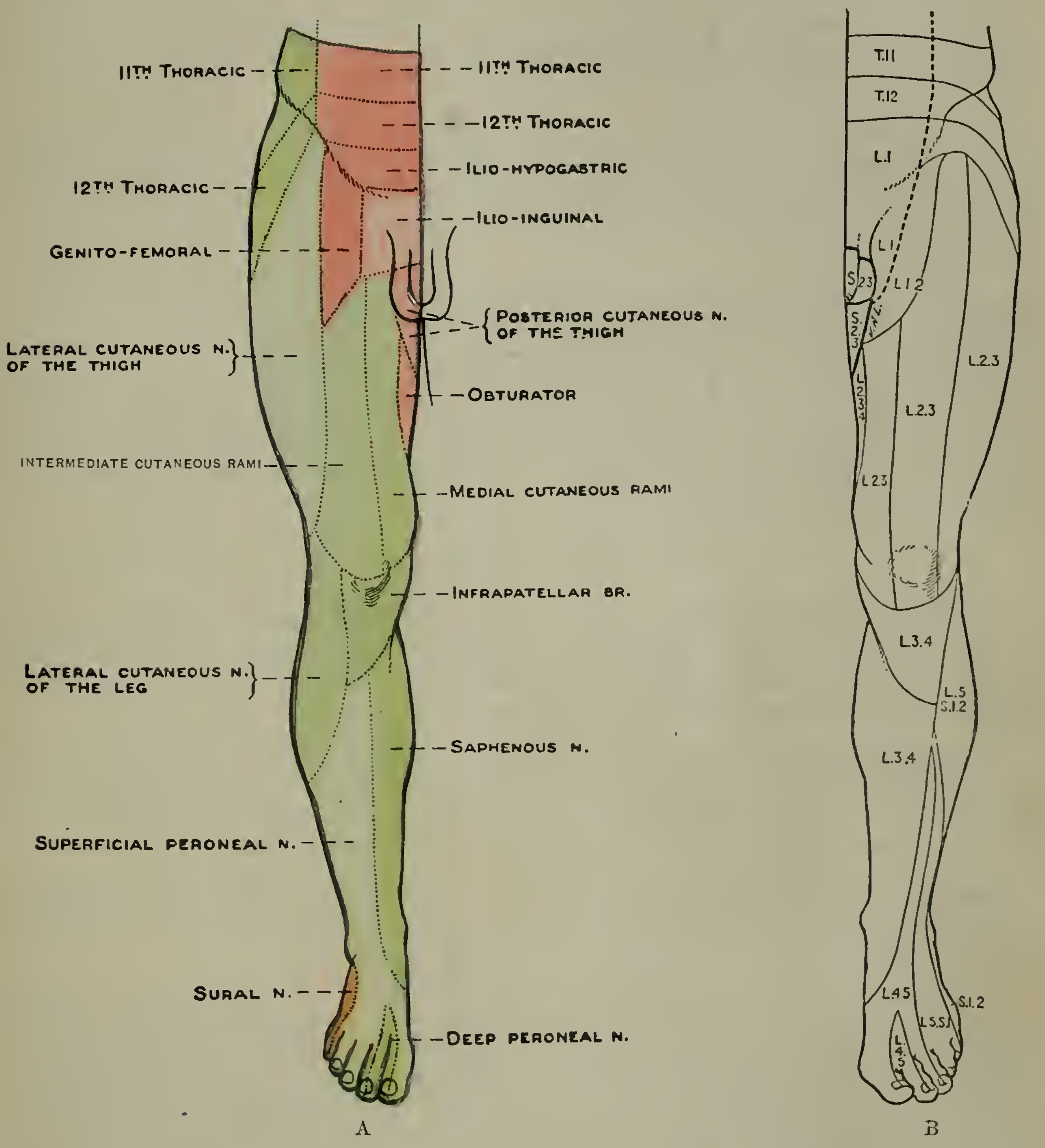


Fig. 619.—Distribution of Cutaneous Nerves on the front of the Lower Limb.

On the left side the distribution of the several nerves is represented in colour.

On the right side a schematic representation is given of the areas supplied by the above nerves, the figures indicating the spinal origin of the branches of distribution to each area.

Branches.—1. A **communicating branch** arises in the adductor canal, and, passing medially behind the sartorius, joins with branches of the obturator nerve in forming the obturator plexus.

2. The **infra-patellar branch** arises at the distal end of the adductor canal, and piercing the sartorius muscle is directed distally and forwards below the patella, and over the medial condyle of the tibia to the front of the knee and proximal part of the leg. It enters into the formation of the patellar plexus.

3. An **articular branch** sometimes arises from the nerve at the medial side of the knee.

4. The **terminal branches** of the saphenous nerve (**rami cutanei cruris mediales**) are distributed to the skin of the front and medial side of the leg and the posterior half of the dorsum and medial side of the foot.

The **patellar plexus** consists of fine communications beneath the skin in front of the knee, between the branches of the cutaneous nerves supplying that region. The nerves which enter into its formation are the infra-patellar branch of the saphenous, medial, and intermediate cutaneous nerves, and sometimes the lateral cutaneous nerve of the thigh.

The **accessory obturator nerve** is only occasionally present (29 per cent., Eisler). It arises from the third, or third and fourth lumbar nerves, between the roots of the obturator and femoral nerves. Associating itself with the obturator, from which, however, it is quite separable, it appears in the abdomen at the medial side of the psoas muscle, and coursing over the pelvic brim behind the external iliac vessels, it leaves the obturator nerve, and enters the thigh in front of the os pubis.

In the thigh, behind the femoral vessels, it usually ends in three branches: a nerve which replaces the branch from the femoral nerve to the pectineus, a nerve to the hip-joint, and a nerve which communicates with the superficial part of the obturator nerve. In some cases it only supplies the nerve to the pectineus; more rarely it is of considerable size, and reinforces the obturator nerve in the innervation of the adductor muscles.

It is more closely associated with the femoral than with the obturator. Its origin is behind the roots of the obturator: it is separated, like the femoral, from the obturator by the pubic bone, and its chief branch, to the pectineus muscle, replaces the normal branch from the femoral nerve. On the other hand, for a part of its course it accompanies the obturator, and in rare cases it may replace branches of that nerve.

PLEXUS SACRALIS.

The sacral portion of the lumbo-sacral plexus is destined almost entirely for the lower limb. It is usually formed by the anterior rami of a part of the fourth lumbar nerve (n. furcalis), the fifth lumbar, the first, and parts of the second, and third sacral nerves (n. bigeminus).

Communications with the Sympathetic.—Each of the nerves named is connected to the lumbar or pelvic sympathetic by *gray rami communicantes*, as already described; and *white rami communicantes* pass from the third and usually also from the second or fourth sacral nerves to join the pelvic plexus of the sympathetic.

Position and Constitution.—The plexus is placed on the posterior wall of the pelvis between the parietal pelvic fascia and the piriformis muscle. In front of it are the pelvic colon, the hypogastric vessels, and the ureter.

The plexus is constituted by the convergence of the nerves concerned towards the inferior part of the greater sciatic foramen, and their union to form a broad triangular band, the apex of which is continued through the greater sciatic foramen below the piriformis muscle into the buttock, as the **sciatic nerve**. From the anterior and posterior surfaces of this triangular band numerous small branches arise, which are distributed to the parts in the neighbourhood of the origin of the nerve.

The sciatic nerve ends in the thigh by dividing into two large nerves, the **tibial** (**O.T. internal popliteal**) and **common peroneal** (**O.T. external popliteal**). In many cases these two nerves are distinct at their origin, and are separated sometimes by fibres of the piriformis muscle. In all cases, on removal of the sheath investing the sciatic nerve, the tibial and peroneal nerves can be traced up to the plexus, from which they invariably take origin by distinct and separate roots.

Formation.—The descending branch of the fourth lumbar nerve (n. furcalis), after emerging from the border of the psoas major muscle, medial to the obturator nerve, divides behind the iliac vessels into anterior and posterior (ventral and dorsal) parts, each of which joins a corresponding part of the fifth lumbar nerve. The anterior ramus of the fifth lumbar nerve descends over the ala of the sacrum, and divides into anterior and posterior parts, which are joined by the corresponding parts of the fourth lumbar nerve. The two resulting trunks are sometimes called the

truncus lumbosacralis or **lumbo-sacral trunk**. The first and second sacral nerves pass almost horizontally laterally from the anterior sacral foramina, and divide in front of the piriformis into similar anterior and posterior parts. The third sacral nerve (n. bigeminus) divides into superior and inferior parts. The inferior part is concerned in forming the pudendal plexus. The superior part is directed laterally, and slightly upwards, towards the second nerve, and does not separate into two parts, but remains undivided.

The nerves mentioned combine to form the sacral plexus, and its main subdivisions, in the following way. Lying in apposition, and converging to the lower part of the greater sciatic foramen, the *posterior* (dorsal) *trunks* of the fourth and fifth lumbar nerves (lumbo-sacral trunk), and of the first and second sacral nerves, combine to form the **common peroneal nerve** and the subordinate nerves which arise from the posterior aspect of the plexus. The *anterior* (ventral) *trunks* of the fourth and fifth lumbar nerves (lumbo-sacral trunk), and of the first and second sacral nerves, together with that part of the third sacral nerve which is contributed to the plexus, unite to form the **tibial nerve** and the subordinate nerves arising from the front of the plexus.

Of these nerves the fifth lumbar and first sacral are the largest; the others diminishing in size as they are traced upwards and downwards. There is no distinct demarcation between the sacral and pudendal plexuses. The second and third sacral nerves (and in some cases the first sacral also) are concerned in the formation of both plexuses.

Branches.—The nerves of distribution derived from the sacral plexus are divided according to their origin into an *anterior* (ventral) and a *posterior* (dorsal) *series*. Each set comprises one of the two essential terminal parts of the sciatic—peroneal and tibial nerves—and numerous smaller collateral branches.

Anterior (Ventral) Branches.

Tibial nerve (L. 4, 5, S. 1, 2, 3)
Muscular branches—
  Nerves to hamstring muscles (L. 4, 5, S. 1, 2, 3)
  Nerves to quadratus femoris (L. 4, 5, S. 1)
  Nerves to gemelli
  Nerves to obturator internus (L. 5, S. 1, 2)
Articular branches (to hip-joint)

Posterior (Dorsal) Branches.

Common peroneal nerve (L. 4, 5, S. 1, 2)
Muscular branches—
  Nerves to short head of biceps (L. 5, S. 1, 2)
  Nerves to piriformis (S. 2)
  Superior gluteal nerve (L. 4, 5, S. 1)
  Inferior gluteal nerve (L. 5, S. 1, 2)
Articular branches (to knee-joint)

NERVUS ISCHIADICUS.

The **sciatic nerve** is the largest nerve in the body. It consists of two nerves, the tibial and the common peroneal, bound together by an investing sheath, which contains, in addition to these nerves, a branch from each: the nerve to the hamstring muscles, from the tibial nerve, and the nerve to the short head of the biceps femoris, from the common peroneal nerve. From the account given of the origin of the fibres of the tibial and common peroneal nerves, it follows that the fibres of the sciatic nerve are derived from the fourth and fifth lumbar and first, second, and third sacral nerves. A thick band about half an inch in breadth is formed, consisting, from the medial to the lateral side, of (1) the nerve to the hamstring muscles, (2) the tibial nerve, (3) the common peroneal nerve, (4) the nerve to the short head of the biceps femoris.

The sciatic nerve leaves the pelvis and enters the gluteal region through the greater sciatic foramen between the piriformis and the superior gemellus. It runs laterally and then downward through the gluteal region, in the hollow between the great trochanter of the femur and the tuberosity of the ischium, accompanied by the inferior gluteal artery and the arteria comitans nervi ischiadici. It is covered posteriorly by the glutæus maximus, and is in relation anteriorly with the following structures, from above downwards: (1) the posterior aspect of the ischium, (2) the nerve to the quadratus femoris, (3) the superior gemellus, (4) the obturator internus, (5) the inferior gemellus, (6) the quadratus femoris.

The nerve enters the thigh by emerging below the inferior border of the glutæus maximus, lying in the angle between the lower border of this muscle above and laterally, and the origin of the hamstring muscles medially. It runs down the back of the thigh, on the posterior surface of the adductor magnus, and is covered by the long head of the biceps femoris, which crosses posterior to the nerve from the medial to the lateral side.

It usually terminates at the proximal angle of the popliteal fossa by dividing into the tibial and common peroneal nerves; but the separation may occur at any higher level, and, as already noted, these two nerves may even be distinct at their origin, in which case the common peroneal usually pierces the piriformis.

The Nerves of Distribution from the Sacral Plexus.

These are divisible into two series—**collateral** and **terminal branches.** Each subdivision consists of a series of *anterior* and *posterior trunks.*

1. Collateral Branches.—The *anterior branches* are (*a*) muscular branches (to the quadratus femoris, gemelli, obturator internus, and hamstring muscles); and (*b*) articular branches (to the hip-joint). These nerves all arise from the anterior aspect of the sacral plexus.

The **nerve to the quadratus femoris** (and **inferior gemellus**) arises from the front of the fourth and fifth lumbar and first sacral nerves. It passes downwards over the back of the capsule of the hip-joint (to which it sends a fine branch) beneath the sacral plexus, gemelli, and obturator internus muscles. It supplies a nerve to the inferior gemellus, and terminates in the deep surface of the quadratus femoris.

The **nerve to the obturator internus** (and **superior gemellus**) arises from the anterior aspect of the fifth lumbar and first two sacral nerves. In the buttock it lies medial to the sciatic nerve on the lateral side of the pudendal vessels; crossing the ischial spine, it enters the ischio-rectal fossa through the lesser sciatic foramen. The nerve supplies, in the buttock, a branch to the superior gemellus, and terminates by entering the pelvic surface of the obturator internus.

The **nerve to the hamstring muscles** forms the most medial part of the sciatic trunk in the lower part of the buttock. It arises from all the roots of the tibial nerve on their anterior aspect, viz., from the fourth and fifth lumbar and the first three sacral nerves. These roots unite to form a cord which is closely associated with the tibial nerve and is placed in front of it and afterwards on its medial side. Extending into the thigh, the trunk is distributed to the hamstring muscles by means of two sets of branches. Just distal to the ischial tuberosity a proximal set of nerves enters the proximal part of the semitendinosus and the ischial head of the biceps. More distally in the thigh the remaining portion of the nerve separates off from the tibial part of the sciatic trunk and supplies branches to the semimembranosus, the distal part of the semitendinosus, and the adductor magnus.

Articular branches for the hip-joint arise from the nerve to the quadratus femoris, and often directly from the anterior surface of the tibial part of the sciatic nerve near its origin. They enter the back of the capsule of the joint in the region of the buttock.

The *posterior branches* are: (*a*) muscular branches—a nerve to the piriformis, the superior gluteal nerve, the inferior gluteal nerve, and a nerve to the short head of the biceps; (*b*) articular branches (to the knee-joint).

These nerves all arise from the posterior aspect of those roots of the sacral plexus, which are associated with the origin of the common peroneal nerve.

The **nerve to the piriformis muscle** may be double. It arises from the back of the second, or first and second sacral nerves, and at once enters the anterior surface of the muscle.

N. Glutæus Superior.—The **superior gluteal nerve** arises from the posterior surface of the fourth and fifth lumbar and first sacral nerves, and is directed backwards and laterally into the buttock, above the piriformis muscle, along with the superior gluteal artery. Under cover of the glutæus maximus and glutæus medius, it passes over the glutæus minimus, along with the inferior branch of the deep division of the superior gluteal artery, to the deep surface of the tensor fasciæ latæ, in which it ends. On its way it supplies branches to the glutæus medius and glutæus minimus muscles.

N. Glutæus Inferior.—The **inferior gluteal nerve** arises from the posterior surface of the fifth lumbar and first two sacral nerves. It appears in the buttock at the lower border of the piriformis muscle, superficial to the sciatic nerve, and at once breaks up into a number of branches for the supply of the glutæus maximus. In its course in the buttock it is closely associated with the posterior cutaneous nerve of the thigh. Its origin is sometimes combined with that of the following nerve.

The **nerve to the short head of the biceps** springs from the lateral side of the common peroneal trunk in the proximal part of the thigh. When traced to its origin, it is found to arise (sometimes in combination with the inferior gluteal nerve) from the fifth lumbar and first two sacral nerves. In its course it is closely applied to the common peroneal nerve, from which it separates in the middle third of the thigh, usually in combination with the articular branches of that nerve for the knee-joint. In some cases it has an independent course in the thigh, and it may be associated in the buttock with the inferior gluteal nerve.

An **articular branch** for the lateral and anterior aspects of the knee-joint generally arises from the common peroneal nerve in common with the nerve to the short head of the biceps. When traced up to the plexus, it is found to arise from the posterior surface of the fourth and fifth lumbar and first sacral nerves. It passes through the proximal part of the popliteal fossa concealed by the biceps muscle, and separates into proximal and distal branches, which accompany the superior and inferior lateral articular arteries to the knee-joint.

2. Terminal Branches.—The **common peroneal** (O.T. **external popliteal**) and **tibial** (O.T. **internal popliteal**) **nerves** are the two main trunks resulting from the combination of the posterior and anterior cords of the sacral plexus respectively. The common peroneal nerve is homologous with the radial nerve of the upper limb; the tibial nerve represents a medio-ulnar trunk; and, as already stated, the two nerves, constituting the sciatic nerve, are enveloped in a common sheath for a variable distance before pursuing an independent course in the leg.

Nervus Peronæus Communis.

The **common peroneal nerve** arises from the posterior part of the sacral plexus from the fourth and fifth lumbar and first two sacral nerves. Incorporated with the sciatic nerve in the buttock and proximal part of the thigh, it passes distally from the bifurcation of that nerve through the popliteal fossa, to its termination at a point about an inch distal to the head of the fibula. It is concealed at first by the biceps muscle. Following the tendon of that muscle, it passes obliquely through the proximal and lateral part of the popliteal fossa and over the lateral head of the gastrocnemius muscle to the posterior aspect of the head of the fibula. In the distal part of its course it is quite superficial, but at its termination it is covered by the peronæus longus muscle lying between the muscle and the neck of the fibula, round which it winds.

Collateral Branches.—These are divided into two sets: (*a*) Nerves arising from the roots or trunk of the nerve while it is in combination with the tibial nerve in the sciatic trunk. These have been already described, as a **muscular branch** to the short head of the biceps, and an **articular branch** to the knee-joint. (*b*) Nerves arising in the popliteal fossa. These are **cutaneous branches**, viz., the lateral sural nerve or lateral cutaneous nerve of the calf and the peroneal anastomotic ramus.

The **lateral sural branch** is irregular in size and distribution, and may be represented by two or more branches (Fig. 620, p. 761). Arising from the common peroneal nerve in the popliteal fossa, often in common with the succeeding nerve, it pierces the deep fascia over the lateral head of the gastrocnemius, and is distributed to the skin on the lateral aspect of the back of the leg in the proximal two-thirds. The extent of its distribution varies with that of the posterior cutaneous nerve of the thigh and the nervus suralis.

The **peroneal anastomotic nerve** (O.T. **communicans fibularis**), arising in the popliteal fossa, passes over the lateral head of the gastrocnemius beneath the deep fascia to the middle third of the leg, where it assists in forming the nervus suralis by its union with an anastomotic (communicating) branch of the tibial nerve called the medial sural nerve or medial cutaneous nerve of the calf. In many cases the two branches do not unite. In such cases the peroneal anastomotic nerve may be limited in its distribution to the skin of the lateral side of the leg, heel, and ankle, or it may be distributed to the area usually supplied by the nervus suralis.

Terminal Branches.—The terminal branches of the common peroneal nerve are three in number: recurrent tibial, deep peroneal (O.T. anterior tibial), and superficial peroneal (O.T. musculo-cutaneous). They arise just distal to the head of the fibula, and are directed forwards, diverging in their course, beneath the peronæus longus muscle.

The **recurrent tibial nerve** is the smallest branch. Passing forwards under cover of the origin of the peronæus longus and the extensor digitorum longus muscles, it divides, distal to the lateral condyle of the tibia, into branches which supply the proximal fibres of the tibialis anterior muscle, the proximal tibio-fibular articulation, and the knee-joint.

NERVUS PERONÆUS PROFUNDUS.

The **deep peroneal nerve** (O.T. **anterior tibial**) passes obliquely distally, under cover of the peronæus longus, extensor digitorum longus, and extensor hallucis longus muscles, to the front of the leg. In its course it is deeply placed upon the interosseous membrane and the distal part of the tibia, in company with the anterior tibial artery lying first lateral, then anterior, and then lateral again, to the vessel. At the ankle it lies under cover of the transverse ligament of the leg and the tendon of the extensor hallucis longus, and, crossing the ankle-joint, it divides on the dorsum of the foot into its terminal branches.

1. **Collateral Branches** (in the leg).—These are given off to the muscles between which the deep peroneal nerve passes, namely: tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peronæus tertius. A fine articular branch supplies the ankle-joint.

2. **Terminal Branches** (on the foot).—The terminal branches are medial and lateral. The **medial branch** passes along the dorsum of the foot, on the lateral side of the dorsalis pedis artery, to the first interosseous space, where it divides into two dorsal digital branches for the supply of the skin of the lateral side of the great toe and the medial side of the second toe (**nervi digitales dorsales, hallucis lateralis et digiti secundi medialis**). Each of these branches communicates with branches of the superficial peroneal (O.T. musculo-cutaneous) nerve. It gives off one or two *dorsal interosseous branches*, which supply the medial tarso-metatarsal and metatarso-phalangeal articulations, and enter the first dorsal interosseous muscle.

The **lateral branch** passes obliquely over the tarsus under cover of the extensor digitorum brevis, and ends in a gangliform enlargement (similar to the gangliform enlargement on the dorsal interosseous nerve of the forearm at the back of the wrist). From this enlargement muscular branches arise for the supply of the extensor digitorum brevis, along with branches for the tarsal, tarso-metatarsal, and metatarso-phalangeal articulations. Its *dorsal interosseous branches* may be as many as four in number. Of these the lateral two, extremely small, may only reach the tarso-metatarsal articulations. The medial two are fine branches, which, besides supplying the articulations, may give branches to the second and third dorsal interosseous muscles.

The branches from the nerve to the interosseous muscles are probably sensory, the motor supply of these muscles being certainly derived from the lateral plantar nerve.

NERVUS PERONÆUS SUPERFICIALIS.

The **superficial peroneal nerve** (O.T. **musculo-cutaneous**), the last of the branches of the common peroneal nerve, passes distal to the head of the fibula and under cover of the proximal fibres of the peronæus longus muscle. Lying in a sheath in the intermuscular septum, between the peronæi and the extensor digitorum longus, it proceeds distally in front of the fibula to the distal third of the leg, where it pierces the deep fascia in two branches, medial and lateral.

Its branches are: (1) *collateral* muscular branches distributed to the peronæus longus and peronæus brevis, as the nerve lies in relation to these muscles; (2) *terminal* cutaneous branches, medial and lateral.

Nn. Cutanei Dorsales Medialis et Intermedius.—The **medial terminal branch (n. cutaneus dorsalis medialis)** courses distally over the transverse ligament of the leg, and after supplying offsets to the distal third of the leg and to the dorsum of the foot, divides into three branches. (1) The most medial branch supplies the skin of the dorsum of the foot and the medial side of the great toe, and communicates with the saphenous nerve. (2) The intermediate branch passes to the interval between the great toe and the second, and divides into two branches which communicate with the medial branch of the deep peroneal nerve. (3) The lateral branch passes to the interval between the second and third toes, and divides into dorsal digital branches to supply the adjacent sides of these toes.

The **lateral terminal branch (n. cutaneus dorsalis intermedius)** of the nerve passes over the transverse ligament of the leg, and after supplying branches to the distal part of the leg and to the dorsum of the foot, divides into two parts, which, passing to the intervals between the third and fourth, and fourth and fifth toes respectively, divide into dorsal digital branches for the adjacent sides of these toes. These branches communicate with offsets of the nervus suralis (nerve of the calf).

The arrangement of the cutaneous branches of the superficial peroneal nerve is liable to considerable variation. The lateral division of the nerve may be increased in size, and may supply the nerve to the adjacent sides of the second and third toes; or it may be reduced in size, in which case the nervus suralis takes its place on the dorsum of the foot, often supplying as many as two and a half toes on the lateral side.

The cutaneous nerves on the dorsum of the toes are much smaller than the corresponding plantar digital nerves. They are reinforced on the dorsum of the terminal phalanges by twigs from the plantar nerves, which supply the tips of the toes and the nails.

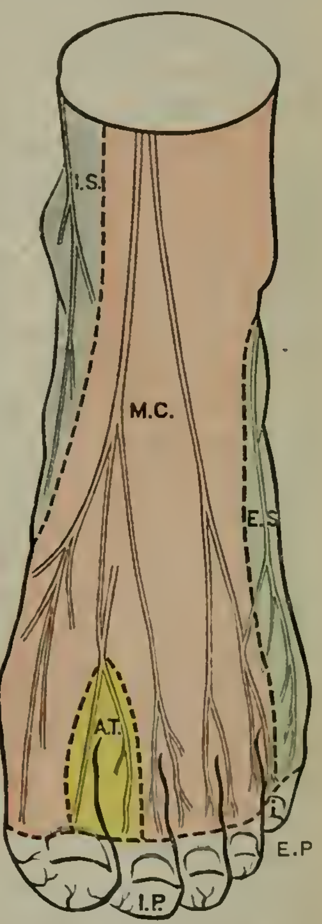


FIG. 620.—DISTRIBUTION OF CUTANEOUS NERVES ON THE DORSUM OF THE FOOT.

I.S., Saphenous nerve; M.C., Superficial peroneal nerve; A.T., Deep peroneal nerve; E.S., Nervus suralis. The extremities of the toes are supplied by the medial and lateral plantar nerves (I.P., E.P.).

NERVUS TIBIALIS.

The **tibial nerve** (O.T. **internal popliteal**) arises from the anterior surface of the sacral plexus, usually from the fourth and fifth lumbar and first three sacral nerves (Fig. 616, p. 748). It is incorporated in the sciatic trunk in the buttock and proximal part of the thigh. At the bifurcation of the sciatic nerve it passes onwards through the popliteal fossa and the back of the leg. The part of the nerve from its origin from the plexus or the bifurcation of the sciatic nerve to the distal border of the popliteus muscle, was formerly called **internal popliteal**; the part of the nerve in the back of the leg being then designated **posterior tibial**. The course of the nerve through the buttock and thigh has already been described (p. 757). In the popliteal fossa it is concealed at first by the semimembranosus and the other hamstring muscles. It passes to the medial side of the popliteal vessels, and is thereafter found upon the popliteus muscle, under cover of the gastrocnemius and plantaris. In the back of the leg, from the distal border of the popliteus muscle to the ankle, the tibial (O.T. posterior tibial) nerve lies on the tibialis posterior muscle and the tibia, and, along with the posterior tibial vessels, occupies a sheath in the intermuscular septum separating the superficial and deep muscles of the back of the leg. In the proximal part of the leg the nerve is medial to the vessels, but, crossing behind them, it lies on their lateral side in the distal portion of its course. It terminates under cover of the ligamentum laciniatum by dividing into the lateral and medial plantar nerves.

The **collateral branches** may be divided into three series, arising respectively in the region of the thigh, the popliteal fossa, and the back of the leg:—

(*a*) *Branches arising from the Roots or Trunk of the Nerve while it is incorporated with the Sciatic Nerve.*—These have been already described as **muscular branches** to the quadratus femoris, gemelli, obturator internus, and the hamstring muscles, and an **articular branch** to the hip-joint (Fig. 623, p. 766).

(*b*) *Branches arising in the Popliteal Fossa proximal to the Knee-Joint.*—These are in three sets—articular, muscular, cutaneous. Vascular branches to the popliteal artery are also described.

1. The **articular branches** are slender nerves, variable in number. There are usually two, an *azygos* branch which pierces the oblique ligament of the knee-joint, and a *medial* branch, a long fine nerve which, crossing the popliteal vessels, runs distally on the medial side of the fossa to accompany the distal medial articular artery to the knee-joint. In its course it gives off a branch, often absent, which accompanies the proximal medial articular artery.

2. The **muscular branches** are five in number. Nerves for the two heads of the *gastrocnemius*, and for the *plantaris* enter those muscles at the borders of the popliteal fossa. A nerve for the *soleus* enters the superficial surface of the muscle. A nerve for the *popliteus* muscle passes over the surface of that muscle, and after winding round its distal border, supplies it on its deep (anterior) surface. As this nerve passes below the popliteus it supplies branches to the *tibialis posterior*, an *interosseous* branch for the interosseous membrane, which can be traced as far as the tibio-fibular syndesmosis, an *articular* branch for the proximal tibio-fibular joint, and a *medullary* branch for the shaft of the tibia.

3. **The Medial Sural Nerve** (O.T. **N. Communicans Tibialis**).—The **cutaneous branch** is the **medial cutaneous nerve of the leg.** This nerve passes from the popliteal fossa in the groove between the two heads of the gastrocnemius muscle, and afterwards lies upon the tendo calcaneus. It pierces the deep fascia in the middle third of the back of the leg, and is joined immediately afterwards by the peroneal anastomotic ramus from the common peroneal nerve. From their union the nervus suralis results, which reaches the foot, winding round the back of the lateral malleolus, along with the small saphenous vein. The nervus suralis supplies cutaneous branches to the lateral side and back of the distal third of the leg, the ankle and heel, and the side of the foot and little toe, as well as articular branches to the ankle and tarsal joints.

The nervus suralis communicates on the foot with the superficial peroneal nerve, and its size varies with the size of that nerve. It may extend on to the dorsum of the foot for a considerable distance, and may either reinforce or replace the branches of the above-named nerve to the intervals between the fourth and fifth and the third and fourth toes. The mode of formation of the nervus suralis is very variable. The usual arrangement is that described. Frequently the peroneal anastomotic nerve and the medial sural nerve (medial cutaneous nerve of the leg) do not unite, and in such cases the more usual arrangement is for the tibial trunk alone to form the nervus suralis (nerve of the calf), the peroneal anastomotic ramus extending only to the ankle and heel. It is less usual for the peroneal anastomotic ramus alone to form the nervus suralis, the medial sural nerve in these cases ending at the heel.

(*c*) *Branches arising in the Back of the Leg distal to the Knee-Joint.*—These branches are mainly muscular and cutaneous.

The **muscular branches** are four in number, comprising nerves to the soleus (entering its deep surface) and tibialis posterior, often arising by a common trunk, and nerves to the flexor digitorum longus and flexor hallucis longus, the latter generally accompanying (and supplying) the peroneal artery for some distance. The nerve to the tibialis posterior supplies twigs to the posterior tibial artery.

The **cutaneous branches** are the **medial calcanean rami**, which pierce the ligamentum laciniatum, and are distributed to the skin of the heel and posterior part of the sole of the foot.

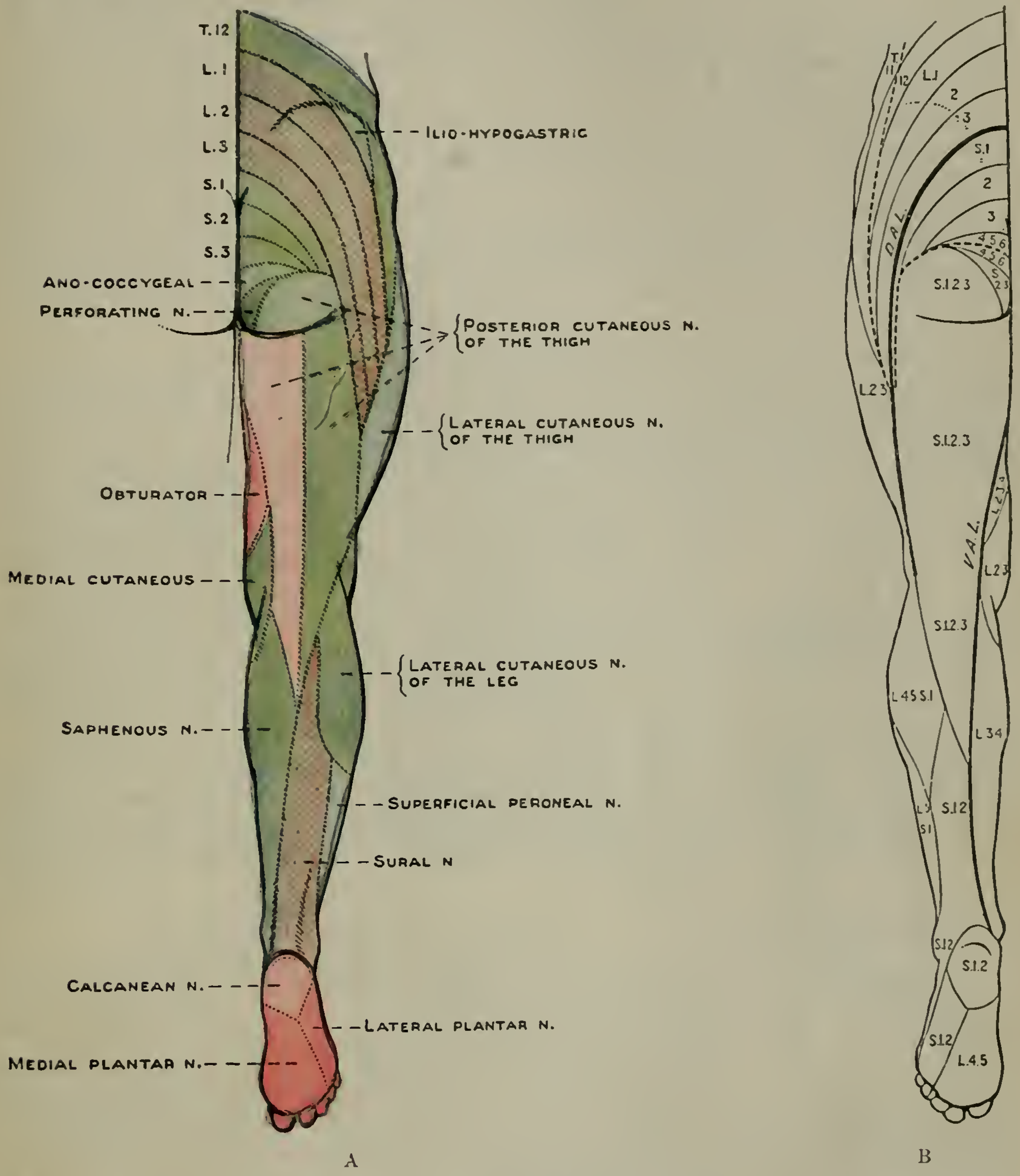


Fig. 621.—Distribution of Cutaneous Nerves on the back of the Lower Limb.

In A the distribution of the several nerves is represented, their names being given.

In B a schematic representation is given of the areas supplied by the above nerves, the figures indicating the spinal origin of the branches of distribution to each centre.

In addition, a *medullary nerve* to the fibula, and a small *articular branch* to the ankle-joint, are supplied by the tibial nerve.

The **terminal branches of the tibial nerve** are the *medial* and *lateral plantar nerves.*

Nervus Plantaris Medialis.

The **medial plantar nerve** is homologous with the median nerve in the hand (Fig. 621, p. 763). It is rather larger than the lateral plantar. It courses forwards in the sole of the foot, under cover of the ligamentum laciniatum and abductor hallucis, to the interval between that muscle and the flexor digitorum brevis, in company with the medial plantar artery.

The **collateral branches** are muscular, cutaneous, and articular. The *muscular* branches supply the abductor hallucis and the flexor digitorum brevis. The plantar *cutaneous* branches are small twigs which pierce the plantar aponeurosis in the interval between these muscles to supply the medial part of the sole of the foot. The *articular* branches are minute twigs which supply the tarsal and tarso-metatarsal articulations.

The **terminal branches** are four in number, the *common plantar digital nerves*, and may be designated first, second, third, and fourth, from medial to lateral side.

The **first** (most medial) branch separates from the nerve before the others, and pierces the plantar aponeurosis behind the ball of the great toe. It supplies a muscular branch to the flexor hallucis brevis, and cutaneous branches to the medial side of the foot and ball of the great toe. It terminates as the plantar proper digital nerve for the medial side of the great toe.

The **second branch** arises along with the third and fourth; after supplying a branch to the first lumbrical muscle, it becomes superficial in the interval between the first and second toes, and terminates by dividing into two *proper digital nerves* for the supply of the adjacent sides of these toes.

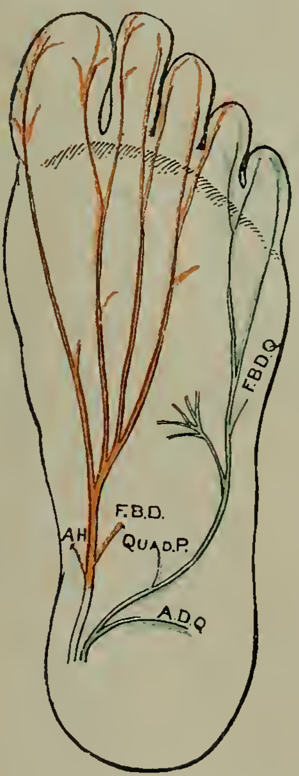


FIG. 622.—SCHEME OF DISTRIBUTION OF THE PLANTAR NERVES.

In brown, medial plantar nerve, and its cutaneous and muscular branches; F.B.D., Flexor digitorum brevis; A.H., Abductor hallucis; F.B.H., Flexor hallucis brevis; L.I., First lumbrical. *In green*, lateral plantar nerve, and its cutaneous and muscular branches; Quad. P., Quadratus plantæ; A.D.Q., Abductor digiti quinti; F.B.D.Q., Flexor brevis digiti quinti.

The **third** and **fourth branches** are entirely cutaneous in their distribution. They become superficial in the intervals between the second and third and the third and fourth toes, respectively, and there divide into proper digital branches for the supply of the adjacent sides of these toes.

The **plantar proper digital nerves** supply the whole length of the toes on the plantar aspect, and, in relation to the terminal phalanges, furnish minute dorsal offsets for the supply of the nails and tips of the toes on their dorsal surface.

The medial plantar nerve thus supplies the skin of the three and a half medial toes in the sole of the foot, and four muscles: the abductor hallucis and flexor digitorum brevis, the flexor hallucis brevis, and the first lumbrical muscle.

NERVUS PLANTARIS LATERALIS.

The **lateral plantar nerve** is homologous with the ulnar nerve in the hand. From its origin, under cover of the ligamentum laciniatum, it extends forwards and laterally in the sole, in company with the lateral plantar artery, between the flexor digitorum brevis and the quadratus plantæ, towards the base of the fifth metatarsal bone. There it terminates by dividing into superficial and deep branches.

Collateral Branches.—*Muscular branches* are given off from the undivided nerve to the quadratus plantæ and abductor digiti quinti muscles. *Cutaneous branches* pierce the plantar fascia at intervals along the line of the intermuscular septum, between the flexor digitorum brevis and abductor digiti quinti.

Terminal Branches—Ramus Superficialis.—The **superficial branch** is mainly cutaneous. Passing forwards between the flexor digitorum brevis and abductor digiti quinti, it divides into lateral and medial parts.

The *lateral branch*, after supplying the flexor quinti digiti brevis muscle, and sometimes one or both interossei of the fourth space, becomes superficial behind the ball of the little toe, and supplies cutaneous twigs to the sole of the foot and ball of the toe. It terminates as the proper digital branch for the lateral side of the little toe.

The *medial branch* passes forwards to the interval between the fourth and fifth toes, where it becomes cutaneous, and divides into two proper digital branches for the supply of the adjacent sides of these toes. It communicates with the fourth terminal branch of the medial plantar nerve.

Ramus Profundus.—The **deep branch** of the lateral plantar nerve, passing deeply along with the lateral plantar artery, extends medially towards the great toe, under cover of (*i.e.* dorsal to) the quadratus plantæ and oblique head of the adductor hallucis. It gives off *articular branches* to the tarsal and tarso-metatarsal joints, and *muscular branches* to the interossei of each space (except in some cases the muscles of the fourth space): to the adductor hallucis, and the lateral three lumbrical muscles. These nerves enter the deep surface of the muscles, that to the second lumbrical reaching its muscle after passing forwards dorsal to the transverse head of the adductor hallucis.

PLEXUS PUDENDUS.

The **pudendal plexus** constitutes the third and last subdivision of the lumbosacral plexus. It is composed, for the most part, of the spinal nerves below those which form the sacral plexus; but, as already stated, there is no distinct point of separation between the two plexuses. On the contrary, there is considerable overlapping, so that two and sometimes three of the principal nerves derived from the pudendal plexus have their origin in common with nerves of the sacral plexus.

The plexus is formed by fibres from the anterior rami of the first three sacral nerves, and by the whole of the anterior rami of the fourth and fifth sacral and coccygeal nerves. The size of the nerves diminishes rapidly from the first sacral to the coccygeal, which is extremely slender.

Position and Constitution.—The plexus is formed on the posterior wall of the pelvis. Of the nerves forming it, the upper ones emerge from the anterior sacral foramina; the fifth sacral nerve appears between the last sacral and first coccygeal vertebra; and the coccygeal nerve appears below the transverse process of that vertebra. The nerves of distribution derived from the plexus are the following:—

1. Visceral branches.
2. Posterior cutaneous nerve of the thigh.
3. Perforating cutaneous nerve.
4. Pudendal nerve.
5. Muscular branches.
6. Ano-coccygeal nerve.

All the nerves, except the visceral branches, are distributed to the perineum. Only two, the posterior cutaneous nerve of the thigh and the perforating cutaneous nerve, send branches to the lower limb.

Visceral Branches.—Like the other spinal nerves, the fourth and fifth sacral and coccygeal nerves are provided with fine *gray rami communicantes* from the sacral sympathetic trunk, which join them after a short course on the front of the sacrum. The third (along with the second or fourth) sacral nerve, in addition, sends a considerable *white ramus communicans* or **visceral branch** direct to the pelvic plexus and viscera.

The Posterior Cutaneous Nerve of the Thigh (O.T. **Small Sciatic**).—This nerve is complex both in origin and distribution (Fig. 623, p. 766). Springing from the junction of the sacral and pudendal plexuses, it is derived from the first three or second and third sacral nerves. It is distributed to the lower limb and perineum, and is associated with other nerves belonging to both regions. It arises from the back of the roots of the sacral plexus in the pelvis. Its higher roots from the first and second sacral nerves are intimately associated with the origin of the inferior gluteal nerve; its lowest root from the third sacral nerve is associated with the origins of the perforating cutaneous or of the pudendal nerve. It enters the buttock through the greater sciatic notch, below the piriformis, along with the inferior gluteal artery and nerve. Proceeding distally, posterior to the sciatic nerve, it enters the thigh at the lower border of the glutæus maximus muscle, where it gives off considerable branches. Becoming gradually smaller as it courses distally over the hamstring muscles to the popliteal fossa, it finally pierces the popliteal fascia in one or more cutaneous branches, which supply the skin over the calf of the leg for a variable distance (Fig. 621, p. 763).

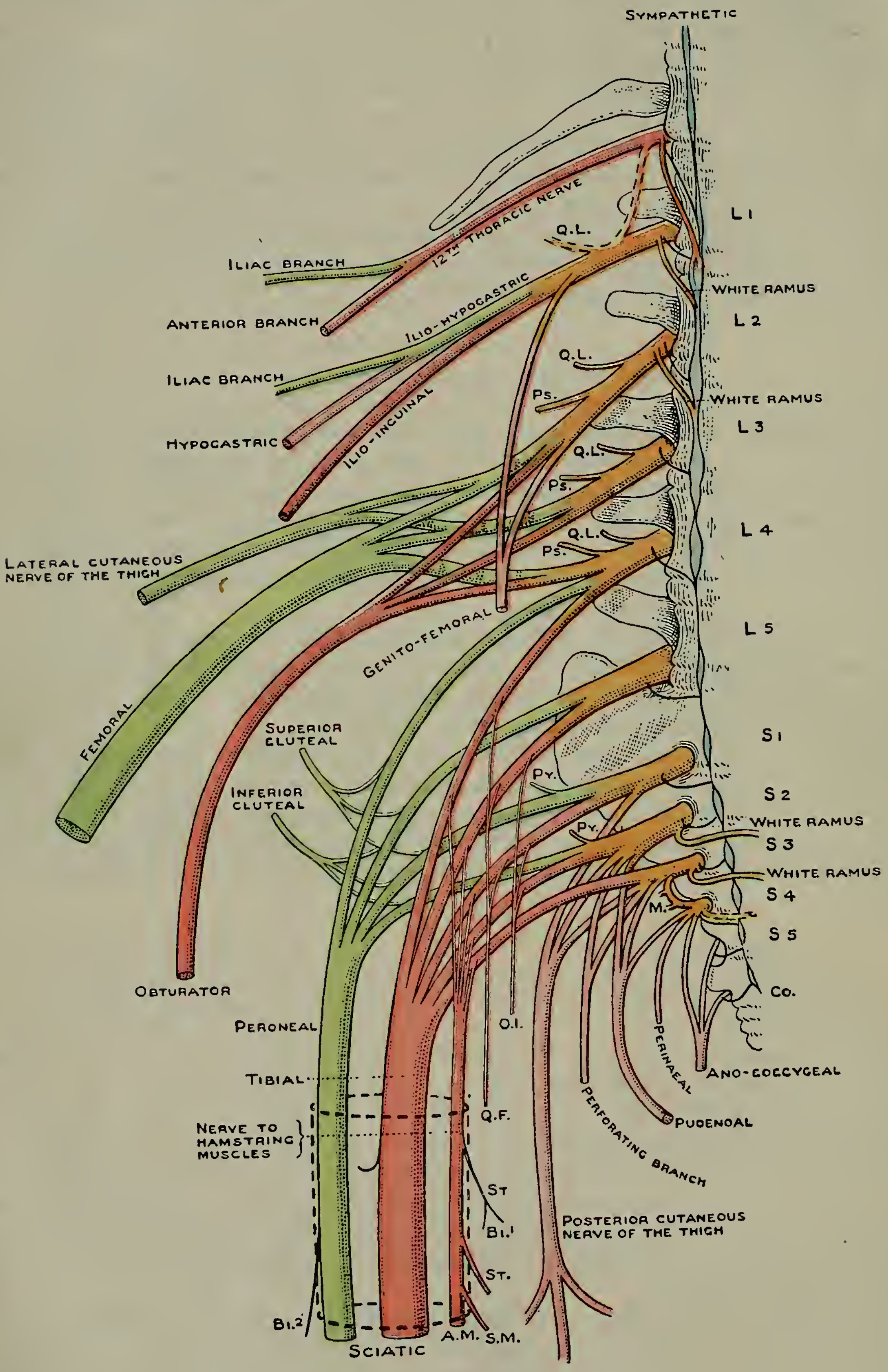


Fig. 623.—Nerves of the Lumbo-Sacral Plexus.

Branches.—The nerve is purely cutaneous. It supplies branches to the perineum, buttock, thigh, and leg.

The **perineal branch** arises at the lower border of the glutæus maximus muscle (Fig. 625, p. 769). It sweeps in a medial direction to the perineum, lying on the origin of the hamstring muscles, distal to the ischial tuberosity; and becoming subcutaneous after passing over the pubic arch, its terminal branches supply the skin of the scrotum and root of the penis, or, in the female, the labium majus and clitoris, some of them being directed backwards towards the anus and central point of the perineum. They communicate with the inferior hæmorrhoidal and perineal branches of the pudendal nerve, and with the ilio-inguinal nerve. In its course to the perineum the nerve gives off *collateral branches* to the skin of the proximal and medial part of the thigh.

The **inferior gluteal branches** are large and numerous (Fig. 623, p. 766). They arise from the nerve beneath the glutæus maximus, and become subcutaneous by piercing the fascia lata at different points along its lower border. They supply the skin of the lower half of the buttock. The most lateral branches, reaching to the back of the greater trochanter, overlap the terminal filaments of the gluteal branches of the lateral cutaneous nerve of the thigh, and the posterior rami of the first three lumbar nerves. The most medial branches, which may pierce the sacro-tuberous ligament, reach nearly to the coccyx, and are co-extensive in their distribution with the branches of the perforating cutaneous nerve, which they reinforce and not infrequently replace.

The **femoral branches** are divisible into two sets—*medial* and *lateral.* They pierce the fascia lata of the thigh at intervals, and supply the skin of the back of the thigh.

The **sural branches** are two or more slender nerves which pierce the fascia over the popliteal fossa, and are distributed for a variable extent to the skin of the back of the leg. They may stop short over the popliteal fossa, or may extend as far as the ankle. Usually they innervate the skin as far as the middle of the calf. They communicate with the nervus suralis.

In cases where the sciatic nerve is naturally divided at its origin into tibial and common peroneal nerves (*e.g.* by the piriformis muscle), the posterior cutaneous nerve also is separated into two parts: a **posterior part**, associated with the common peroneal nerve and arising in common with the lower roots of the inferior gluteal nerve (usually from the first and second sacral nerves), and comprising the gluteal and lateral femoral branches; and an **anterior part**, associated with the tibial nerve and arising usually from the second and third sacral nerves, along with the perforating cutaneous and pudendal nerves, and comprising the perineal and medial femoral branches.

Perforating Cutaneous Nerve (n. perforans ligamenti tuberoso-sacri (Schwalbe), n. cutaneus clunium inferior medialis (Eisler)).—This nerve arises from the back of the second and third sacral nerves (Fig. 623, p. 766). At its origin it is associated with the lower roots of the posterior cutaneous nerve of the thigh. Passing distally it pierces the sacro-tuberous ligament, along with the coccygeal branch of the inferior gluteal artery; and after winding round the lower border of the glutæus maximus muscle, or in some cases piercing its lower fibres, it becomes cutaneous a little distance from the coccyx, and supplies the skin over the lower part of the buttock and the medial part of the fold of the nates.

The perforating cutaneous nerve is not always present. In a minority of cases it is associated at its origin with the pudendal nerve. When absent as a separate nerve, its place is taken by (1) gluteal branches of the posterior cutaneous nerve of the thigh, or (2) a branch from the pudendal nerve, or (3) a small nerve (n. perforans coccygeus major, Eisler), arising separately from the posterior part of the third and fourth sacral nerves.

Muscular Branches.—Between the third and fourth sacral nerves (occasionally reinforced by the second, Eisler) a plexiform loop is formed, from which muscular nerves are given off to the levator ani (supplying the muscle on its pelvic surface), coccygeus, and external sphincter. The nerve to the external sphincter (*perineal branch of fourth sacral*) pierces the sacro-tuberous ligament and the coccygeus muscle, to which it gives offsets, and appears in the ischio-rectal fossa between the glutæus maximus and the external sphincter. Besides supplying the posterior fibres of the external sphincter, it distributes cutaneous offsets to the skin of the ischio-rectal fossa and the fold of the nates behind the anus. This nerve, in some instances, replaces the perforating cutaneous nerve.

Ano-coccygeal Nerve.—By the union of the remaining part of the fourth with the fifth sacral and coccygeal nerves, the so-called **plexus coccygeus (coccygeal plexus)** is formed. A fine descending branch of the fourth sacral nerve passes over or through the sacro-tuberous ligament, to join the fifth sacral nerve. This fifth sacral nerve, joined by the descending branch of the fourth, descends alongside the coccyx and is again joined by the coccygeal nerve, so that a plexiform cord, the *ano-coccygeal nerve,* results, homologous with the inferior caudal trunk of tailed animals. Fine twigs arise from it, which pierce the sacro-tuberous ligament and supply the skin in the neighbourhood of the coccyx, medial to the branches of the perforating cutaneous nerve and behind the anus.

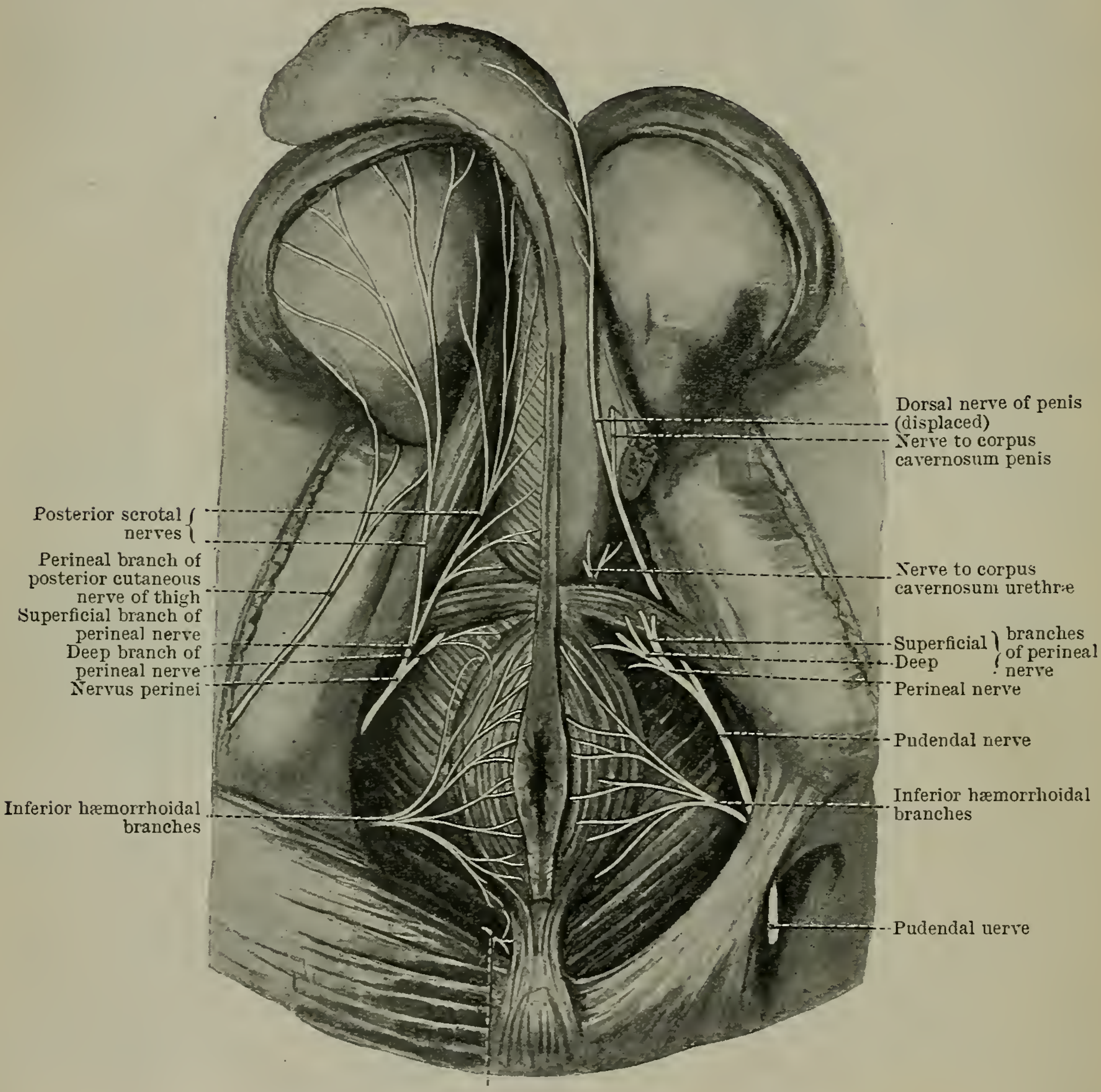

Dorsal nerve of penis (displaced)
Nerve to corpus cavernosum penis
Posterior scrotal nerves
Perineal branch of posterior cutaneous nerve of thigh
Superficial branch of perineal nerve
Deep branch of perineal nerve
Nervus perinei
Nerve to corpus cavernosum urethræ
Superficial
Deep
branches of perineal nerve
Perineal nerve
Pudendal nerve
Inferior hæmorrhoidal branches
Inferior hæmorrhoidal branches
Pudendal nerve

FIG. 624.—DISTRIBUTION OF THE PUDENDAL NERVE.

NERVUS PUDENDUS.

The **pudendal nerve** (O.T. **pudic**) is the principal nerve for the supply of the perineum. It arises in the pelvis usually by three roots from the second, third, and fourth sacral nerves (Fig. 623, p. 766). (Frequently one of its branches, the inferior hæmorrhoidal nerve, arises independently from the third and fourth sacral nerves.) The nerve passes to the buttock through the greater sciatic foramen, below the sciatic nerve, and lies on the sacro-spinous ligament, or the spine of the ischium, medial to the internal pudendal artery. It enters the perineum along with the artery through the lesser sciatic foramen. In the perineum it is deeply placed in the lateral wall of the ischio-rectal fossa, enclosed in a special sheath derived from the parietal pelvic fascia covering the medial surface of the obturator internus muscle. At the anterior limit of the ischio-rectal fossa, the nerve approaches the surface and divides at the base of the urogenital diaphragm into its terminal branches, the perineal nerve and the dorsal nerve of the penis.

The branches of the nerve are essentially the same in the two sexes. As a rule no branches are given off till it enters the perineum, but sometimes the inferior hæmorrhoidal nerve has an independent origin from the plexus, merely accompanying the pudendal nerve in the first part of its course; and in exceptional cases the perforating cutaneous nerve of the buttock is a branch of the pudendal nerve.

The **inferior hæmorrhoidal nerve** arises from the pudendal nerve under cover of the glutæus maximus, at the posterior part of the ischio-rectal fossa. In cases in which it has an independent origin from the plexus, it arises from the third and fourth sacral nerves. It crosses the ischio-rectal fossa in company with the inferior hæmorrhoidal vessels, and separates into numerous branches—muscular, cutaneous, and communicating.

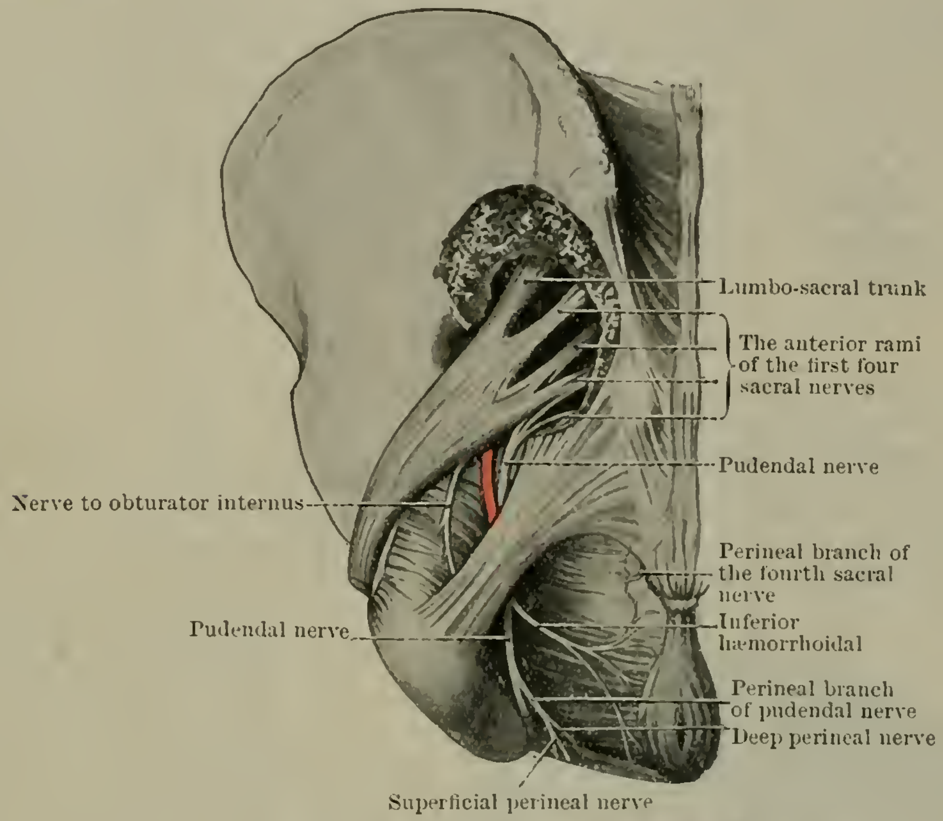

Lumbo-sacral trunk
The anterior rami of the first four sacral nerves
Pudendal nerve
Nerve to obturator internus
Perineal branch of the fourth sacral nerve
Pudendal nerve
Inferior hæmorrhoidal
Perineal branch of pudendal nerve
Deep perineal nerve
Superficial perineal nerve

FIG. 625.—THE ORIGIN AND COURSE OF THE PUDENDAL NERVE.

The **muscular branches** end in the external sphincter ani muscle. The **cutaneous branches** supply the skin around the anus. The **communicating branches** connect the inferior hæmorrhoidal with three other nerves—the perineal branches of the posterior cutaneous nerve of the thigh, pudendal, and fourth sacral nerves.

The **perineal nerve**, one of the two terminal branches of the pudendal nerve, arises near the base of the urogenital diaphragm. It almost immediately divides into two parts, superficial and deep.

The **superficial part** is purely cutaneous and consists of two nerves, the posterior or lateral and the anterior or medial superficial perineal nerves (nn. scrotales posteriores or nn. labiales posteriores), which pass, along with the superficial perineal vessels, to the anterior part of the perineum. The **posterior or lateral superficial perineal nerve**, at the anterior limit of the ischio-rectal fossa, usually passes over the base of the urogenital diaphragm and over the (superficial) transversus perinei muscle. The **anterior or medial superficial perineal nerve**, lying more deeply, pierces the base of the fascia inferior of the urogenital diaphragm and goes underneath or through the transversus perinei muscle. Becoming superficial in the anterior (urethral) triangle of the perineum, they are distributed to the skin of the scrotum (or labium majus), and communicate with the perineal rami of the posterior cutaneous nerve of the thigh and with the inferior hæmorrhoidal nerve.

The **deep part** of the perineal nerve is mainly but not entirely muscular. Coursing forwards through the anterior part of the ischio-rectal fossa, it passes between the two layers of fascia of the urogenital diaphragm towards the urethra. It supplies muscular branches to the anterior parts of the levator ani and external sphincter, to the transversus perinei superficialis and profundus, ischio-cavernosus, bulbo-cavernosus (or sphincter vaginæ), and sphincter urethræ membranaceæ. It terminates as the nerve to the bulb, which, piercing the urogenital diaphragm, enters the bulb of the urethra and supplies the erectile tissue of the bulb and corpus cavernosum urethræ, as well as the mucous membrane of the urethra as far as the glans penis.

The **dorsal nerve of the penis or clitoris**, the other terminal branch of the pudendal nerve, accompanies the internal pudendal artery above the fascia inferior of the urogenital diaphragm. It passes forward close to the pubic arch, lying under cover of the crus and ischio-cavernosus and fascia inferior of the urogenital diaphragm, and upon the sphincter urethræ membranaceæ muscle; piercing the fascia inferior of the urogenital diaphragm near its apex, at the lateral side of the dorsal artery of the penis (or clitoris), it passes on to the dorsum of the penis or clitoris, to which it is distributed in its distal two-thirds, sending branches round the sides of the organ to reach its under surface. In the female the nerve is much smaller than in the male. The dorsal nerve of the penis supplies one branch, the **nerve to the corpus cavernosum penis**, as it lies between the fasciæ of the urogenital diaphragm. This is a slender nerve, which, piercing the fascia inferior of the urogenital diaphragm, supplies the erectile tissue of the crus and corpus cavernosum penis.

MORPHOLOGY OF THE PUDENDAL PLEXUS.

The structures occupying the perineum are placed in the ventral axis of the body, and comprise, from before backwards, the penis and scrotum, or mons Veneris and vulva, the central point of the perineum, the anus and ischio-rectal fossa, and the coccyx. They are placed on the medial side of the attachment of the lower limbs—the penis or mons Veneris in relation to the preaxial border; the coccyx in relation to the postaxial border of the limb.

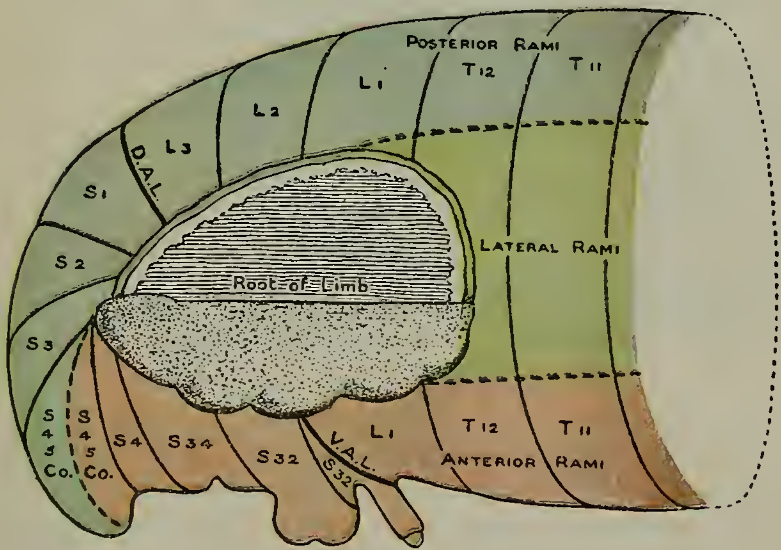


FIG. 626.—SCHEME of the innervation of the hinder portion of the trunk and of the perineum, and the interruption of the segmental arrangement of the nerves associated with the formation of the limb.

The nerves of the perineum, thus reaching the ventral axis of the trunk, are homologous with the anterior (ventral) terminations of other nerves. They are separable into two series. The perineum is supplied mainly through the pudendal plexus by the last four sacral and the coccygeal nerves, but it is also innervated to a minor extent by the first lumbar nerve through the ilio-inguinal nerve, which reaches the root of the penis and the scrotum. The region is thus supplied by two series of widely separated nerves, which have their meeting-place on the dorsum and side of the penis and scrotum. This junction of the ilio-inguinal and pudendal nerves constitutes the beginning of the **ventral axial line** (Fig. 626, p. 770), which extends peripherally along the medial side of the lower limb. Apart from this break in their distribution, a definite numerical order may be followed in the arrangement of the perineal nerves. The higher parts of the perineum are innervated by the higher spinal nerves; the lower parts, by the lower nerves. This is best exemplified in the distribution of the cutaneous nerves. The base of the penis and scrotum (or mons Veneris) is supplied by the first lumbar nerve (ilio-inguinal). The dorsal nerve of the penis (or clitoris), when traced back to the pudendal plexus, is found to come from the second, and to a less extent from the third sacral nerves; the scrotal nerves (perineal branches of the pudendal and posterior cutaneous nerve of the thigh) similarly arise from the third, and to a less extent from the second sacral nerves; the skin of the ischio-rectal fossa and anus is innervated by the inferior hæmorrhoidal (third and fourth sacral nerves), and the perineal branch of the fourth sacral nerve. The ano-coccygeal nerve (coccygeal plexus), lastly, supplies the skin round the coccyx (fourth and fifth sacral and coccygeal nerves).

Judged from its nerve supply the perineum is to be regarded as occupying, for the most part, a position behind or more caudal than that of the lower limb in relation to the trunk. There is here a remarkable gap in the numerical sequence of the nerves supplying the ventral axis of the body. All the nerves between the first lumbar and the second sacral fail to reach the mid-ventral line of the trunk and are wholly concerned in the innervation of the lower limb.

At the preaxial border of the limb (groin) the first lumbar nerve, the highest nerve supplying the perineum, is concerned also in innervating the skin of the limb. At the postaxial border of the limb (fold of the nates and back of the thigh), the nerves which are the highest of those constituting the pudendal plexus (the second and third sacral nerves) are also implicated in innervating that border of the limb. The fourth sacral nerve is concerned only to a very slight extent in the innervation of the limb by means of the perineal branch, which reaches the beginning of its postaxial border; the last two spinal nerves are wholly unrepresented in the limb proper and end entirely in the trunk behind the limb.

The Distribution of the Spinal Nerves to the Muscles and Skin of the Limbs.

By dissection, experiment, and clinical observation, it is conclusively proved that, as a rule, each nerve of distribution in the limb, whether to muscle or skin, is made up of fibres derived from more than one spinal nerve; and, further, that in cutaneous distribution a considerable overlapping occurs in the course of the several peripheral nerves. Moreover, the arrangement of the distribution of the nerves to skin and to muscles is not identical. In the case of the skin of the limbs, by the covering of the limb being drawn on to it from adjacent parts in the process of growth, cutaneous nerves are engaged which are derived from sources not represented in the muscular innervation of the limbs. Again, among the muscles, some have undergone fusion, others have become rudimentary, and others again have altered their position in the limb.

Innervation of the Skin of the Limbs.

While the scheme of cutaneous innervation of the limbs is fundamentally segmental, yet the arrangement is confused and complicated by various causes. The growth of the limb from the trunk has caused the skin to be drawn out over it like a stretched sheet of india-rubber (Herringham), and at the same time the extent of the dorsal area of the limb is increased at the expense of the ventral area. The central nerves of the plexus remain buried deeply in the substance of the limb, only coming to the surface towards the periphery. The proximal parts of both surfaces of the limb thus become innervated by cutaneous nerves otherwise not necessarily concerned in the innervation of the limbs. Herringham has shown that—(A) *Of two spots on the skin, that nearer the preaxial border tends to be supplied by the higher nerve.* (B) *Of two spots in the preaxial area, the lower tends to be supplied by the lower nerve; and of two spots in the postaxial area, the lower tends to be supplied by the higher nerve.* In other words, from the root of the limb along the preaxial border to its distal extremity, and along the postaxial border to the root of the limb again, there is a definite numerical sequence of spinal nerves supplying skin areas through nerves of the limb plexuses, as is illustrated, for example, in Fig. 609, p. 735. A similar numerical sequence in the arrangement of the nerves is also found extending over the dorsal and ventral surfaces of the limbs from preaxial to postaxial border, except in certain situations.

On the dorsal and ventral surfaces of both upper and lower limbs there is a hiatus, for a certain distance, in the numerical sequence of the spinal nerves in their cutaneous distribution, explicable on the ground that the central nerves of the plexus, which fail to reach the surface in these situations, are replaced by cutaneous branches from neighbouring nerves. This hiatus has been named the *axial area or line.*

In the upper limb, *the dorsal axial area or line* extends from the median line of the back, opposite the vertebra prominens, to the insertion of the deltoid. *The ventral axial area or line* extends anteriorly from the median plane of the trunk, at the sternal synchondrosis, across the chest, distally along the front of the arm and forearm to the wrist.

In the lower limb, *the dorsal axial area or line* may be traced from the median plane of the back over the posterior superior iliac spine, across the buttock and thigh, to the head of the fibula. *A ventral axial area or line* can also be traced from the root of the penis along the medial side of the thigh and knee, and along the back of the leg to the heel.

These areas or lines represent the meeting-place and overlapping of nerves, which are not in numerical sequence; and it is only at the peripheral parts of the limbs, on the dorsal and ventral surfaces, that the nerves appear in numerical sequence from the preaxial to the postaxial border. In the case of the upper limb the hiatus is caused, in both surfaces of the limb, by the absence of cutaneous branches of the seventh cervical nerve; in the case of the lower limb the hiatus is due to the absence of branches from the fifth lumbar nerve on both surfaces of the limb, and the absence of branches from the fourth lumbar nerve, in addition, on the dorsal surface.

These points in the innervation of the skin of the limbs are illustrated by Figs. 609, 610, pp. 735, 736, and by Fig. 598, p. 716, and Fig. 626, p. 770.

INNERVATION OF THE MUSCLES OF THE LIMBS.

The following laws appear to be applicable to the upper and lower limbs alike :—

1. *No limb-muscle receives its nerve-supply from posterior rami.*
2. *The dorsal and ventral strata of muscles are always supplied by the corresponding dorsal and ventral branches of the nerves concerned. The ventral muscular stratum is more extensive than the dorsal; the ventral nerves are the more numerous, and the additional nerves are postaxially placed.* The spinal nerves supplying muscles of the upper limb are C. 5, 6, 7, 8 (dorsal), and C. 5, 6, 7, 8, T. 1 (ventral); the nerves for the muscles of the lower limb are L. 2, 3, 4, 5, S. 1, 2 (dorsal), and L. 2, 3, 4, 5, S. 1, 2, 3 (ventral).
3. *The dorsal and ventral trunks of the nerves are distributed in the limb in a continuous, segmental manner*; so that, "of two muscles, that nearer the head end of the body tends to be supplied by the higher nerve, and that nearer the tail end by the lower nerve" (Herringham).
4. *The nerves placed most centrally in the plexus extend furthest into the limb, and the more preaxial nerves terminate sooner in the limb than the more postaxial nerves.*

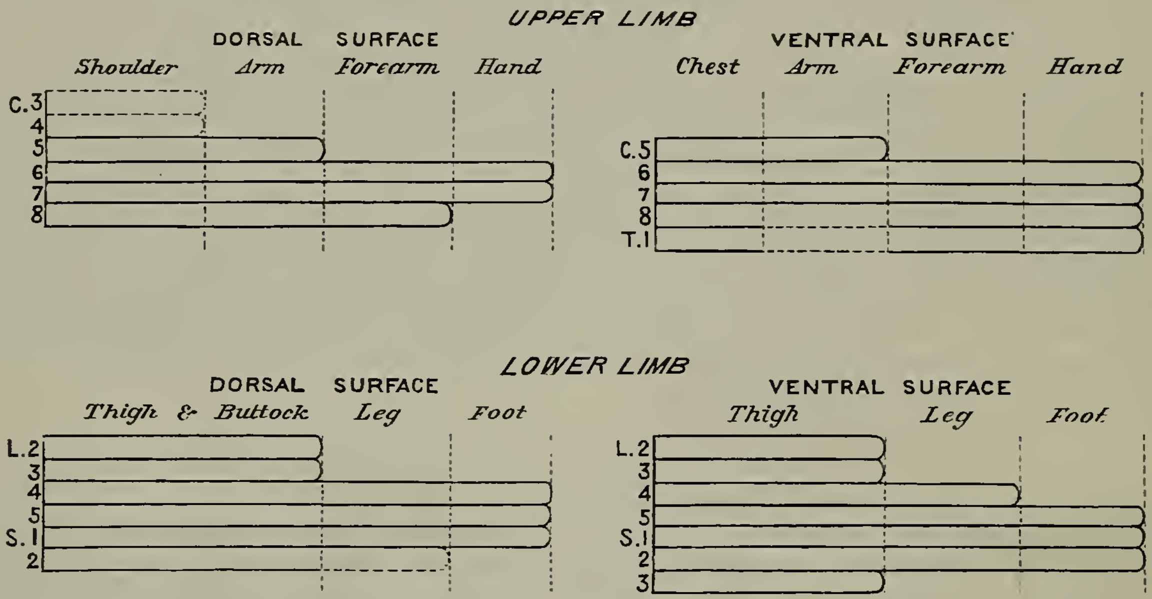


DIAGRAM of the segmental distribution of the muscular nerves of the upper and lower limbs.

The only exception to this rule is on the ventral (anterior) surface of the arm, where a suppression of the muscle elements leads to an absence of the regular series of segmental nerves (C. 8, T. 1) on its postaxial border. These nerves reappear in the forearm, and the occasional "axillary arches" may be regarded as the muscular elements usually suppressed, and, when present, supplied by these nerves.

Muscles with a Double Nerve Supply.—The existence of more than one nerve to a muscle indicates usually that the muscle is composite and is the representative of originally separate elements, belonging to more than one segment or to both surfaces of the limb. In the case of the pectoralis major, subscapularis and flexor digitorum profundus, adductor magnus, and soleus, parts of the same (ventral or dorsal) stratum have fused, to form muscles innervated from the corresponding ventral or dorsal nerves. The other muscles having a double nerve-supply—brachialis, biceps femoris, and (sometimes) pectineus—are examples of fusion at the preaxial or postaxial border of muscular elements derived from the dorsal and ventral surfaces of the limb, which are correspondingly innervated by branches from both dorsal and ventral series : *e.g.*, the brachialis is innervated by the musculo-cutaneous and radial nerves; the biceps femoris by the peroneal (short head) and tibial nerves (long head); and the pectineus, by the femoral and (sometimes) obturator nerves.

THE LIMB PLEXUSES.

COMPOSITION OF THE LIMB PLEXUSES.

In all mammals the same definite plan underlies the constitution of the limb plexuses. The nerves concerned are the anterior rami of certain segmental spinal nerves, which (with certain exceptions at the preaxial and postaxial borders) are destined wholly and solely for the innervation of the limb. Each of the anterior rami engaged divides into a pair of **secondary trunks**, named **dorsal** or posterior, **ventral** or anterior. The dorsal and ventral trunks again subdivide into **tertiary trunks**, which combine with the corresponding subdivisions of neighbouring dorsal and ventral trunks to form the **nerves of distribution.** The combinations of *dorsal trunks* provide a series of nerves for the supply of that part of the limb which is derived from the *dorsal surface* of the embryonic limb bud (coloured green in Fig. 626, p. 770, for the upper limb, and green and pink in Fig. 626, p. 770, for the lower limb); the combinations of *ventral trunks* give rise to nerves of distribution to the regions corresponding to its *ventral surface* (coloured red in both the above-noted diagrams for the upper and lower limbs respectively).

In the regions of the limbs no anterior cutaneous branches, derived from the limb nerves, supply the trunk. The whole of the nerve is carried into the limb and is absorbed in its innervation, and the dorsal and ventral trunks forming the limb plexuses are to be looked upon as homologous with the lateral and anterior trunks of an intercostal nerve.

Significance of the Limb Plexuses.

It is obvious that something more than convenience of transit for the spinal nerves to skin and muscles is secured by the formation of the limb plexuses. It has been shown that by their combinations in the plexuses, every spot or area of skin in the limbs is innervated by more than one spinal nerve; and generally, also, each limb-muscle is supplied by more than one spinal nerve. Each cutaneous area and each limb muscle is thus brought into relationship with a wider area of the spinal medulla than would occur if the plexuses were non-existent. A simultaneous record of sensation is thus transmitted from any given point on the surface of the limb through more than one posterior root; and a more ready co-ordination of muscular movement is brought about by the transmission of motor impulses from the anterior root of a given spinal nerve to more than one muscle at the same time. Whilst segmentation becomes less obvious, increased co-ordination is effected both of movement and sensation. In a word, a plexus exists to supply the whole limb and the limb as a whole, as an organ which has its different active parts connected with the central nervous system by means of the limb plexus.

DEVELOPMENT OF THE SPINAL NERVES.

I. **Origin of the Spinal Nerve Roots.**—Whilst both the posterior and anterior roots are developed from cells of the neural plate, they differ as regards their exact site of origin.

The **posterior roots** are derived entirely from the neural crest, the origin of which from the cells of the lateral margin of the neural plate is described in the section on Human Embryology (p. 36). At the time when they first appear, the neural crest is a flattened cellular band which extends from the auditory vesicle along the lateral border of the neural tube to its caudal extremity. In the spinal region the crest shows segmental ganglionic enlargements along its ventral border, whilst its dorsal border shows a continuous cellular bridge throughout its length. Central processes are developed from the cells (neuroblasts) of the ganglionic enlargements, and, travelling upward through the crest, leave it along its dorsal border in segmental bundles to grow into the alar lamina of the neural tube. With the establishment of these dorsal root fibres the cellular bridge of the neural crest disappears, and the ganglionic enlargements thus become separated into individual spinal ganglia; these grow ventrally and come into relation with the anterior roots. Peripheral processes are developed from the ganglionic neuroblasts and emerge from the ventral border of the ganglia to join the fibres of the anterior root, with which they course as the posterior root fibres of the spinal nerves.

The **anterior roots**, on the contrary, are developed from the neural tube, which is a derivative of the medial portion of the neural plate. Processes from the neuroblasts situated in the mantle zone of the basal lamina grow out in small bundles which pierce the external limiting membrane and emerge in a continuous longitudinal series of rootlets from the ventro-lateral wall of the tube. Outside the tube these rootlets are grouped into segmental bundles, the anterior roots, which join the dorsal roots just peripheral to the spinal ganglia.

II. **Formation of the Spinal Nerve.**—The fibres of the posterior root ganglion and the anterior root grow by extension from the cells with which they are respectively connected, and meet in the space between the myotome and the side of the medullary tube to form the **spinal nerve**. In the adult there is a fundamental division of the spinal nerve into posterior and anterior rami In the process of development this separation is even more obvious. As the fibres of the posterior and anterior roots approximate, they separate at the same time each into two unequal portions: the smaller parts of the two roots unite together to form the **posterior ramus**, and the larger parts unite to form the **anterior ramus** of the spinal nerve.

The **posterior ramus**, curving laterally and dorsally, passes through the myotome and is connected with it. In the substance of the myotome it separates into branches as it proceeds towards the dorsal wall of the embryo. At a later stage, the branches are definitely arranged into a lateral and a medial series.

The **anterior ramus** grows gradually in a ventral direction to reach the somato-splanchnopleuric angle, under cover of the growing myotome. It spreads out at its distal end and eventually separates into two portions: a smaller, splanchnic, or visceral; and a larger, somatic, or parietal portion. (1) The smaller, **splanchnic, or visceral portion** grows inwards, dorsal to the Wolffian ridge, to be connected through the sympathetic trunk with the innervation of organs in the splanchnic area. This branch of the spinal nerve becomes the **white ramus communicans** of the sympathetic. It is not present in the case of all the spinal nerves, but only in relation to the thoracic and upper lumbar and the third and second or fourth sacral nerves. It will be referred to again in connexion with the sympathetic system. (2) The larger, **somatic, or parietal portion** becomes the main part of the anterior ramus of the nerve. It continues the original ventral course of the nerve, and, reaching the body wall, subdivides into two terminal branches—a *lateral branch*, which grows laterally and downwards and reaches the lateral aspect of the trunk, after piercing the myotome; and a ventral or *anterior branch*, which grows onwards in the body wall to reach the ventral axis. This arrangement is met with in the trunk between the limbs and in the neck.

III. **Formation of Limb Plexuses.**—The method of growth of the spinal nerves, just described, is modified in the regions where the limbs are developed. In relation to the limbs, which exist in the form of buds of undifferentiated cellular mesoblast before the spinal nerves have any connexion with them, the development of the anterior ramus of the nerve proceeds exactly in the way described, up to the point of formation of somatic and splanchnic branches. The **somatic branches** then stream out into the limb bud, passing into it below the ends of the myotomes and spreading out into a bundle of fibres at the basal attachment of the limb. Later, the nerves separate, each into a pair of definite trunks, which are named posterior or **dorsal** and anterior or **ventral**, and which, dividing round a central core of mesoderm, proceed to the dorsal and ventral surfaces respectively of the limb bud. While this process is going on, a *secondary union* takes place between parts of adjacent dorsal and ventral trunks. Dorsal trunks unite with dorsal trunks, ventral trunks unite with ventral trunks, to form the nerves distributed ultimately to the surfaces and periphery of the limb. These **dorsal and ventral trunks** are homologous with the **lateral** and **ventral branches** of the somatic nerves in other regions.

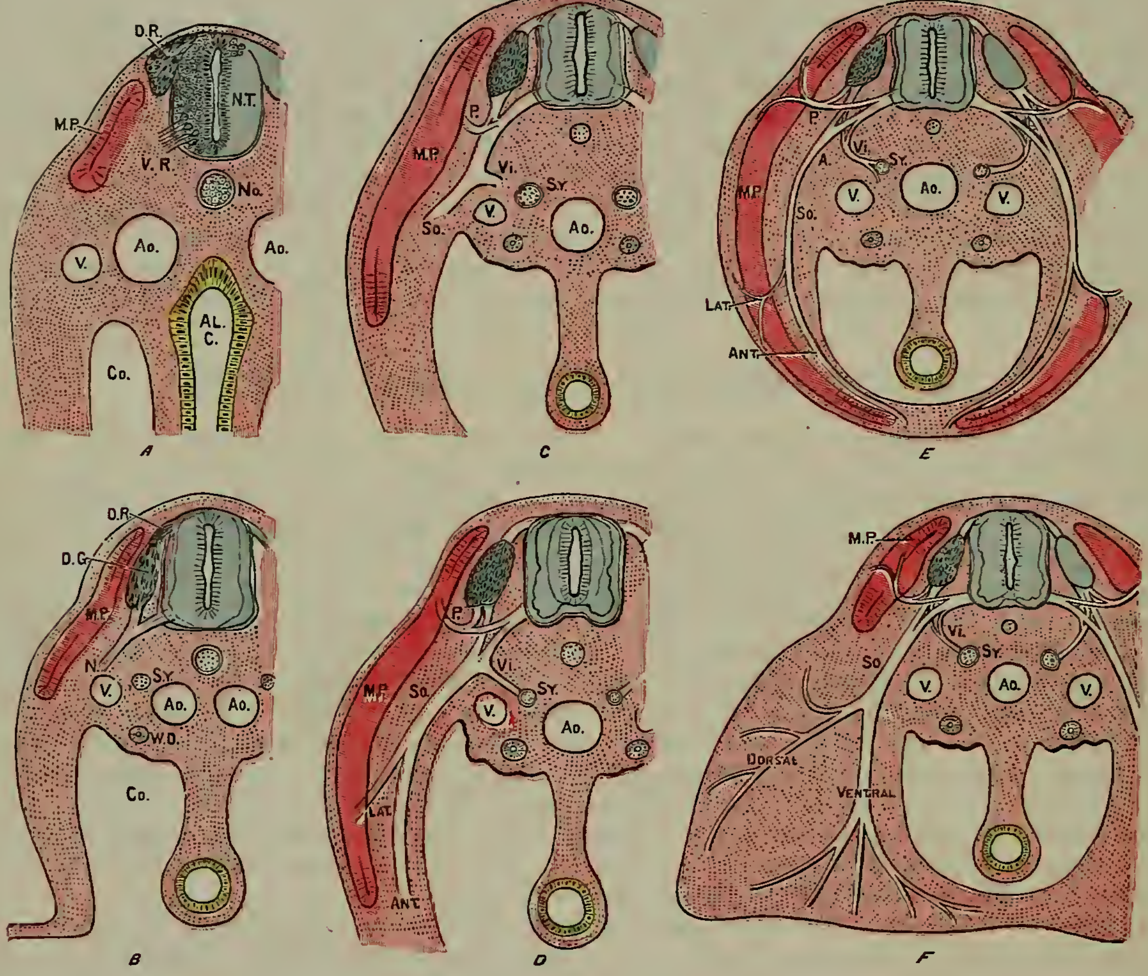


FIG. 627.—DEVELOPMENT OF THE SPINAL NERVES.

A, Formation of nerve roots.

D.R., Posterior root.
V.R., Anterior root.
N.T., Neural tube.
No., Notochord.
Al.C., Alimentary canal.
Ao., Aorta.
V., Cardinal vein.
M.P., Muscle plate.

B, Formation of nerve trunk (N).

D.G., Spinal ganglion.
Sy., Sympathetic trunk.
W.D., Wolffian duct.
Co., Cœlom.

C, Formation of nerves.

So., Somatic division.
Vi., Visceral branch.
P., Posterior ramus.

D, E, Formation of subordinate branches.

Lat., Lateral, and
Ant., Anterior, branches.

F, Formation of nerve trunks in relation to the limb: dorsal and ventral trunks corresponding to lateral and anterior trunks in D and E.

III. THE SYMPATHETIC NERVOUS SYSTEM.

The **Sympathetic Nervous System** is that portion of the peripheral nervous system which serves functionally to distribute efferent impulses of central origin to the involuntary musculature of the viscera, heart, blood-vessels and skin, and the glandular epithelium generally; and it further serves to collect afferent impulses from the viscera, and transmit them to the central nervous system. It consists of a complex aggregation of ganglia, plexuses, and nerves, widely distributed throughout the whole body; but since the tissues it supplies are most abundant in the visceral or splanchnic organs, the largest and most evident part of the system is found in the body-cavities, and occasions the name "visceral" or "splanchnic" nervous system sometimes applied to it. In these regions it forms a pair of elongated gangliated trunks, lying one on each side of the vertebral column and extending throughout the length of the body from the base of the skull to the coccyx. At the cephalic end each gangliated trunk is continued into the cranial cavity in the form of plexuses round the internal carotid artery, and thereby establishes relations with some of the cerebral nerves. At their caudal ends the two gangliated trunks unite in a single median ganglion placed in front of the coccyx, the *ganglion impar*. Each gangliated trunk is connected to the peripheral spinal nerves by one series of nerves (the white and gray rami communicantes), and to the viscera by another series of nerves; in the course of the latter there occur the numerous plexuses and subsidiary ganglia of the system. These parts indicate the most obvious distribution of the sympathetic system, but since the characteristic tissues innervated by it occur also in the head region, and in the body-wall (somatic) area generally, a wider extension of the system is to be expected, and sympathetic fibres are found in connexion with tissues as far removed from the body-cavity as, for example, the eye or skin.

The sympathetic nervous system is essentially dependent on and subservient to the central nervous system, from which it can no more be separated sharply, either anatomically or developmentally, than can the rest of the peripheral nervous system. For just as the cell bodies of the motor or efferent neurones of the cerebro-spinal system lie in the gray matter of the spinal medulla, so do the efferent fibres of the sympathetic system take origin in the same part, wherein they are connected with the central regulatory mechanism of the viscera. Moreover, the two peripheral systems of fibres are closely related in the first part of their course from the central axis: in the thoracic and lumbar regions the fibres of both systems emerge together in the anterior nerve roots, and only subsequently do the sympathetic leave the spinal ones by way of the white rami communicantes to join the gangliated trunk; and in the sacral region the sympathetic fibres emerge in the second, third, and fourth sacral nerves.

There is one marked difference, however, between the efferent fibres of the two systems. Those of the cerebro-spinal nerves pass continuously from their central origins to the tissues innervated; but those of the sympathetic system always enter and terminate in a ganglion from which a new fibre passes on to the periphery. Hence in the sympathetic system there are to be distinguished two series of fibres in the efferent path: **preganglionic** (medullated) fibres running from the central nervous system to sympathetic ganglia, and **postganglionic** (nearly all non-medullated) fibres passing from the ganglia onwards to their destinations (Fig. 628, p. 776). It may be added that the interruption so formed is probably the only break in the course of the efferent path, and it may occur either in a ganglion of the trunk, or in a collateral ganglion of a plexus, or in a terminal ganglion in close relation to the nerve-ending in a viscus. The sensory or afferent visceral fibres, on the other hand, pass through the sympathetic ganglia without interruption to reach their cell stations in the posterior root ganglia of the spinal nerves.

The efferent fibres of the sympathetic system as above outlined are not the only ones of central origin which supply the involuntary musculature and glandular epithelium of the body generally. For general visceral efferent fibres are also found as components of certain cerebral nerves, namely, the oculo-motor, facial, glossopharyngeal, vagus and accessory nerves; the preganglionic fibres of this cranial outflow do not enter the ganglia of the sympathetic trunk, but end in terminal ganglia of the system. Similarly at the lower end of the central axis, there are found visceral efferent fibres in the second, third, and fourth sacral nerves, the pelvic splanchnic branches, which similarly avoid the gangliated trunk and end in the ganglia of the pelvic sympathetic plexuses. These two streams of fibres, termed cranial and sacral respectively, which emerge from the central axis and escape, as it were, above and below the gangliated trunks, have been classed together as a "**parasympathetic**" group, in contradistinction to the thoracico-lumbar efferent stream, the preganglionic fibres of which end in the ganglion of the trunk, and comprise the sympathetic system proper. A distinction between the two groups is justified not

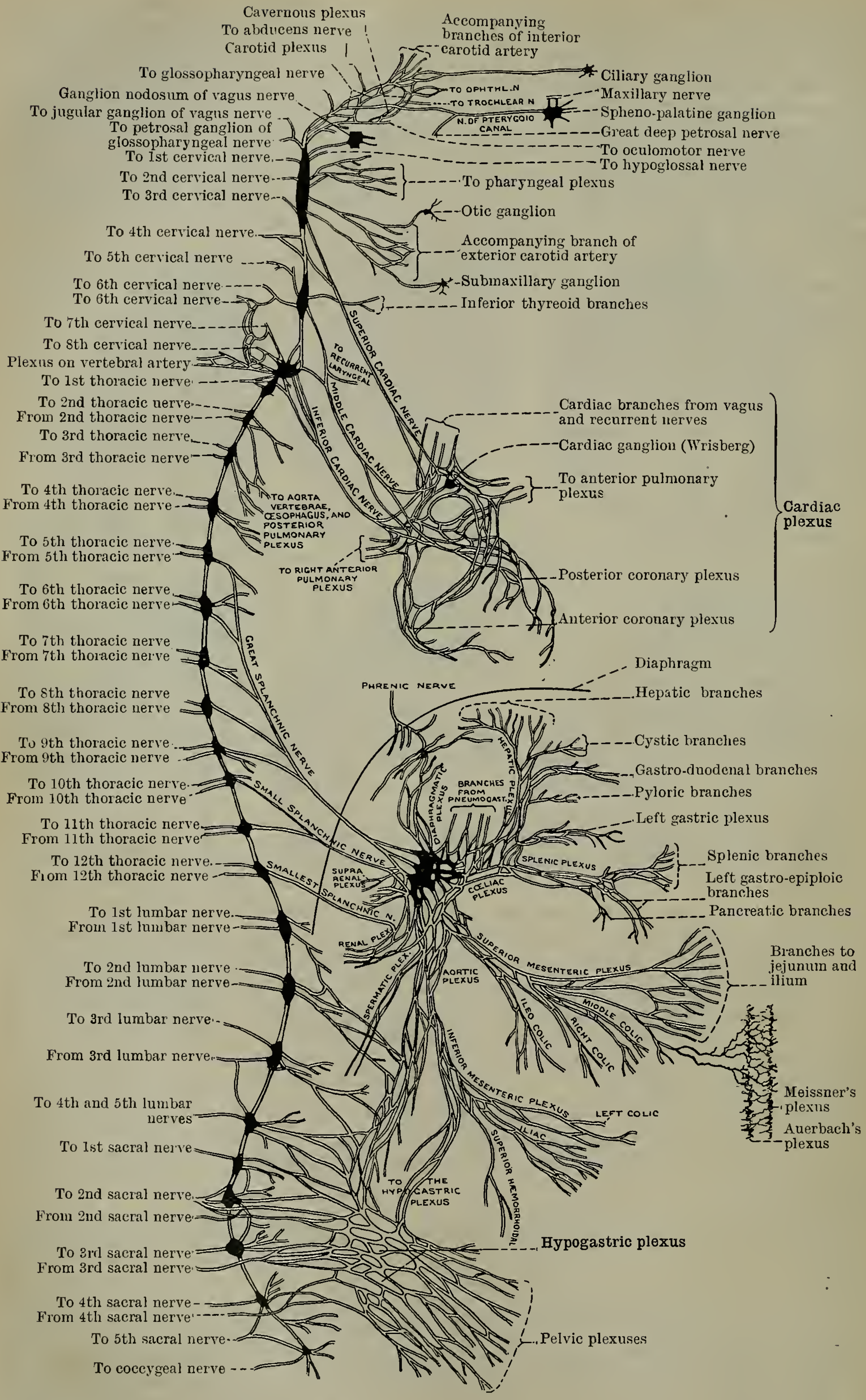


Fig. 628.—Plan of the Main Parts of the Sympathetic Nervous System. (After Flower, modified, with permission of Messrs. J. and A. Churchill.)

only from their relation to the gangliated trunks, but from the fact that in response to the action of certain drugs the cranio-sacral or parasympathetic groups of neurones agree with each other and differ from the thoracico-lumbar or sympathetic ones. The chief glands and viscera receive usually a double nerve supply, one from each class, and these are held to be physiologically antagonistic.

As a designation which would include both these groups of fibres, that is, to denote the sum total of all general visceral *efferent* neurones in the body, both preganglionic and postganglionic, and whether associated with cerebral or spinal nerves, the term **Autonomic Nervous System** was introduced by Langley. The name denotes the efferent nervous system of the glands and involuntary musculature throughout the whole body. It is a *functional* and not an anatomical subdivision of the nervous system, and it includes only *efferent* neurones. Its preganglionic neurones are partly included in the cerebro-spinal system, and the terminal parts of their fibres, together with the postganglionic neurones, lie in the sympathetic system as usually denoted. The afferent visceral fibres do not form part of the autonomic system, but are considered apart from their anatomical disposition as belonging to the cerebro-spinal peripheral nervous system.

Such functional differentiation of the neurones concerned with the innervation of involuntary musculature is generally accepted, but it appears probable that a further subdivision of the system is necessary to connote the nervous mechanism responsible for those purely local reflexes which are completed in the wall of the gastro-intestinal tract, since these so-called myenteric reflexes (possibly associated with the plexuses of Auerbach and Meissner) are described as occurring after section of all the nerves leading to the gut wall. For this mechanism the term "**enteric nervous system**" is sometimes used.

General Structure of the Sympathetic System.—The sympathetic system is composed of two elements—ganglia and nerve fibres.

(A) A **ganglion** consists of a larger or smaller number of nerve cells, almost all multipolar, though a few are unipolar or bipolar. Each cell is enclosed in a nucleated capsule of connective tissue, and is provided with one axon and a number of dendrites. Some of the dendrites ramify beneath the capsule, hence being termed intracapsular; they may form a network around the cell or be localised in the form of a glomerulus. Other dendrites are extracellular; they pierce the capsule and run throughout the ganglion, taking part in the formation of an intercellular plexus, and making contact with the capsules of other cells. This plexus is joined by the ramifications of the entering preganglionic fibres, some of which also pierce the capsules of cells to meet the intracapsular dendrites. One preganglionic fibre can in this way directly influence many ganglionic neurones, which explains the difference between the comparatively small number of fibres which enter a ganglion and the large number that leave it. There appears to be no evidence of commissural neurones or sensori-motor synapses between the ganglion cells. The axon of a ganglion cell (a postganglionic fibre) is usually unmyelinated, though it may be myelinated at its origin from the parent cell. It may enter into the composition of (*a*) a gray ramus communicans; (*b*) a peripheral branch from the sympathetic trunk or from a ganglion; or (*c*) a commissural cord, and emerge from the trunk at a higher or lower level. The ganglia may be classified as follows:—

(1) Those of the sympathetic trunks or **central ganglia** (*ganglia trunci sympathici*). These are variable in form and size, but are more or less segmental in position. They are always connected together by narrow cords formed by ascending and descending fibres, and in this way the gangliated trunks are formed. There are 21 or 22 ganglia in each trunk of which 3 are associated with the cervical nerves, 10 or 11 with the thoracic, 4 with the lumbar, and 4 with the sacral spinal nerves; the ganglion impar is common to both trunks. (2) The intermediate or **collateral ganglia** (*ganglia plexuum sympathicorum*), which are found in connexion with the great prevertebral plexuses. (3) The **terminal ganglia**, which lie in close relation to the endings of the nerves in the viscera.

(B) The **nerve-fibres** in the sympathetic system are of two classes, medullated and non-medullated, though the distinction is not absolute. Those fibres which enter it from the central nervous system (**preganglionic**) are medullated, but are rather smaller than the somatic efferent fibres. The fibres which arise from cells situated in the sympathetic ganglia (**postganglionic**) are nearly all non-medullated or only partially medullated; a few possess delicate sheaths. The nerve fibres are aggregated to form the white and gray rami communicantes, the commissural cords of the gangliated trunks, and the peripheral branches of the trunk and ganglia.

(i.) The **white rami communicantes** are all medullated fibres. They take origin from the anterior rami of certain spinal nerves in two streams: **thoracico-lumbar** from the first or second thoracic to the second lumbar nerve inclusive, and **pelvic**, or **sacral**, from the second and third, or third and fourth sacral nerves. The cervical nerves do not give off white rami; those of the pelvic group do not enter the gangliated trunk, but all the rest traverse this cord to reach their destination. The roots of these white rami communicantes arise from both posterior and anterior roots of the spinal nerves, but in largest numbers from the anterior root. The *fibres from the anterior root* are of very small size. They are the axons of nerve cells within the spinal medulla, which enter the sympathetic trunk through the white ramus, and end by forming arborisations around the cells of a sympathetic ganglion; they are therefore preganglionic in position. There are three known courses for such a fibre to take in relation to the sympathetic system: (*a*) It may end in the ganglion with which the ramus is immediately related; (*b*) it may course upwards or downwards in the connecting cord to reach a neighbouring ganglion; (*c*) it may pass beyond the sympathetic trunk to end in relation to cells of a peripheral (collateral) ganglion along with fibres of distribution from the sympathetic ganglia. These fibres are *splanchnic efferent fibres*; they contain motor fibres for the unstriped muscular tissue of the vessels and viscera, and secretory fibres for the glands in the splanchnic area. The *fibres from the posterior root* of the spinal nerve entering into the composition of the white ramus communicans are the axons of spinal ganglion cells. They constitute the *splanchnic afferent fibres*, and traverse the sympathetic gangliated trunk, passing upwards, downwards, and peripherally, without being connected with its cells. They are the sensory fibres from the viscera, with which they are associated along with the peripheral branches arising from the sympathetic trunk itself. It is not certain that fibres from the spinal ganglia are only found in connexion with nerves provided with distinct white rami. Similar medullated fibres are found also in the gray rami communicantes.

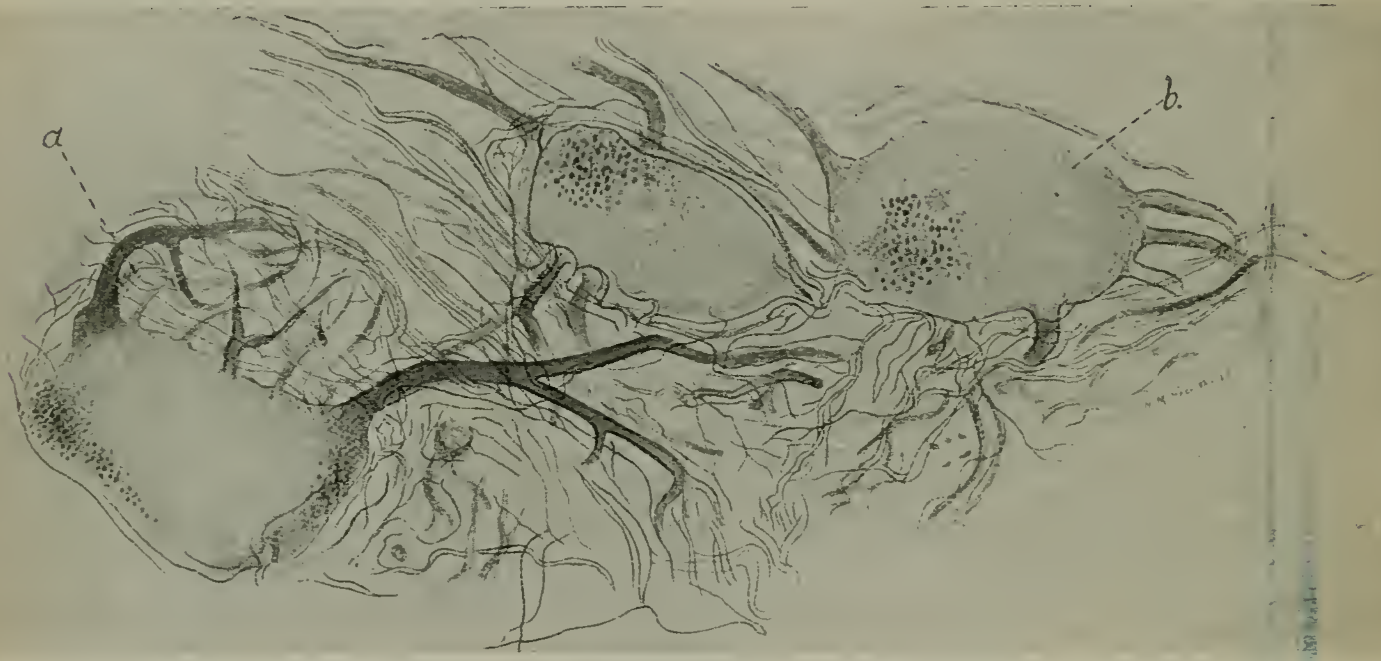


FIG. 629.—NERVE CELLS FROM THE HUMAN SUPERIOR CERVICAL GANGLION. (Ranson.)
a, Unicellular dendritic glomerulus. *b*, Cell provided only with extracapsular dendrites.
(Pyridine silver × 100.)

The **gray rami communicantes** form a series of non-medullated fibres (with a small number of medullated fibres intermingled) proceeding *from the ganglia to the spinal nerves*; they are therefore postganglionic in position. These gray rami are found in connexion with each and all of the spinal nerves. Their origin from the gangliated trunk is quite irregular: they may come from the ganglia or the commissure; they may divide after their origin, so that two spinal nerves are supplied from one ganglion; or two ganglia may supply branches to a single spinal nerve. The gray ramus is distributed along the somatic divisions of the spinal nerves, supplying branches to unstriped muscular fibres (vaso-motor, pilomotor) and glands (secretory). They also provide small recurrent branches, ending in the membranes enveloping the spinal nerve-roots. Mingled with the non-medullated fibres of the gray rami are a small number of medullated fibres, some of which may be regarded as afferent fibres—axons passing to the spinal ganglia which are incorporated with the gray rami.

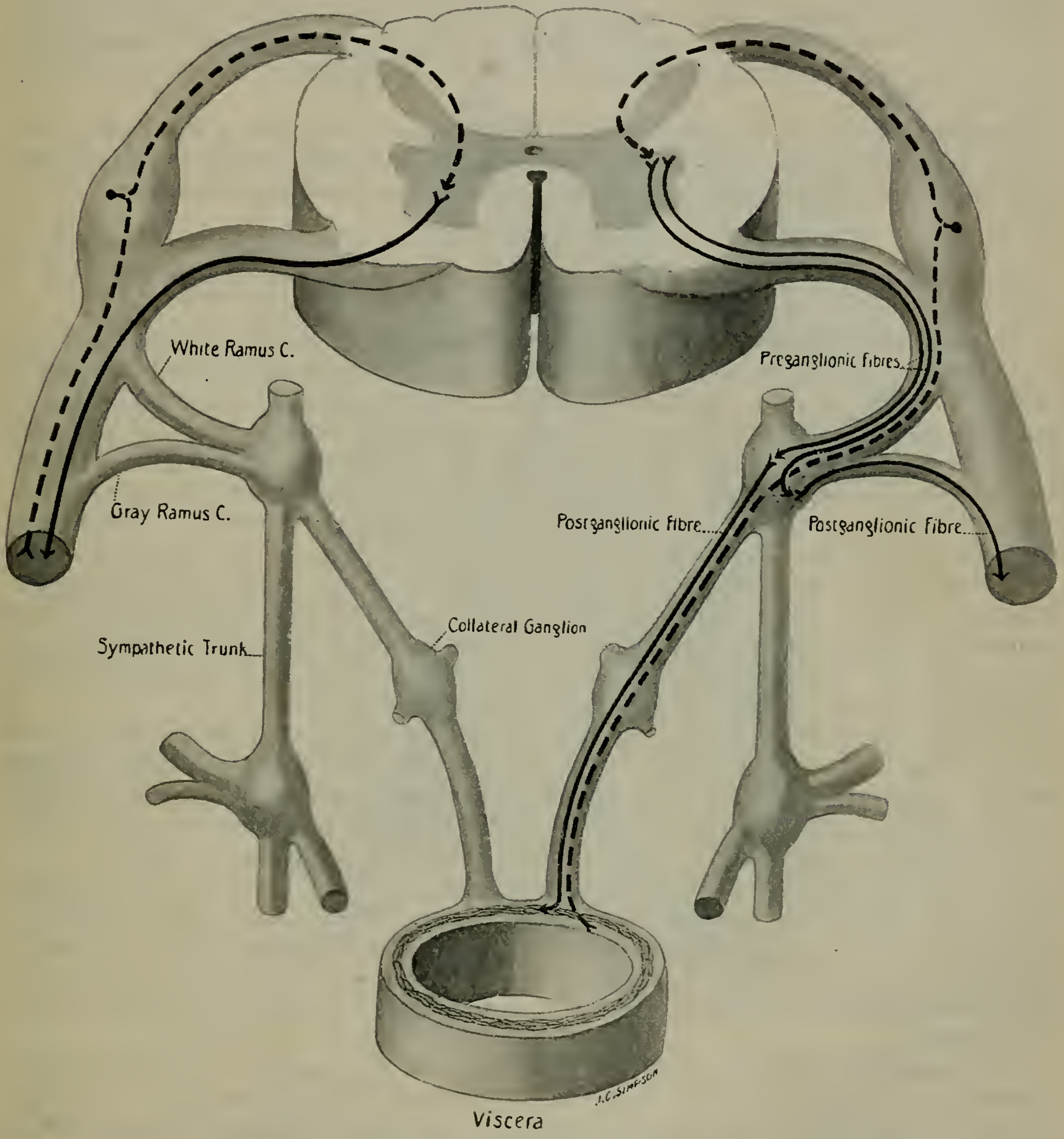


Fig. 630.—Scheme showing the Relation of the Sympathetic System to the Spinal Nerves and Medulla Spinalis.

The main splanchnic fibres are shown on the right side, and, for contrast, the somatic on the left. Afferent fibres are indicated by broken lines, efferent fibres by continuous ones.

(ii.) The **connecting cords** of the sympathetic system are composed of white and gray fibres. The *white fibres* are: (1) splanchnic efferent fibres, passing to a ganglion above or below the point of entrance into the sympathetic system; (2) splanchnic afferent fibres, guided along the connecting cord and over or through the ganglia. The *gray fibres* are the axons of sympathetic ganglion cells; like the white fibres, they may pass along the connecting cord for a certain distance upwards or downwards before entering the splanchnic area as peripheral branches. There is no evidence of a purely associative neurone uniting one ganglion of the trunk with another.

(iii.) The peripheral branches of the sympathetic trunk are likewise composed of white and gray fibres. (1) The *white fibres* may be either splanchnic afferent fibres on their way from the viscera through the gangliated trunk to the spinal ganglia, or splanchnic efferent fibres which, after traversing the gangliated trunk, without interruption (and being therefore still preganglionic in character) proceed to join and end in collateral or terminal ganglia in relation to viscera; (2) the *gray fibres* are postganglionic efferent branches, the axons of the ganglion cells, distributed on the one hand peripherally to the vessels and viscera of the splanchnic area, and on the other hand centrally through the gray rami communicantes and the somatic divisions of the spinal nerves, to the glands and involuntary muscles in the somatic area, as secretory, and vaso-motor and pilo-motor fibres.

Description of the Sympathetic System.—For convenience of description the gangliated trunks are dealt with first, in four regional parts, cephalic and cervical, thoracic, abdominal, and pelvic; and the great plexuses are described afterwards.

I. PARS CEPHALICA ET CERVICALIS SYSTEMATIS SYMPATHICI.

The **cephalic** and **cervical part of each sympathetic trunk** is to be regarded as an upward prolongation of the primitive sympathetic system along the great vessels of the neck into the head region. It is characterised by the absence of **segmental ganglia** and by the absence of **white rami communicantes** joining it to the spinal nerves. Its connexion with the spinal nervous system is through the white rami communicantes of the upper thoracic nerves, which join the gangliated trunk in the thorax, and stream upwards into the cervical portion of the trunk. Its branches are distributed to structures belonging to head, neck, and thorax: (1) motor fibres to involuntary muscles (*e.g.* dilator of the pupil); (2) vaso-motor fibres for arteries of the head, neck, and upper limbs; (3) pilo-motor fibres (along the cervical spinal nerves) to the skin of the head and neck; (4) cardio-motor fibres; and (5) secretory fibres (*e.g.*, submaxillary gland). No afferent fibres appear to be present in the cervical part of the trunk.

Each trunk extends from the root of the neck, where it is continuous, in front of the neck of the first rib, with the thoracic portion of the trunk, to the base of the skull, and thus constitutes the **cervical** part of the system. It is then continued upwards into the skull in the form of plexiform branches upon the internal carotid artery to join the **cephalic** part of the system (p. 782).

The **cervical part** of each sympathetic trunk is placed upon the prevertebral muscles and behind the carotid vessels. It consists of a narrow cord composed of medullated and non-medullated fibres, with two or three ganglia—a *superior* ganglion at the upper end, an *inferior* ganglion at the point of junction with the thoracic portion of the trunk, and a *middle* ganglion varying in position and often absent.

The **superior cervical ganglion** is situated at the base of the skull, and lies between the internal jugular vein and the internal carotid artery. It is the largest of the sympathetic ganglia, measuring an inch or more in length. It is thought to be formed by the coalescence of four ganglia corresponding with the upper four cervical nerves.

The **middle cervical ganglion** is of small size, is frequently absent, and may be divided into two parts, indicating ganglia corresponding to the fifth and sixth cervical nerves. It is usually placed in front of the inferior thyreoid artery as it passes behind the carotid sheath.

The **inferior cervical ganglion** is joined by the connecting cord to the middle (or superior) ganglion above, and is usually only imperfectly separated from the first thoracic ganglion below, the two when fused being sometimes called the *stellate ganglion.* It is of considerable size, irregular in shape, and is placed behind the first part of the vertebral artery in the interval between the last cervical transverse process and the neck of the first rib.

The **branches** from the cervical sympathetic ganglia and connecting cords are divisible into two sets—(*A*) **Central** communicating branches for other nerves; (*B*) **Peripheral** branches of distribution, which alone, or along with other nerves, form plexuses, accompanying and supplying vessels and viscera of the head, neck, and thorax. Although this distinction is made, it is to be borne in mind that the branches of communication are as much nerves of distribution as the others.

Ganglion Cervicale Superius.

Numerous branches arise from the ganglion. They are all composed of post-ganglionic fibres, and comprise vaso-motor, pilo-motor, and secretory fibres to certain cerebral and spinal nerves, vaso-motor fibres to the branches of the external and internal carotid arteries, and branches to the heart (accelerator) and pharynx.

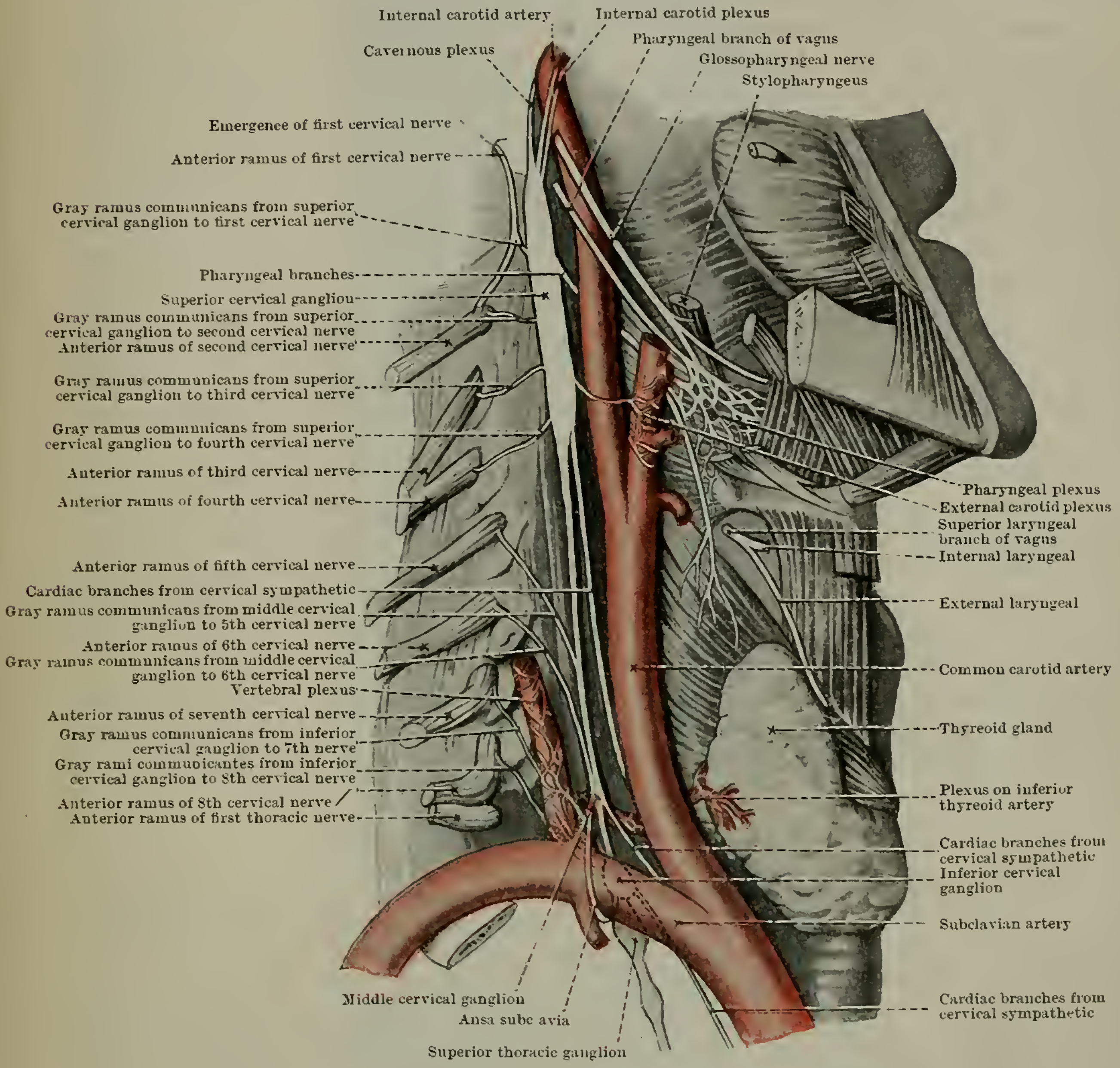

Internal carotid artery
Internal carotid plexus
Pharyngeal branch of vagus
Cavernous plexus
Glossopharyngeal nerve
Stylopharyngeus
Emergence of first cervical nerve
Anterior ramus of first cervical nerve
Gray ramus communicans from superior cervical ganglion to first cervical nerve
Pharyngeal branches
Superior cervical ganglion
Gray ramus communicans from superior cervical ganglion to second cervical nerve
Anterior ramus of second cervical nerve
Gray ramus communicans from superior cervical ganglion to third cervical nerve
Gray ramus communicans from superior cervical ganglion to fourth cervical nerve
Anterior ramus of third cervical nerve
Anterior ramus of fourth cervical nerve
Anterior ramus of fifth cervical nerve
Cardiac branches from cervical sympathetic
Gray ramus communicans from middle cervical ganglion to 5th cervical nerve
Anterior ramus of 6th cervical nerve
Gray ramus communicans from middle cervical ganglion to 6th cervical nerve
Vertebral plexus
Anterior ramus of seventh cervical nerve
Gray ramus communicans from inferior cervical ganglion to 7th nerve
Gray rami communicantes from inferior cervical ganglion to 8th cervical nerve
Anterior ramus of 8th cervical nerve
Anterior ramus of first thoracic nerve
Pharyngeal plexus
External carotid plexus
Superior laryngeal branch of vagus
Internal laryngeal
External laryngeal
Common carotid artery
Thyreoid gland
Plexus on inferior thyreoid artery
Cardiac branches from cervical sympathetic
Inferior cervical ganglion
Subclavian artery
Middle cervical ganglion
Ansa subclavia
Superior thoracic ganglion
Cardiac branches from cervical sympathetic

Fig. 631.—Distribution of the Sympathetic in the Neck.

Central Communicating Branches.—1. *Gray rami communicantes* pass from the ganglion to the anterior rami of the first four cervical nerves.

2. **Communications with Cerebral Nerves.**—Just outside the skull, in the deep part of the neck, communicating branches pass to the following cerebral nerves: (*a*) to both the petrous ganglion of the glossopharyngeal and the jugular ganglion of the vagus (the *jugular nerve*); (*b*) to the ganglion nodosum of the vagus; (*c*) to the hypoglossal nerve.

Peripheral Branches of Distribution.—1. **Pharynx.**—A **pharyngeal branch** passes behind the carotid sheath to reach the wall of the pharynx, where it joins (along with the pharyngeal branches of the glossopharyngeal and vagus nerves) in the formation of the **ascending pharyngeal plexus**, and assists in supplying the muscles and mucous membrane of the pharynx.

2. **Heart.**—The **superior cardiac** branch is a slender nerve which, on the *right side*, descends behind the large vessels, but usually in front of the inferior thyreoid artery, and enters the thorax either in front or behind the subclavian artery to join the deep cardiac plexus at the back of the aortic arch. On the *left side* the course of the nerve is similar in the neck, but in the superior mediastinum it passes between the left common carotid and subclavian arteries, and across the aortic arch, to join with the inferior cervical cardiac branch of the vagus in the formation of the **superficial** cardiac plexus. In their course both nerves form connexions with the other cardiac nerves of the sympathetic, and with cardiac and other branches of the vagus (recurrent and external laryngeal).

3. **Vessels.**—(*a*) The **external carotid branches** pass forwards to the external carotid artery, and form the **plexus caroticus externus (external carotid plexus)**, which supplies offsets to that artery and its branches, as well as to the **glomus caroticum** (O.T. **inter-carotid body**). From the subordinate plexuses on the external maxillary and middle meningeal branches of the artery sympathetic fibres are supplied to the submaxillary ganglion and otic ganglion, respectively.

(*b*) The **internal carotid branches** form an upward prolongation of the ganglion which applies itself in the form of bundles of nerve-fibres to the internal carotid artery as it enters the carotid canal in the temporal bone. The branches separate into lateral and medial parts, which form plexuses investing the artery in the cranium. The lateral division forms the inferior or internal **carotid plexus (pl. caroticus internus)**; the medial division gives rise to the superior or **cavernous plexus (pl. cavernosus).** Both plexuses supply offsets to the artery and its branches, and form communications with certain cerebral nerves.

The **internal carotid plexus** communicates by fine branches with (*a*) the abducent nerve, and (*b*) the semilunar ganglion, and gives off (*c*) the great deep petrosal and (*d*) the carotico-tympanic nerves. The **deep petrosal nerve** joins the greater superficial petrosal nerve from the genicular ganglion of the facial, in the foramen lacerum. By their union the **pterygoid nerve** is formed, which, after traversing the pterygoid canal, ends in the spheno-palatine ganglion. The **carotico-tympanic nerves** pass to the tympanic plexus.

The **cavernous plexus** communicates with (*a*) the oculo-motor, (*b*) the trochlear nerve, and (*c*) the ophthalmic division of the trigeminal nerve; it also (*d*) supplies twigs to the hypophysis (pituitary body), and (*e*) forms the sympathetic root of the ciliary ganglion.

CEPHALIC PART OF THE SYMPATHETIC SYSTEM.

The internal carotid nerve together with its plexuses may be considered as an upward extension of the gangliated trunk. Associated with its branches are four cephalic ganglia, the ciliary, otic, sphenopalatine, and submaxillary, comparable to the ganglia of the trunk, but more conveniently described from their closer anatomical disposition in connexion with the branches of the trigeminal nerve (see Fig. 628, p. 776 and note on p. 692). The carotid, cavernous, and tympanic plexuses, together with the above-named ganglia, and possibly with the addition of small parts of the genicular, petrosal, and jugular ganglia (since cell bodies of sympathetic neurones are found within them), form the main bulk of the cephalic part of the sympathetic system. The jugular nerve, passing from the superior cervical ganglion to the jugular ganglion of the vagus and the petrous ganglion of the glossopharyngeal, is to be considered an additional source of sympathetic fibres to this part of the system. The various branches and connexions of these ganglia and plexuses (*e.g.*, those of the otic ganglion, the tympanic plexus, and the petrosal nerves) are, again, more conveniently described in relation with the cerebral nerves.

GANGLION CERVICALE MEDIUM.

Gray Communicating Branches.—1. *Gray rami communicantes* arise from the ganglion or from the connecting cord, and join the anterior rami of the fifth and sixth cervical nerves. 2. The **ansa subclavia (Vieussenii)** is a loop of communication from this ganglion, which, after passing in front of and supplying offsets to the subclavian artery and its branches, joins the inferior cervical ganglion.

Peripheral Branches of Distribution.—1. **Heart.**—A **middle cardiac branch**, which may be the largest of the three cardiac nerves, descends, either separately or in company with other cardiac nerves, behind the large vessels into the thorax, where it ends in the deep part of the cardiac plexus on each side.

2. **Thyreoid Gland.**—Branches extend medially along the inferior thyreoid artery to supply the thyreoid gland.

When the middle ganglion is absent the branches described arise from the connecting cord.

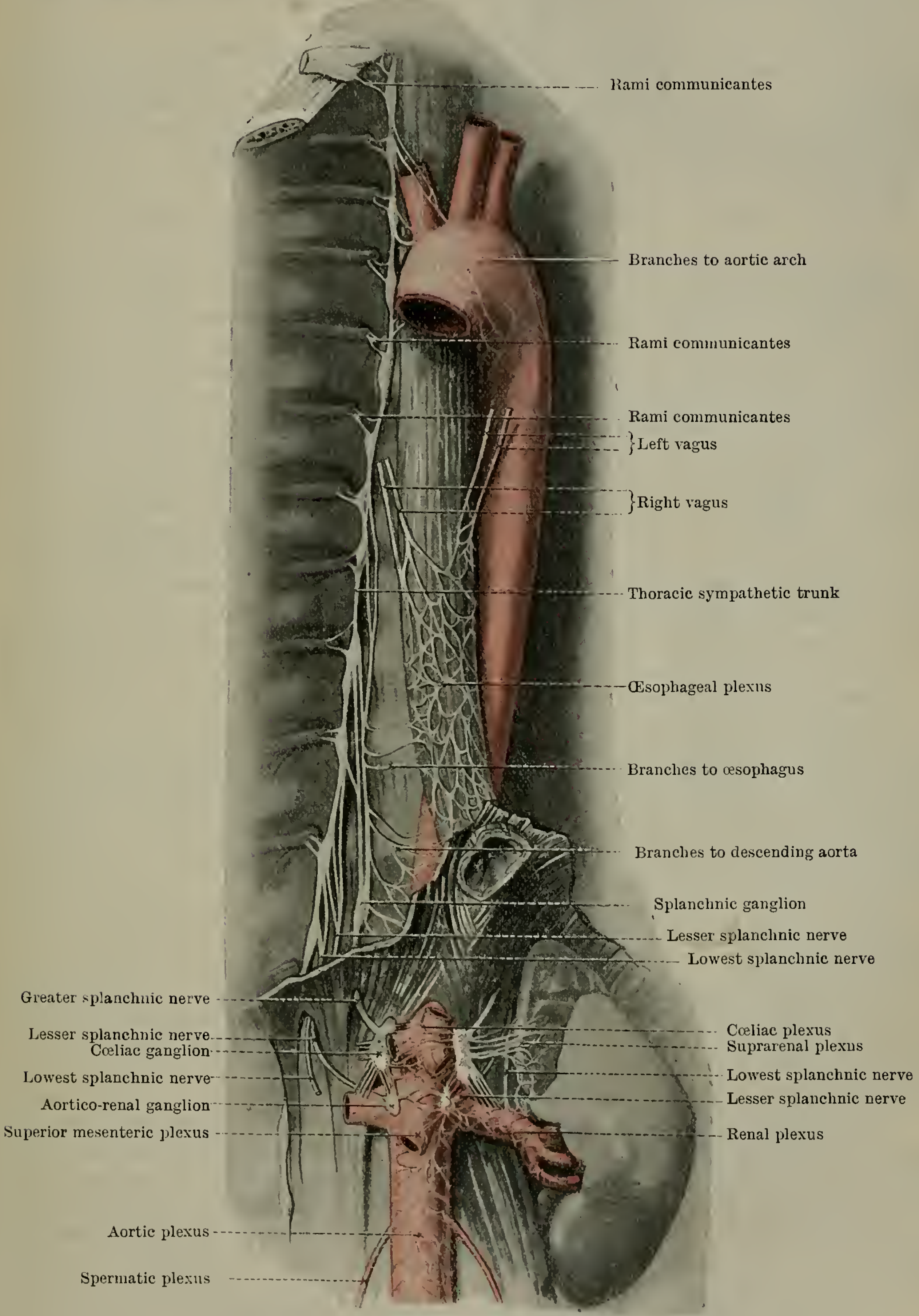


FIG. 632.—THE SYMPATHETIC TRUNK IN THE THORAX.

GANGLION CERVICALE INFERIUS.

Central Communicating Branches.—1. *Gray rami communicantes* arise from this ganglion for the anterior rami of the seventh and eighth cervical nerves.

2. The **ansa subclavia** already mentioned connects the middle and inferior ganglia over the front of the subclavian artery. 3. A communication frequently occurs with the **recurrent nerve.**

Peripheral Branches of Distribution.—1. **Heart.**—An **inferior cardiac branch** is given off on each side to enter the deep cardiac plexus. On the left side it is often blended with the middle cardiac nerve.

2. **Vessels.**—(*a*) The **vertebral plexus** is a dense plexus of fibres surrounding the vertebral artery and accompanying its branches in the neck and the cranial cavity. (*b*) The **subclavian plexus** is derived from the ansa subclavia (subclavian loop), and supplies small offsets to the subclavian artery. It gives branches to the **internal mammary artery**, and communicates with the **phrenic nerve.**

II. PARS THORACALIS SYSTEMATIS SYMPATHICI.

The **thoracic part of the sympathetic trunk** lies behind the pleura, in front of the necks of the first to the tenth ribs, and the intercostal vessels and nerves. It consists of a number of ganglia of an irregularly angular or fusiform shape, joined together by connecting bands of considerable thickness. The number of ganglia is usually ten or eleven; but the first—and sometimes others—may be so fused with the neighbouring ganglia as to reduce the number still further.

This part of the sympathetic trunk is characterised by its union with the thoracic spinal nerves. Each thoracic nerve, with the rare exception of the first, sends a **visceral branch** (white ramus communicans) to join the gangliated trunk in the thorax. These white rami separate into two main streams in relation to the sympathetic trunk. Those of the *upper five* nerves are for the most part directed upwards to be distributed through the cervical part of the sympathetic trunk in the manner already described. The white rami of the *lower thoracic* nerves are for the most part directed downwards in the inferior part of the sympathetic trunk and its branches, to be distributed in the abdomen; at the same time some of their fibres are directly supplied to certain thoracic viscera,—lungs, aorta, œsophagus.

These white rami are composed of (1) **splanchnic afferent fibres** passing from its peripheral branches through the sympathetic trunk into the ganglia of the spinal nerves—medullated nerve-fibres unconnected with sympathetic ganglion cells; and (2) **somatic** and **splanchnic efferent fibres**, small medullated nerves which, after a longer or shorter course in the gangliated trunk or its peripheral branches, become connected with the sympathetic ganglion cells, or with the cells of peripheral (collateral or terminal) ganglia, from which again (non-medullated) axons proceed to supply branches to viscera and vessels.

The peripheral branches supplying *thoracic organs* contain vaso-motor fibres for the lungs and aorta. The peripheral branches from the *lower* part of the sympathetic trunk in the thorax, receiving white rami from the lower thoracic nerves, are distributed mainly to structures below the diaphragm. They comprise (*a*) viscero-inhibitory fibres for the stomach and intestines; (*b*) motor fibres for part of the rectum; (*c*) pilo-motor fibres for the lower part of the body; (*d*) vaso-motor fibres for the abdominal aorta and its branches, and for the lower limbs; (*e*) secretory, and (*f*) sensory fibres for the abdominal viscera.

The **branches** from the gangliated trunk are, as in the neck, divisible into two sets—(*A*) Central branches, communicating with other nerves, and (*B*) peripheral branches, distributed in a plexiform manner to the thoracic and abdominal viscera.

(*A*) **Central Communicating Branches.**—The **white rami communicantes** from the thoracic nerves have already been described. Passing forwards from the anterior rami of the nerves, they become connected with the ganglia or the connecting cord of the sympathetic.

The **gray rami communicantes** are *branches* arising irregularly from each thoracic ganglion; passing backwards along with the white rami, they join the anterior rami of the thoracic nerves, and are distributed in a manner already described (p. 775).

(*B*) **Peripheral Branches of Distribution.**—These branches arise irregularly from the ganglia and the connecting cord. They are composed of non-medullated (splanchnic efferent) fibres derived from the ganglion cells, and medullated fibres (splanchnic efferent and afferent) derived directly from the white rami, without the intervention of the cells of the ganglia.

1. **Pulmonary Branches.**—From the gangliated trunk opposite the second, third, and fourth ganglia fine filaments arise which join the posterior pulmonary plexus.

2. **Aortic Branches.**—The upper part of the thoracic aorta receives fine branches from the upper five thoracic ganglia.

3. **Splanchnic Nerves.**—Three nerves arise from the inferior part of the gangliated trunk, partly from the ganglia themselves, and partly from the connecting cord between the ganglia. Actually they consist in greater part of fibres of the white rami which merely traverse the gangliated trunks on their way to their distribution. Passing downwards over the bodies of the thoracic vertebræ, they pierce the diaphragm, to end in the abdomen.

(*a*) The **greater splanchnic nerve** arises from the gangliated trunk between the fifth and ninth or tenth ganglia. By the union of several irregular strands a nerve of considerable size is formed, which descends in the posterior mediastinum, and piercing the crus of the diaphragm, joins at once the anterior end of the *cœliac ganglion.* In its course in the thorax the **splanchnic ganglion** is formed upon the nerve opposite the eleventh or twelfth thoracic vertebra; it is more prominent in the fœtus than in the adult. From both nerve and ganglion branches arise in the thorax, for the supply of the œsophagus and descending thoracic aorta (Fig. 632).

(*b*) The **lesser splanchnic nerve** arises from the gangliated trunk opposite to the ninth and tenth ganglia. It passes over the bodies of the lower thoracic vertebræ, pierces the diaphragm near or along with the greater splanchnic nerve, and ends in the **cœliac plexus** (*aortico-renal ganglion*).

(*c*) The **lowest splanchnic nerve** arises from the last thoracic ganglion of the sympathetic, or it may be a branch of the lesser splanchnic nerve. It pierces the diaphragm, and ends in the *renal plexus.* It is not always present.

III. PARS ABDOMINALIS SYSTEMATIS SYMPATHICI.

The **abdominal or lumbar part of the sympathetic trunk** is placed upon the bodies of the lumbar vertebræ, medial to the origins of the psoas major muscle, and in front of the lumbar vessels. It is connected with the thoracic portion of the trunk by an attenuated cord which either pierces or passes behind the diaphragm. It is continuous below with the pelvic portion of the trunk by means of a connecting cord, which passes behind the common iliac artery.

It is joined by medullated fibres (white rami communicantes) from the first two or three lumbar spinal nerves, and it contains, as well, medullated fibres continued down from the lower part of the thoracic sympathetic trunk, and derived from the visceral branches (white rami communicantes) of the lower thoracic nerves.

This part of the trunk is characterised by great irregularity in the number of the ganglia. They are usually four in number, but there are frequently more (up to eight); and in extreme cases fusion may occur to such an extent that the separation of individual ganglia becomes impossible.

1. **Central Communicating Branches.**—**White rami communicantes.**—Only the first two (or three) lumbar spinal nerves send visceral branches (white rami communicantes) to the upper lumbar ganglia or to the sympathetic trunk. These nerves form the lower limit of the thoracic-lumbar visceral branches of the spinal nerves. They comprise vaso-motor fibres (for the genital organs), and motor fibres for the bladder and uterus.

Gray rami communicantes pass from the gangliated trunk to the anterior rami of the lumbar nerves in an irregular manner. One ramus may divide so as to supply branches to two adjacent spinal nerves; or one spinal nerve may be joined by several (two to five) gray rami from the sympathetic trunk.

The rami course deep to the origin of the psoas major muscle and over the bodies of the vertebræ. Gray rami sometimes pierce the fibres of the psoas muscle.

2. **Peripheral Branches of Distribution.**—From the lumbar sympathetic trunk numbers of small branches arise irregularly, and supply the abdominal aorta, reinforcing the **aortic plexus** (derived from the cœliac plexus).

IV. PARS PELVINA SYSTEMATIS SYMPATHICI.

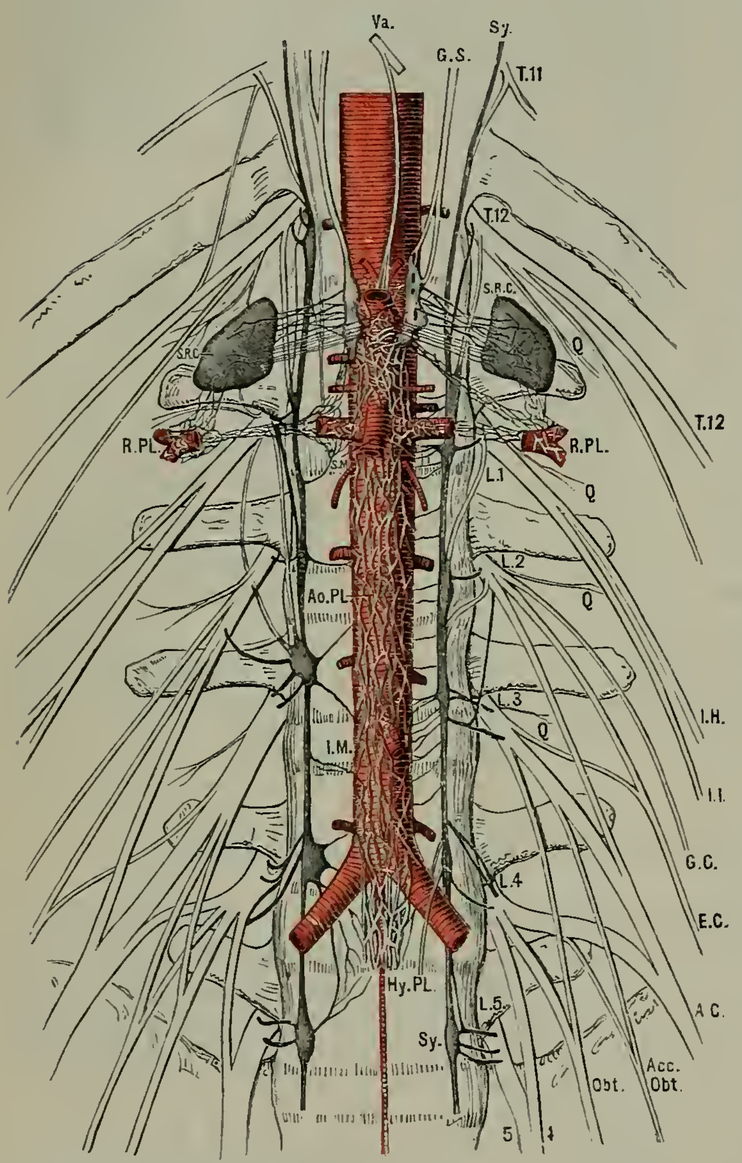


FIG. 633.—THE LUMBAR PORTION OF THE SYMPATHETIC GANGLIATED TRUNK AND LUMBAR PLEXUS. (From a dissection.)

T.11, T.12, L.1, L.2, L.3, L.4, L.5, Anterior rami of spinal nerves, with white and gray rami communicantes.

Sy., Sympathetic trunk; Va., Vagus nerve; G.S., Greater splanchnic nerve, joining cœliac ganglion; S.R.C., Suprarenal gland and plexus; R.Pl., Renal plexus; Ao.Pl., Aortic plexus; S.M., Superior mesenteric plexus; I.M., Inferior mesenteric plexus; Hy.Pl., Hypogastric plexus; Q., Nerves to quadratus lumborum; I.H., Ilio-hypogastric nerve; I.I., Ilio-inguinal nerve; G.C., Genito-femoral nerve; E.C., Lateral cutaneous nerve; A.C., Femoral nerve; Acc. Obt., Accessory obturator nerve; Obt., Obturator nerve; 4, 5, Lumbo-sacral trunk.

The **pelvic** or **sacral part of the sympathetic trunk,** like the cervical and lower abdominal portions of this system, receives no *white rami communicantes* from the spinal nerves. The **visceral branches** (*pelvic splanchnic*) of the third sacral nerve, and usually, also, the second or fourth sacral nerve, enter the **pelvic plexus** without being directly connected with the sympathetic trunk. These nerves, however, are to be regarded as homologous with the white rami communicantes of the thoracico-lumbar nerves (*abdominal splanchnic*).[1] They convey to the pelvic viscera—(1) motor and inhibitory fibres for rectum, uterus, and bladder, (2) vaso-dilator fibres for the genital organs, and (3) secretory fibres for the prostate gland.

This portion of the sympathetic trunk is placed on the pelvic surface of the sacrum, medial to the anterior sacral foramina. It is connected above by a cord with the abdominal portion of the sympathetic, and below it ends in a plexiform union over the coccyx with the trunk of the other side, the two being frequently connected by the **ganglion impar or coccygeal ganglion.** The number of ganglia is variable; there are commonly four. They are of small size, gradually diminishing from above downwards.

Gray communicating branches arise irregularly in the form of **gray rami communicantes** from the sacral ganglia, which join the anterior rami of the sacral and coccygeal nerves.

Peripheral Branches of Distribution.—(1) **Visceral branches** of small size arise from the upper part of the pelvic sympathetic trunk, and join the **pelvic plexus** (see below).

(2) **Parietal branches,** also of small size, ramify over the front of the sacrum, and form, in relation to the middle sacral artery, a plexiform union with branches from the sympathetic trunk of the other side.

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[1] These pelvic splanchnic nerves form the sacral part of the cranio-sacral or **parasympathetic** system referred to in the note on p. 775.

PLEXUS SYMPATHICI.

The **smaller plexuses** associated with the branches of the cervical sympathetic ganglia, namely, the carotid and cavernous, the external carotid, pharyngeal, thyreoid, vertebral and subclavian plexuses, have been described above.

The **pulmonary** and **œsophageal** plexuses, though receiving branches from the thoracic ganglia, are described with the vagus nerve, since it contributes much more to their formation.

There remain the great **prevertebral plexuses** situated in the thorax, abdomen, and pelvis, and named the **cardiac, cœliac, hypogastric,** and **pelvic** plexuses; each of these main networks is continued on into a large number of subsidiary smaller plexuses.

Plexus Cardiacus.

The cardiac branches of both sympathetic trunks combine with the cervical and thoracic cardiac branches of both vagus nerves to form the **cardiac plexus.** This is situated at the base of the heart, and is divided into a superficial and a deep part.

The **superficial cardiac plexus** is placed in the hollow of the aortic arch, superficial to the pericardium. It usually contains a small ganglion (**cardiac ganglion of Wrisberg**), situated on the right side of the ligamentum arteriosum, and is joined by two small nerves—(1) the cardiac branch from the superior cervical ganglion of the sympathetic, and (2) the inferior cervical cardiac branch of the vagus—both of the left side—which reach it after passing over the arch of the aorta.

Branches and **Communications.**—From the plexus branches of communication pass (1) to the left half of the **deep cardiac plexus**, between the aortic arch and the bifurcation of the pulmonary artery; (2) to the left **anterior pulmonary plexus** along the left branch of the pulmonary artery; (3) the branches of distribution to the heart extend along the pulmonary artery to join the **anterior (right) coronary plexus**, which supplies the substance of the heart in the course of the right coronary artery.

The **deep cardiac plexus** is much larger. It is placed behind the arch of the aorta, on the sides of the trachea, just above its bifurcation. It consists of two lateral parts, joined together by numerous communications around the termination of the trachea. The two portions of the plexus are different in their constitution and distribution. The *right half* of the plexus is joined by both the cervical and thoracic branches of the right vagus and by the branches of the right recurrent nerve, as well as by branches from the superior, middle, and inferior cervical ganglia of the sympathetic. The *left half* of the plexus is joined by the upper cervical cardiac branch of the left vagus, by branches from the left recurrent nerve, and by branches from the middle and inferior cervical ganglia of the left sympathetic; it also receives a contribution from the superficial cardiac plexus. In other words, all the cardiac branches both from the vagi and cervical sympathetic ganglia of the two sides combine to form the deep cardiac plexus, save only the cardiac branch of the left superior sympathetic ganglion and the lower cervical cardiac branch of the left vagus, which form the superficial plexus (see Fig. 634).

The deep cardiac plexus is distributed to the heart and lungs. The *right half* of the plexus for the most part constitutes the **right** or **anterior coronary plexus**, reaching the heart alongside the ascending aorta, and is distributed to the heart substance in the course of the right coronary artery. It is reinforced by fibres from the superficial cardiac plexus, which reach the heart along the pulmonary artery. Fibres from the right half of the deep cardiac plexus pass also to join the **posterior coronary plexus**, and others extend laterally to join the **anterior pulmonary plexus** of the right side.

The *left half* of the deep cardiac plexus, reinforced by fibres from the superficial cardiac plexus, is distributed to the heart in the form of the **left** or **posterior coronary plexus**, which is joined by a few fibres behind the pulmonary artery from the right half of the plexus, and supplies the heart substance in the course of the left coronary artery. The left half of the plexus contributes also to the **left anterior pulmonary plexus** by fibres which extend laterally to the root of the lung along the left branch of the pulmonary artery.

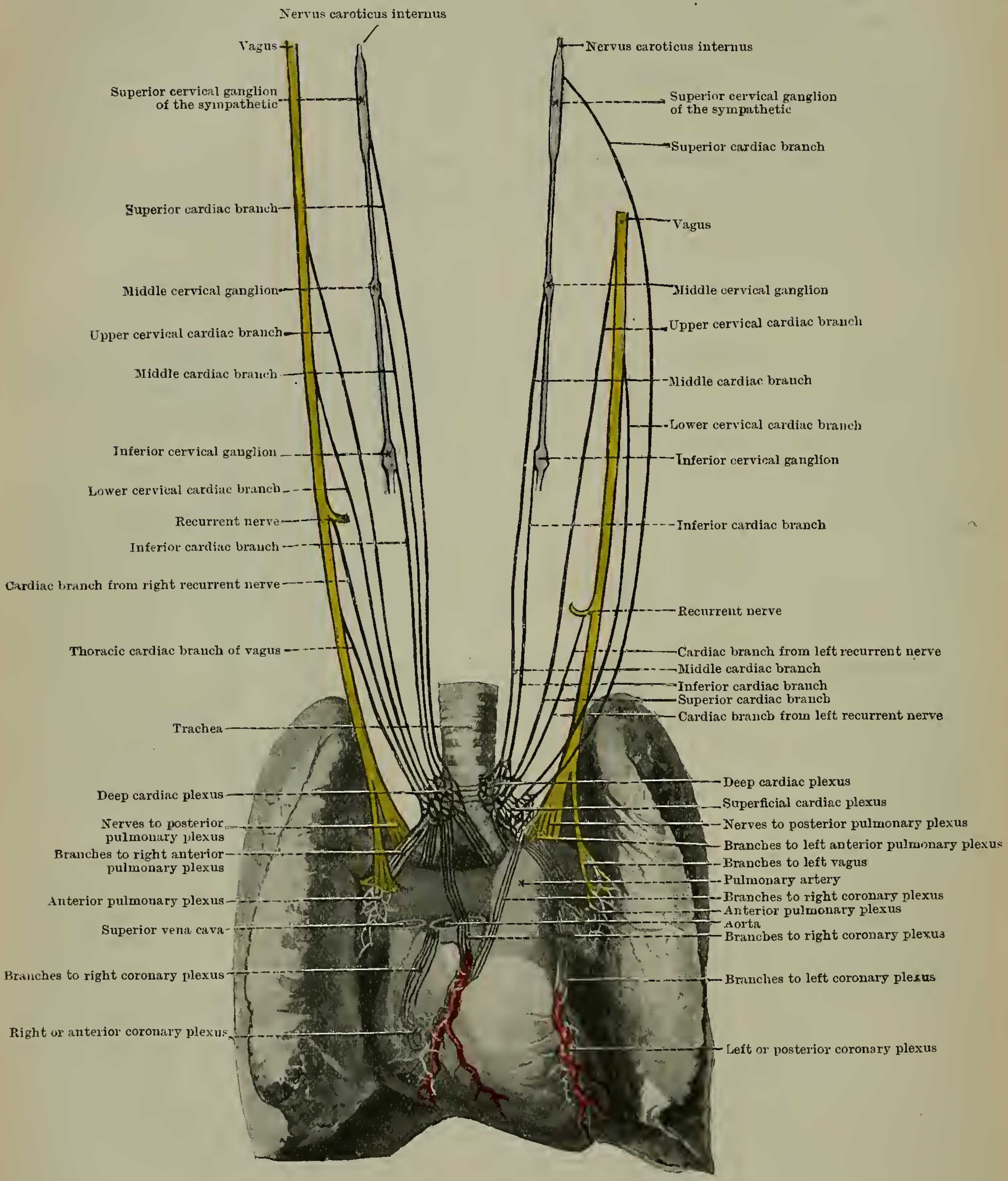
Nervus caroticus internus
Vagus
Superior cervical ganglion of the sympathetic
Superior cardiac branch
Middle cervical ganglion
Upper cervical cardiac branch
Middle cardiac branch
Inferior cervical ganglion
Lower cervical cardiac branch
Recurrent nerve
Inferior cardiac branch
Cardiac branch from right recurrent nerve
Thoracic cardiac branch of vagus
Trachea
Deep cardiac plexus
Nerves to posterior pulmonary plexus
Branches to right anterior pulmonary plexus
Anterior pulmonary plexus
Superior vena cava
Branches to right coronary plexus
Right or anterior coronary plexus
Nervus caroticus internus
Superior cervical ganglion of the sympathetic
Superior cardiac branch
Vagus
Middle cervical ganglion
Upper cervical cardiac branch
Middle cardiac branch
Lower cervical cardiac branch
Inferior cervical ganglion
Inferior cardiac branch
Recurrent nerve
Cardiac branch from left recurrent nerve
Middle cardiac branch
Inferior cardiac branch
Superior cardiac branch
Cardiac branch from left recurrent nerve
Deep cardiac plexus
Superficial cardiac plexus
Nerves to posterior pulmonary plexus
Branches to left anterior pulmonary plexus
Branches to left vagus
Pulmonary artery
Branches to right coronary plexus
Anterior pulmonary plexus
Aorta
Branches to right coronary plexus
Branches to left coronary plexus
Left or posterior coronary plexus

Fig. 634.—The Cardiac Branches of the Vagus and the Pulmonary Plexuses.

The pulmonary plexuses are described on p. 703 in connexion with the vagus nerve.

THE CŒLIAC AND PELVIC PLEXUSES.

These great plexuses serve to distribute nerves to the viscera and vessels of the abdominal and pelvic cavities. Taken together they include three plexuses—the cœliac plexus, the hypogastric plexus, and the pelvic plexus, which are associated in the main with the aorta and the hypogastric arteries, whilst their numerous extensions form subsidiary plexuses which invest and are generally named after the branches of these vessels. They are constituted by peripheral branches of the lower thoracic, abdominal, and upper pelvic parts of the sympathetic trunk; and they are related to the central nervous system by means of the visceral branches (white rami communicantes) of the lower thoracic and upper lumbar nerves on the one hand, and by the visceral branches of the second and third, or third and fourth sacral nerves, on the other hand. The thoracico-lumbar series join the sympathetic trunk, and reach the cœliac plexus mainly through the splanchnic nerves, and to a lesser extent through the abdominal part of the sympathetic trunk The sacral series enter the pelvic plexus without connexion with the sympathetic trunk. The hypogastric plexus serves as a connecting link between the cœliac and pelvic plexuses.

Plexus Cœliacus.

The **cœliac** or **solar plexus**, the largest of the prevertebral plexuses, lies on the posterior abdominal wall in relation to the abdominal aorta and behind the stomach. It is composed of three elements: the **cœliac plexus** surrounding the origin of the cœliac artery, between the crura of the diaphragm; and two **cœliac ganglia**, each lying on the corresponding crus of the diaphragm, and overlapped by the suprarenal gland, and on the right side by the inferior vena cava. The plexus is continuous with subordinate plexuses, diaphragmatic, suprarenal, renal, and superior mesenteric. It is continued downwards into the aortic plexus, which, by means of the **hypogastric nerves**, is connected with the **hypogastric plexus**, which again forms the chief origin of the **pelvic plexuses**.

The **cœliac ganglia** constitute the chief ganglionic centres in the cœliac plexus. They are irregular in form. They are often partially subdivided, and one detached portion at the lower end is named the **aortico-renal ganglion**. Other small scattered masses of cells are present in the cœliac plexus. At the upper end the cœliac ganglion receives the *greater splanchnic nerve*. The aortico-renal ganglion at its lower end receives the *lesser splanchnic nerve*. Branches from the ganglion radiate in all directions—medially to join the cœliac plexus, upwards to form the diaphragmatic plexus, laterally to the suprarenal plexus, downward to the renal, superior mesenteric, and aortic plexuses.

The **cœliac plexus** forms a considerable plexiform mass surrounding the cœliac artery. It consists of a dense meshwork of fibres with ganglia intermingled, joined by numerous branches from the cœliac ganglion on each side, and by branches from the right vagus nerve. It is continuous below with the superior mesenteric and aortic plexuses. Investing the cœliac artery, it forms subsidiary plexuses which are distributed along the branches of the artery. The **left gastric plexus** supplies branches to the œsophagus and stomach; the **hepatic plexus** supplies branches to the liver and gall-bladder, stomach, duodenum, and pancreas; and the **splenic plexus** sends offsets to the spleen, pancreas, and stomach.

Subordinate plexuses are formed on the aorta and its branches by nerves derived from the cœliac ganglia and cœliac plexus.

(*a*) The **phrenic plexus** consists of fibres arising from the cœliac ganglion, and it accompanies the inferior phrenic artery. Besides supplying the diaphragm, it gives branches to the suprarenal plexus, and—on the right side to the inferior vena cava—on the left side to the œsophagus. It communicates on each side with the phrenic nerve. At the junction of the plexus and the phrenic nerve of the right side a ganglion is formed (**phrenic ganglion**).

(*b*) The **suprarenal plexus** is of considerable size. It is mainly derived from branches of the cœliac ganglion, reinforced by nerves from the inferior part of the cœliac plexus which stream laterally on the suprarenal arteries. It is joined by branches from the phrenic plexus above and from the renal plexus below. The nerves enter the substance of the suprarenal gland.

(*c*) The **renal plexus** is derived from (1) branches of the cœliac ganglion, and

(2) fibres from the aortic plexus, extending laterally along the renal artery to the hilum of the kidney. It receives also the lowest splanchnic nerve, and is connected by numerous branches to the suprarenal plexus.

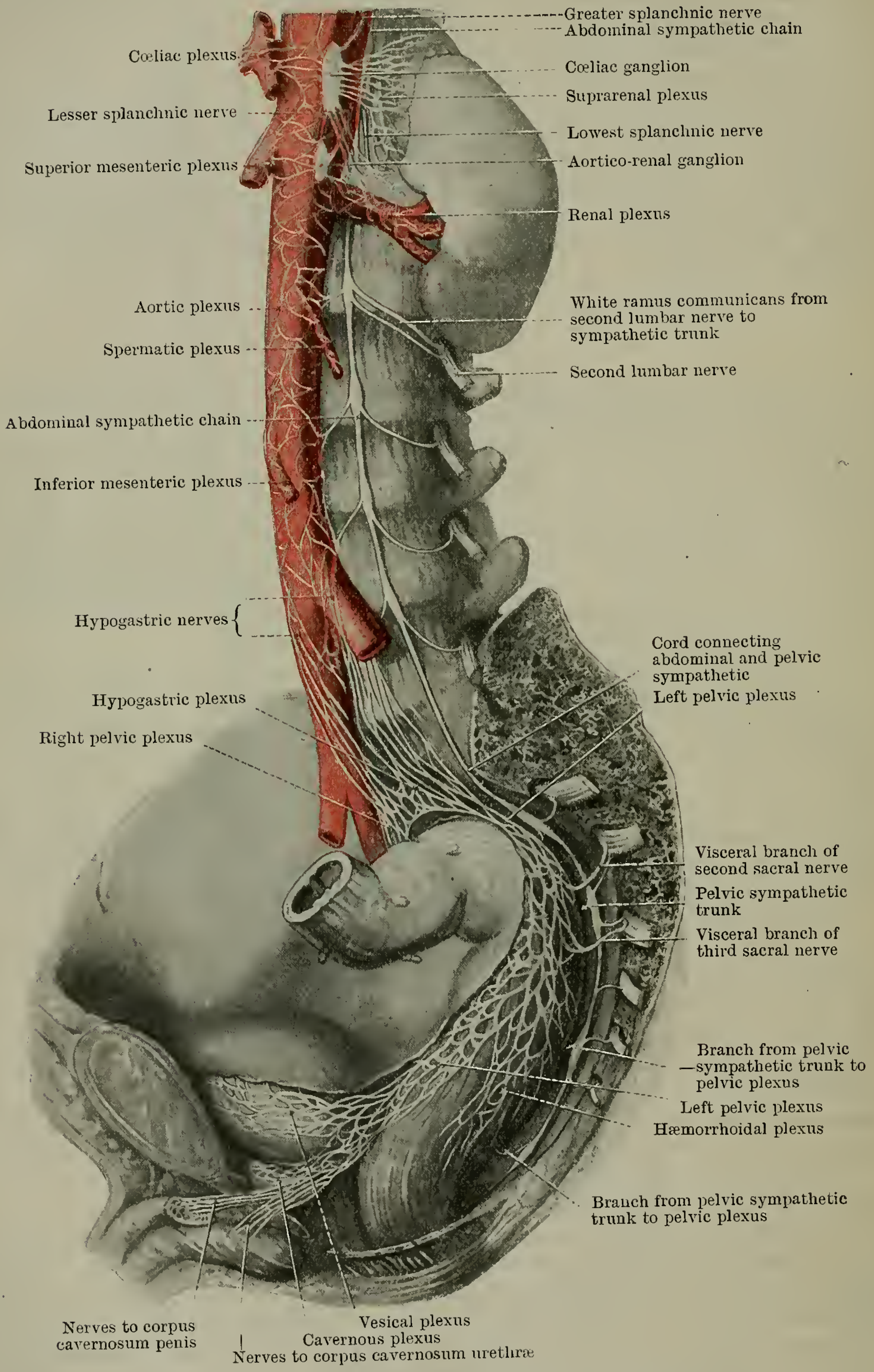
Greater splanchnic nerve
Abdominal sympathetic chain
Cœliac plexus
Cœliac ganglion
Suprarenal plexus
Lesser splanchnic nerve
Lowest splanchnic nerve
Superior mesenteric plexus
Aortico-renal ganglion
Renal plexus
Aortic plexus
White ramus communicans from second lumbar nerve to sympathetic trunk
Spermatic plexus
Second lumbar nerve
Abdominal sympathetic chain
Inferior mesenteric plexus
Hypogastric nerves
Cord connecting abdominal and pelvic sympathetic
Left pelvic plexus
Hypogastric plexus
Right pelvic plexus
Visceral branch of second sacral nerve
Pelvic sympathetic trunk
Visceral branch of third sacral nerve
Branch from pelvic —sympathetic trunk to pelvic plexus
Left pelvic plexus
Hæmorrhoidal plexus
Branch from pelvic sympathetic trunk to pelvic plexus
Nerves to corpus cavernosum penis
Vesical plexus
Cavernous plexus
Nerves to corpus cavernosum urethræ

Fig. 635.—The Sympathetic in the Abdomen and Pelvis.

(*d*) The **superior mesenteric plexus** is inseparable above from the cœliac plexus, and is joined on each side by fibres from the cœliac and aortico-renal ganglia. It is continuous below with the aortic plexus. A separate detached ganglionic mass (**superior mesenteric ganglion**) is present in the plexus. Accompanying the superior mesenteric artery it forms subordinate plexuses around the branches of the vessel. The plexuses at first surround the intestinal arteries, but near the intestine they form fine plexuses between the layers of the mesentery, from which branches pass to the wall of the gut. This plexus supplies the small intestine, cæcum, vermiform process, ascending and transverse portions of the colon.

(*e*) The **aortic plexus** is the continuation of the cœliac plexus downwards around the abdominal aorta. It is continuous above with the cœliac and superior mesenteric plexuses; it is reinforced by the peripheral branches of the lumbar sympathetic trunk; and it is connected with the hypogastric plexus below by the **hypogastric nerves**. Besides investing and supplying the aorta, the plexus is connected with various subordinate plexuses on the branches of the artery. It contributes to the suprarenal and renal plexuses, and it gives rise to the spermatic or ovarian, and the inferior mesenteric plexuses.

The **spermatic plexus** invests and accompanies the spermatic artery. It is derived from the aortic plexus, and receives a contribution from the renal plexus. It supplies the spermatic cord and testis.

The **plexus of the ovarian artery** in the female arises like the spermatic plexus. It accompanies the ovarian artery to the pelvis, and supplies the ovary, broad ligament, and uterine tube. It forms communications in the broad ligament with the **uterine plexus** (from the pelvic plexus), and sends fibres to the uterus.

The **inferior mesenteric plexus** is a derivative from the aortic plexus, prolonged along the inferior mesenteric artery. It forms subordinate plexuses on the branches of the artery (colic, sigmoid, and superior hæmorrhoidal), and is distributed to the descending colon, iliac colon, pelvic colon, and upper part of the rectum.

PLEXUS PELVINI.

The **hypogastric nerves** form the continuation of the aortic plexus into the pelvic cavity. They consist of numerous plexiform bundles of nerve-fibres which descend along the front and back of the bifurcation of the aorta and the origin of the common iliac arteries, and over the sacral promontory, where, becoming inextricably mingled, they constitute the hypogastric plexus.

The **hypogastric plexus** is continued downwards in front of the sacrum on each side of the rectum, and ends in the pelvic plexuses.

The **pelvic plexuses** are formed by the separation of the hypogastric plexus into two halves at the sides of the rectum. Each is joined by fibres from the upper portion of the pelvic part of the sympathetic trunk, and by the **visceral or pelvic splanchnic branches** (white rami communicantes) from the second and third or third and fourth sacral nerves. Accompanying the hypogastric artery and its branches, each pelvic plexus gives off subordinate plexuses for the pelvic viscera.

(*a*) The **hæmorrhoidal plexus** supplies the rectum, and joins the superior hæmorrhoidal plexus from the inferior mesenteric plexus.

(*b*) The **vesical plexus** accompanies the vesical arteries to the bladder-wall. Besides supplying the muscular wall and mucous membrane of the bladder, it forms subordinate plexuses for the lower part of the ureter, the vesicula seminalis, and the ductus deferens.

(*c*) The **prostatic plexus** is of considerable size. It is placed on both sides of the gland, and, in addition to supplying its substance and the prostatic urethra, it sends offsets to the neck of the bladder and the vesicula seminalis. It is continued forwards on each side to form the **plexus cavernosus penis (cavernous plexus of the penis)**. Bundles of nerves pierce the layers of the fascia of the urogenital diaphragm, and, after supplying the membranous urethra, give off branches which enter and supply the corpus cavernosum penis. The cavernous nerves communicate with branches of the pudendal nerve and give offsets to the corpus cavernosum urethræ and the penile portion of the urethra.

(*d*) The **uterine plexus** passes upwards with the uterine artery between the layers of the broad ligament, and is distributed to the surfaces and substance of the organ. It communicates between the layers of the broad ligament with the plexus of the ovarian artery.

The **vaginal plexus** is formed mainly by the visceral branches of the sacral nerves entering the pelvic plexus. It supplies the wall and mucous membrane of the vagina and urethra, and provides a **cavernous plexus** for the clitoris. The uterine and vaginal plexuses of the female correspond to the prostatic plexus of the male.

DEVELOPMENT OF THE SYMPATHETIC NERVOUS SYSTEM.

Though primarily developed from cells which arise in the neural crest, the ganglia of the sympathetic system also contain cells which, in the trunk region at least, are derived from the neural tube. Embryologically, then, the sympathetic ganglia, plexuses, and nerves have a common origin with the remainder of the peripheral nervous system, and differ from it only in that the sympathetic cells have wandered farther from their place of origin than have those of the cerebro-spinal nerves.

When the neural tube detaches itself from the general ectodermal covering of the embryonic body, the neural crest becomes divided into right and left crests, each of which migrates ventro-laterally into the space between the neural tube and the myotomes. These crests extend continuously on each side from the caudal end of the neural tube forwards to the auditory vesicle.

In the **spinal region** each crest becomes segmented into primitive ganglia, which contain not only the primordia of the spinal ganglia but also cells destined for the sympathetic and chromaffin systems. From the ventral border of these primitive spinal ganglia the sympathetic neuroblasts detach themselves and individually migrate outwards along the paths of the developing dorsal roots of the spinal nerves. Meanwhile other cells have wandered out along the ventral roots from the neural tube to join the cells of neural-crest origin. Once the cells from each of these sources have mingled it is impossible to distinguish between them, nor is it possible to state precisely what part each plays in the subsequent development of the sympathetic system. Leaving the spinal nerves, these errant cells migrate into the neighbourhood of the aorta, where by rapid proliferation they form compact masses which fuse from segment to segment and produce a continuous longitudinal cord, the **gangliated trunk.**

In the meantime, from the dorsal and ventral roots of the spinal nerves, centrifugal fibres grow out along the path previously followed by the cells. Somewhat later centripetal fibres are pushed out from the sympathetic trunk to join the spinal nerve trunk. The centrifugal fibres become myelinated and form the **white rami communicantes**, whilst the centripetal ones remain unmyelinated and form the **gray rami.** With the development of commissural fibres, the segmental character of the sympathetic trunks becomes evident throughout the thoracic and abdominal regions; the condensations which result in the three cervical ganglionic masses are also apparent.

The cells which form the ganglia of the **prevertebral plexuses** have the same origin as have those of the gangliated trunks, differing only in that, instead of stopping in the neighbourhood of the aorta, they have migrated onwards in the loose mesoderm to come into closer relationship with the structures they supply. The cells of terminal plexuses, on the contrary, though arising from the neural crest, do not make any connexion with the gangliated trunk; those of the cardiac, pulmonary, and greater part of the enteric plexuses migrate along the vagus nerve, whilst those of the enteric plexus in the terminal part of the digestive tube travel along the lumbar and sacral nerves.

In the **head region** the sympathetic ganglia are not segmentally arranged, though, just as in the spinal region, they are developed primarily from cells which arise in the neural crest and migrate outwards through the cerebro-spinal ganglia on their way to the periphery. Moreover, just as the ganglia of the sympathetic trunk are connected with one another by commissural fibres, so are the cranial ganglia connected with one another and with the gangliated trunk by means of the plexuses along the internal carotid artery. The four small **cephalic sympathetic ganglia** arise from cells the majority of which are developed in connexion with the semilunar ganglion, though there are probably added to these ganglia some few cells of either oculo-motor, facial, or glossopharyngeal origin.

The **ciliary ganglion** receives the majority of its cells from the semilunar ganglion by way of the ophthalmic nerve, but a few are contributed *via* the oculo-motor nerve.

The **sphenopalatine ganglion** is also derived mainly from the semilunar, its cells migrating along the maxillary nerve. The earliest cells, however, advance peripherally along the greater superficial petrosal branch of the facial nerve.

The **otic ganglion** arises from cells which migrate along the lesser superficial petrosal nerve from the petrosal ganglion, but it also receives some from the semilunar ganglion through the mandibular nerve.

The **submaxillary ganglion** arises from cells which have migrated along the mandibular and lingual nerves, but probably also derives some cells from the facial by way of the chorda tympani nerve.

ORGANA SENSUUM ET INTEGUMENTUM COMMUNE.

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ORGANA SENSUUM.

The **organs of the senses** constitute the apparatus by which man is made acquainted with his surroundings.

Every sense-organ consists of (*a*) a peripheral or receptive portion, where impulses are generated in response to external stimuli, (*b*) an intermediate or conductive part, along which the impulses are conveyed, and (*c*) a central or perceptive portion, where they are collected and transformed into sensations. The intermediate and central parts have been described in the section on the Nervous System; the peripheral parts form the subject matter of this chapter, and may be grouped under two headings:—(1) those connected with the *special senses* of smell, sight, hearing, and taste, and located in the nose, eye, ear, and mouth, respectively; and (2) those of *general sensations* (the muscular sense, and the senses of pressure, heat, cold, and pain), which are widely distributed throughout the body.

ORGANON OLFACTUS.

The nose is the peripheral **olfactory organ** and consists of the nasus externus, which projects from the face, and the cavum nasi, which is divided by a vertical septum into right and left chambers.

Nasus Externus.—The **external nose** is a more or less triangular pyramid, of which the upper angle or **root** is usually separated from the forehead by a depression, while the **base**, directed downwards, is perforated by two elliptical orifices, the **nares** or **nostrils**, which are separated from one another by a median septum. The free angle is named the **apex**; and the anterior border, joining root and apex, the **dorsum**; the upper part of the dorsum is supported by the nasal bones, and is termed the **bridge**. Each side of the nose forms an open angle (*naso-facial angle*) with the cheek, and ends below in a rounded eminence, the **ala nasi**, the free edge of which forms the lateral boundary of the corresponding naris; the ala nasi is limited above by a furrow, the **alar sulcus**. Over the root of the nose the skin is thin and movable, but over the apex and alæ it is thick and adherent, and contains numerous large sebaceous glands.

The external nose receives its blood-supply from the external maxillary and ophthalmic arteries; its veins open into the anterior facial vein and also communicate with the ophthalmic vein. Its principal lymph-vessels follow the course of the anterior facial vein and open into the submaxillary lymph-glands,—but from the root of the nose one or two lymph-vessels run lateralwards in the upper eyelid and end in the upper anterior auricular lymph-glands, and a third group runs below the orbit to the lower anterior auricular lymph-glands. The muscles of the external nose are supplied by the facial nerve, and the skin covering it is supplied by the infra-trochlear and naso-ciliary branches of the ophthalmic nerve and the infra-orbital branch of the maxillary nerve.

CARTILAGINES NASI.

Five chief cartilages are concerned in the formation of the nose; they are the lateral and greater alar cartilages on either side, and the cartilage of the septum.

Cartilago Nasi Lateralis.—The **lateral cartilage** (Figs. 637, 638) is triangular in shape and is situated immediately below the nasal bone. Its posterior edge is thin and is attached to the maxilla and to the nasal bone by fibrous tissue. Its anterior edge is thick; its upper part is directly continuous with the cartilage of the septum, but its lower part is separated from this cartilage by a narrow fissure. Its lower edge is joined, by fibrous tissue, to the upper margin of the greater alar cartilage.

Cartilago Alaris Major.—The **greater alar cartilage** (Figs. 636, 637, 638) encircles the anterior part of the nostril and assists in keeping it open. It consists of a lateral and a medial crus, which unite in a rounded angle at the apex of the nose. The **lateral crus** is oval in outline and is attached to the lateral cartilage and to the maxilla by fibrous tissue. Above and behind it two or three *lesser alar cartilages* are embedded in the fibrous tissue. The inferior edge of the lateral crus does not descend as far as the opening of the nostril, the lower part of the ala nasi being devoid of cartilage, and composed of fatty and connective tissue covered with skin. The **medial crus** (Fig. 639) bounds the medial wall of the nostril and lies in the septum mobile nasi below the cartilage of the septum, and in contact with the medial crus of the opposite greater alar cartilage. The medial crura of the greater alar cartilages are separated, in front, by a notch which corresponds with the apex of the nose.

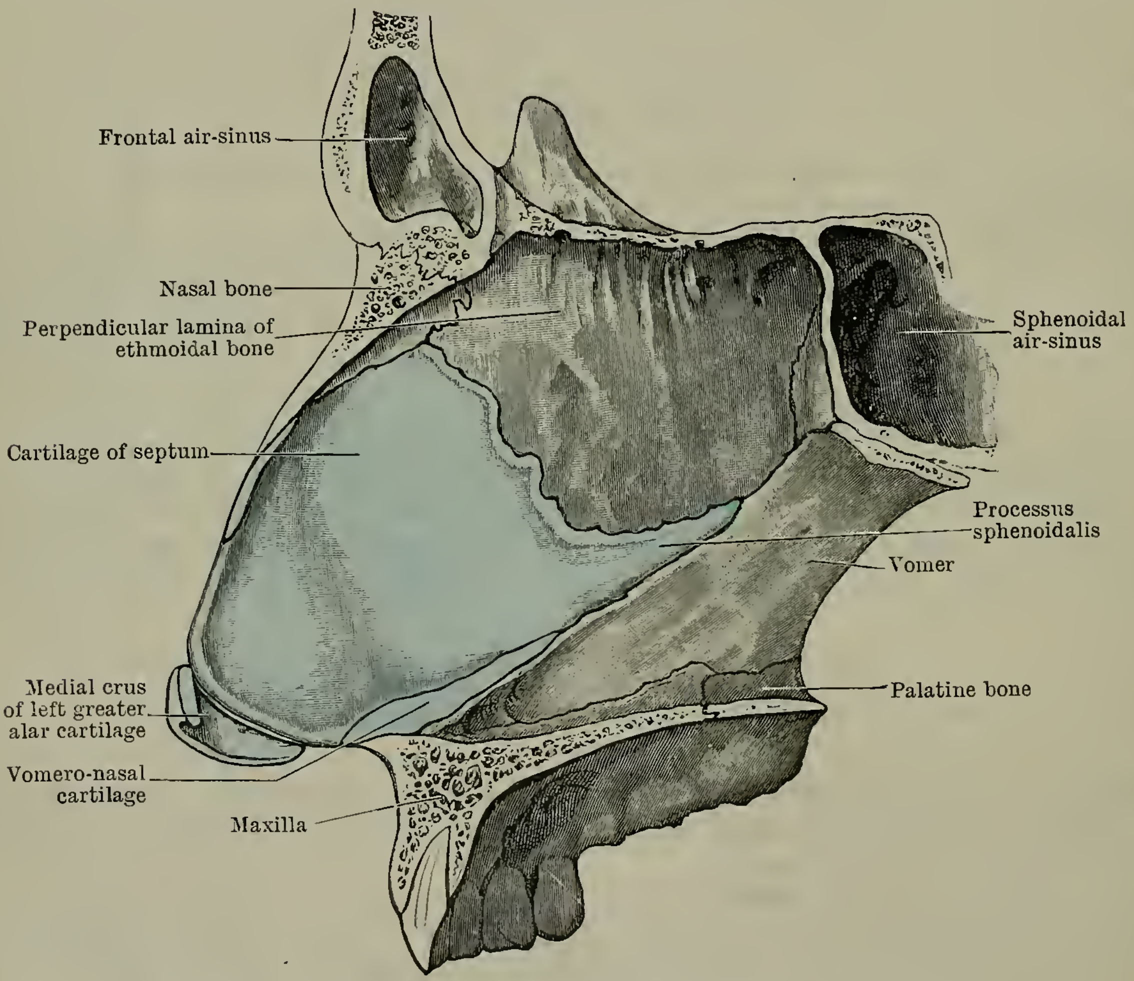

FIG. 636.—VIEW OF THE NASAL SEPTUM FROM THE LEFT SIDE.

Cartilago Septi Nasi.—The **cartilage of the septum** (Fig. 636) is of an irregularly quadrilateral form. Its postero-superior edge is attached to the perpendicular lamina of the ethmoidal bone; its postero-inferior margin to the vomer and to the nasal crests of the maxillæ. Its antero-superior border is thick, and is fixed above to the back of the internasal suture; immediately below this suture it is directly continuous with the upper parts of the lateral cartilages, which may be looked upon as its wing-like expansions. The lower part of each lateral cartilage is separated from the cartilage of the septum by a fissure which is filled by fibrous tissue; in this fibrous tissue a small accessory cartilage is usually seen. The antero-inferior border of the cartilage of the septum is short, and is attached by fibrous tissue to the medial crura of the greater alar cartilages; its anterior angle is rounded and does not reach as far as the apex of the nose. The cartilage of the septum may be prolonged backwards (especially in children) as a narrow process, the **processus sphenoidalis**, into the angle between the vomer and the ethmoidal bone.

On either side of the postero-inferior edge of the cartilage of the septum, there is a narrow band of cartilage, the **vomero-nasal cartilage** (Fig. 636); it is attached to the vomer, and is best seen in a frontal section of the nose.

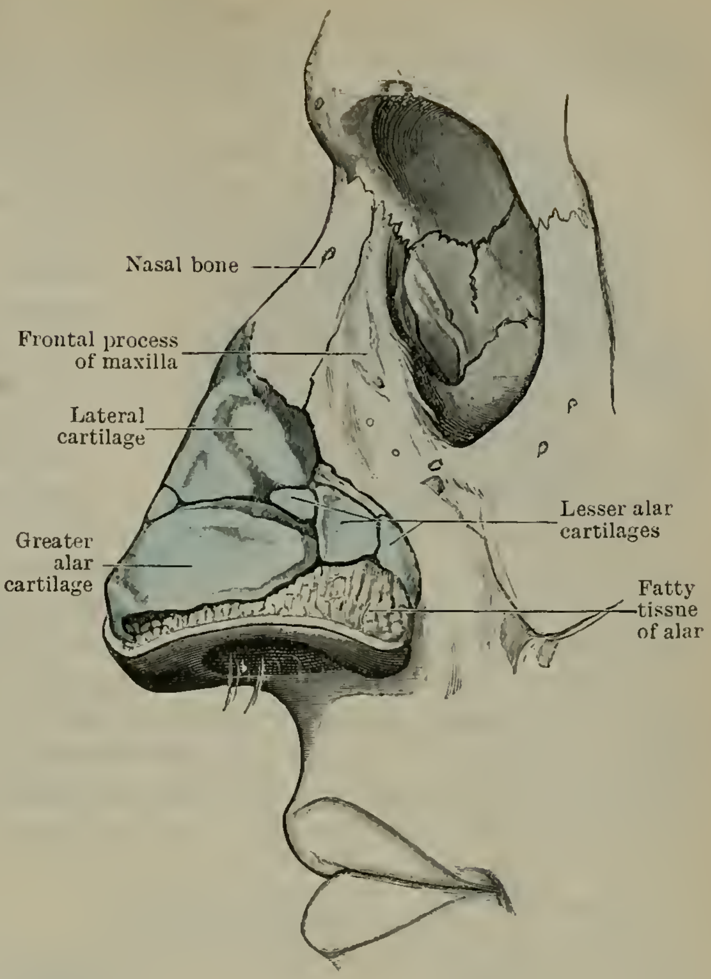

Fig. 637.—Profile View of the Bony and Cartilaginous Skeleton of the External Nose.

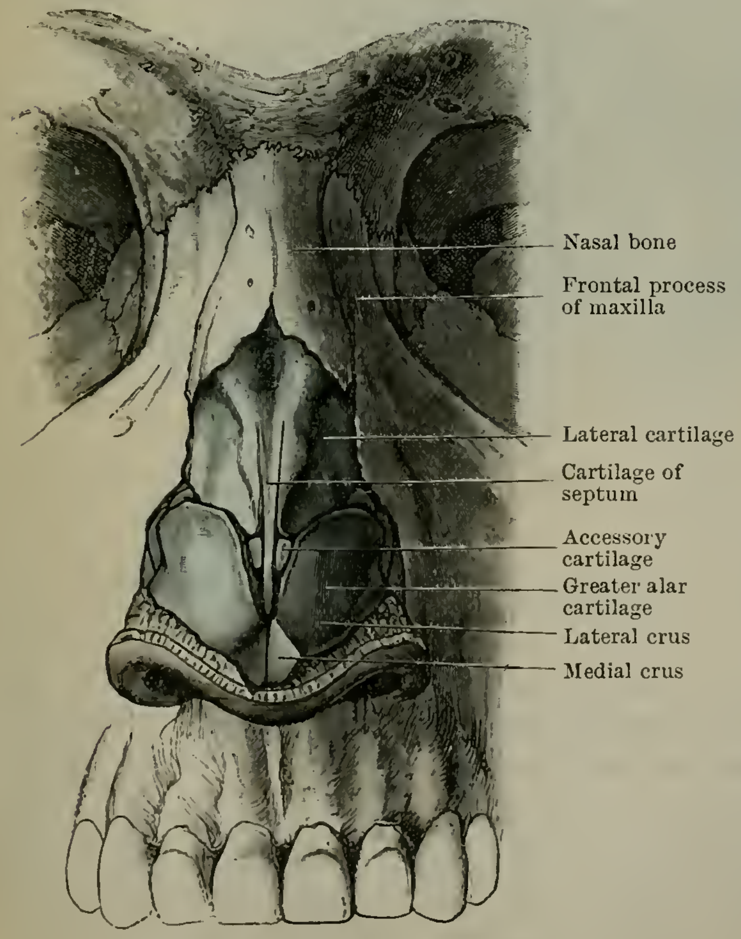

Fig. 638.—Front View of the Bony and Cartilaginous Skeleton of the External Nose.

The lowest part of the nasal septum is not formed by the septal cartilage, but by the medial crura of the greater alar cartilages and by the skin, and, being freely movable, is termed the **septum mobile nasi.**

CAVUM NASI.

The **nasal cavity** (Fig. 640) is divided by the nasal septum into a right and a left cavity; these extend from the nares or nostrils in front to the choanæ behind, and open, through the latter, into the nasal part of the pharnyx. On the lateral wall of each cavity are the orifices of the frontal, ethmoidal, sphenoidal, and maxillary air-sinuses, and the orifice of the naso-lacrimal duct.

Immediately above the naris there is a slightly expanded area, the **vestibule**, which is bounded laterally by the lateral crus of the greater alar cartilage, and medially by the lower part of the septum. It is lined with skin, and is prolonged as a small recess towards the apex of the nose. The vestibule is partly subdivided by a curved ridge; and, in its lower part, there are hairs and sebaceous glands, the hairs being curved downwards to guard the entrance to the nostril; the upper part is smooth, and is limited superiorly by a slightly marked arched prominence, the **limen nasi**, which is caused by the lower edge of the lateral cartilage.

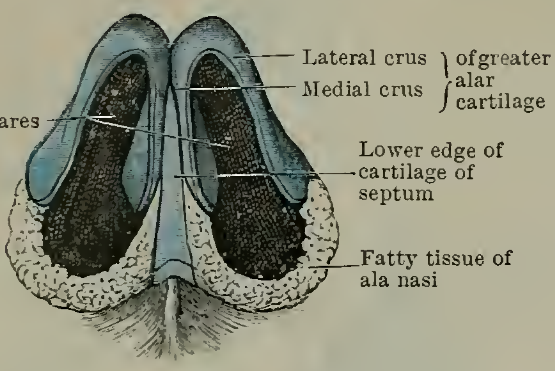

Fig. 639.—Cartilages of Nose from below.

Each nasal cavity is divided into a superior or olfactory, and an inferior or respiratory region. The **olfactory region**, to which alone the olfactory nerves are distributed, is a narrow slit-like space, and comprises the anterior part of the superior nasal concha and the corresponding portion of the septum nasi. The **respiratory region** includes the rest of the cavity.

Septum Nasi (Fig. 636).—The septum nasi consists of a bony and a cartilaginous part. The bony part is formed, in front, by the frontal spine, and the crest of the nasal bones; in the middle, by the lamina perpendicularis of the ethmoidal bone; behind, by the vomer and by the rostrum of the sphenoidal bone; below, by the nasal crests of the maxillæ and palatine bones. The bony part is deficient below and in front, and the gap is filled by the septal cartilage (p. 794). In the septum nasi, a little above and in front of the naso-palatine recess, is a minute orifice, not always recognisable, from which a blind pouch, the **vomero-nasal organ of Jacobson**, extends upwards and backwards for a distance of from 2 to 9 mm., and is supported by the vomero-nasal cartilage. In man the vomero-nasal organ is rudimentary, but in many of the lower animals it is well developed (Fig. 641), and is lined with epithelium similar to that covering the olfactory region, and supplied by branches of the olfactory nerve.

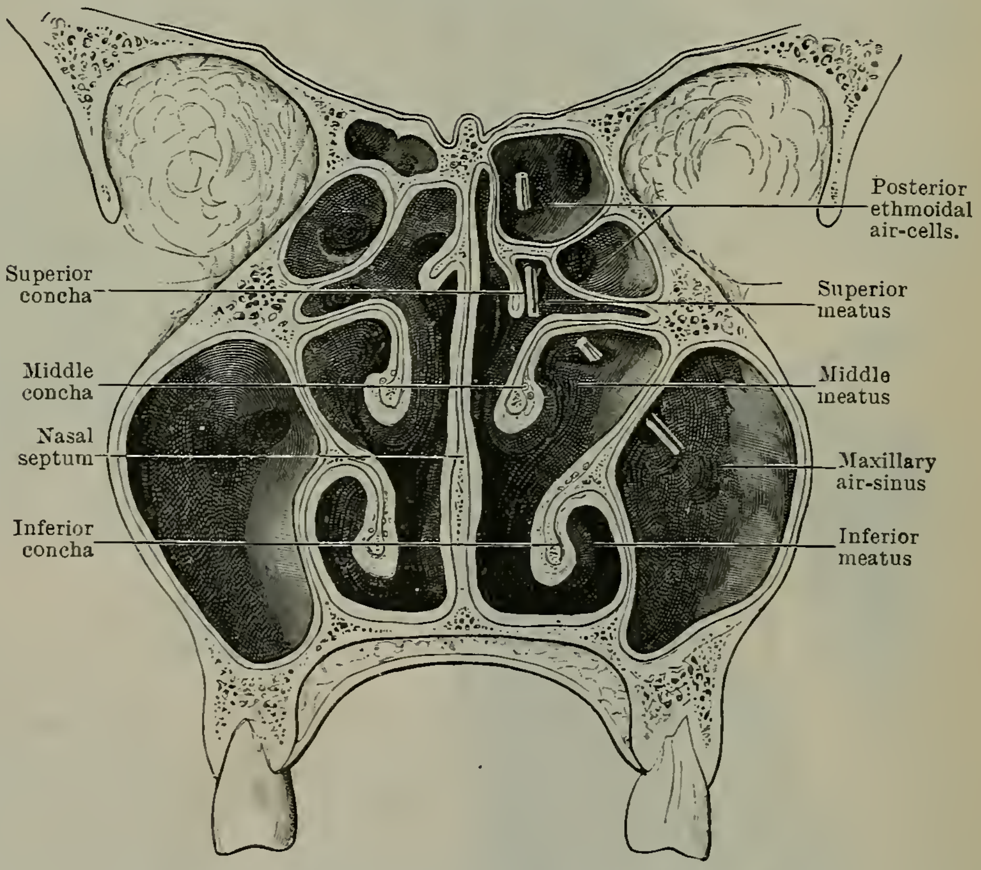

Fig. 640.—Frontal Section through the Nasal Cavities; Anterior Half of Section viewed from behind.

Until the seventh year of life the nasal septum lies, as a rule, in the median plane, but after this age it is very often bent to one or other side—more frequently to the right—the deflection being greatest usually along the line of junction of the vomer with the perpendicular lamina of the ethmoidal bone. Deflection of the septum is more common in European than in non-European skulls—occurring in about 53 per cent. of the former and in about 28 per cent. of the latter (Zuckerkandl). Associated with, or apart from, this deviation, crests or spurs of bone are found, projecting from the septum into one or other nasal cavity, in about 20 per cent. of skulls.

Lateral Wall (Fig. 642).—In the lateral wall of the nasal cavity, above the superior nasal concha, there is a narrow recess, the **recessus sphenoethmoidalis**, into the posterior part of which the sphenoidal air-sinus opens. The **superior meatus** of the nose is a short oblique fissure, below and lateral to the superior nasal concha; the posterior ethmoidal air-cells open into this meatus by one or more orifices. A small meatus, bounded superiorly by a concha suprema, frequently exists above the superior meatus.

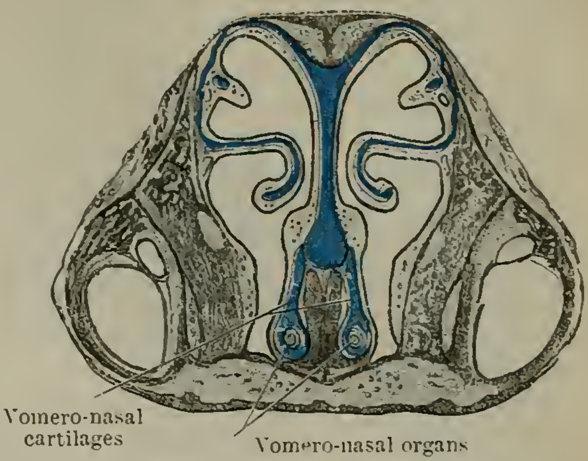

Fig. 641.—Section through Nose of a Kitten, showing position of the vomero-nasal organs.

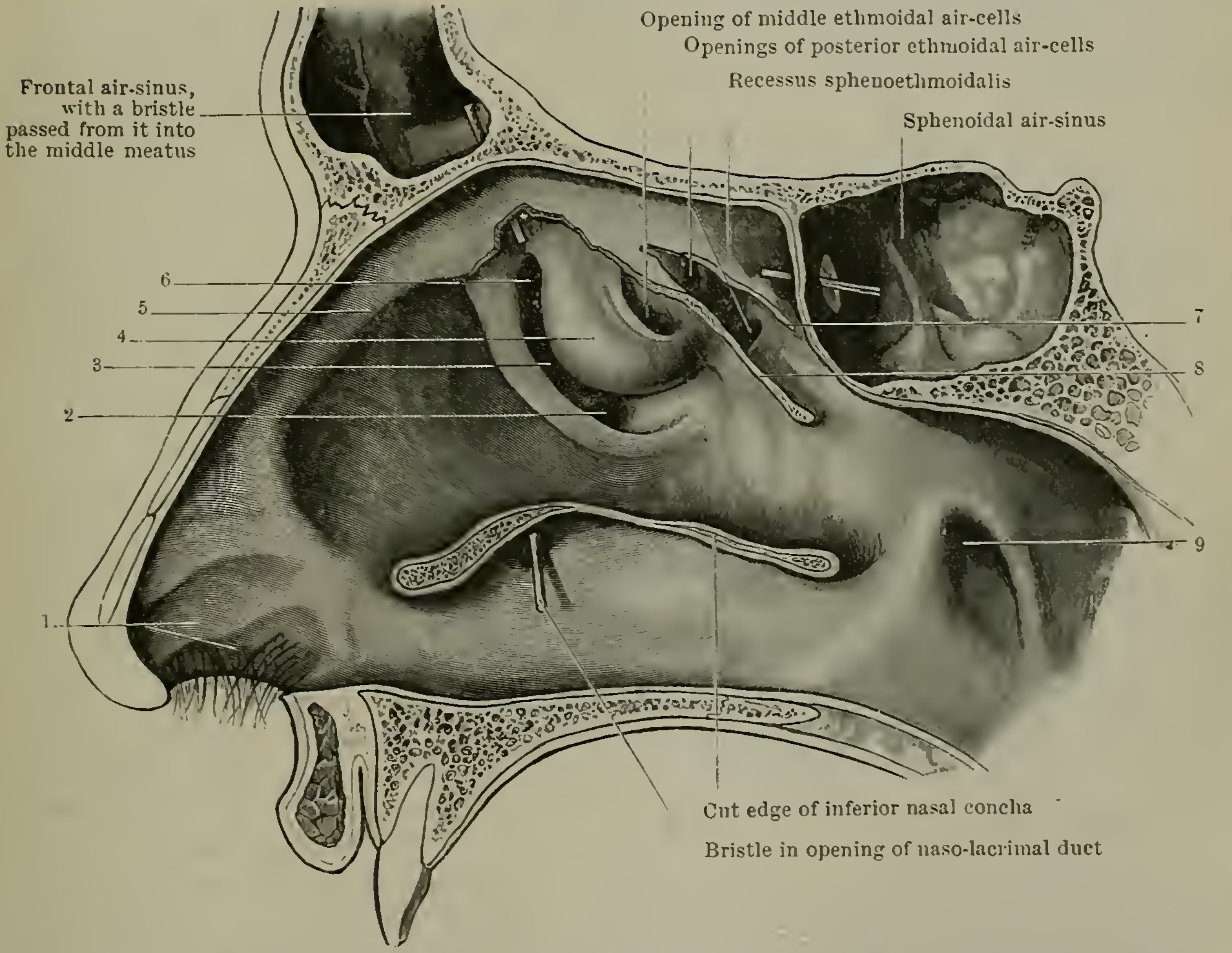
Frontal air-sinus, with a bristle passed from it into the middle meatus
Opening of middle ethmoidal air-cells
Openings of posterior ethmoidal air-cells
Recessus sphenoethmoidalis
Sphenoidal air-sinus
6
5
4
3
2
1
7
8
9
Cut edge of inferior nasal concha
Bristle in opening of naso-lacrimal duct

Fig. 642.—View of the Lateral Wall of the Nose—the Nasal Conchæ having been removed.

1. Vestibule.
2. Opening of maxillary air-sinus.
3. Hiatus semilunaris.
4. Bulla ethmoidalis.
5. Agger nasi.
6. Opening of anterior ethmoidal air-cells.
7. Cut edge of superior nasal concha.
8. Cut edge of middle nasal concha.
9. Pharyngeal orifice of auditory tube.

The **middle meatus**, situated below and lateral to the middle nasal concha, is a roomy passage, and is continued forwards into a slightly depressed area, termed the **atrium meatus nasi**, which lies immediately above the vestibule. The atrium is limited superiorly and anteriorly by a low ridge, the **agger nasi**, the representative of the *naso-turbinal* found in many mammals. If the middle nasal concha be removed the lateral wall of the meatus is exposed. On it there is a narrow semilunar cleft, the **hiatus semilunaris**, which is bounded above by a rounded elevation, the **bulla ethmoidalis**, and below by the sharp edge of the processus uncinatus of the ethmoidal bone. The size of the bulla varies with that of the middle ethmoidal air-cells, which are contained within it and open on or near its upper surface. Through the hiatus semilunaris the middle meatus opens into the **infundibulum** or **frontal recess**, a curved channel, limited above by the bulla ethmoidalis, and below by the lateral surface of the processus uncinatus. The anterior end of the infundibulum receives the openings of the anterior ethmoidal air-cells, and, in rather more than fifty per cent. of skulls, is continued upwards as the **fronto-nasal duct** into the frontal air-sinus; in the remainder it is shut off from the lower end of the fronto-nasal duct by the union of the bulla ethmoidalis with the upper part of the processus uncinatus, and the fronto-nasal duct then opens into the anterior part of the middle meatus. The **ostium maxillare** or opening of the maxillary air-sinus is placed below the bulla ethmoidalis, and is hidden by the lower end of the processus uncinatus; an accessory ostium is frequently seen in the middle meatus, above the posterior part of the inferior nasal concha. The narrow slit-like interval between the nasal septum and the medial surface of the middle nasal concha is named the **olfactory cleft or sulcus.**

The **inferior meatus** lies below and lateral to the inferior nasal concha; the slit-like orifice of the naso-lacrimal duct opens into the anterior part of this meatus (p. 820).

Roof.—The roof of the nasal cavity is very narrow, except at its posterior part, and is divisible into three portions, fronto-nasal, ethmoidal, and sphenoidal, in accordance with the bones which enter into its formation.

Floor.—The floor of the nasal cavity is formed by the palatine process of the maxilla and the horizontal part of the palatine bone. In it, close to the inferior margin of the septum and immediately over the incisive foramen, a funnel-shaped depression, the *naso-palatine recess,* is sometimes seen; it is directed downwards and forwards, and indicates the position of a communication which existed between the nasal and buccal cavities in early fœtal life.

Membrana Mucosa Nasi.—The **nasal mucous membrane** lines the entire nasal cavity except the vestibule; it is firmly bound to the subjacent periosteum and perichondrium. It is continuous, through the choanæ, with the mucous lining of the nasal part of the pharynx; through the naso-lacrimal and lacrimal ducts, with the conjunctiva; and, through the apertures leading into the accessory air-sinuses of the nose, with the delicate lining of these cavities.

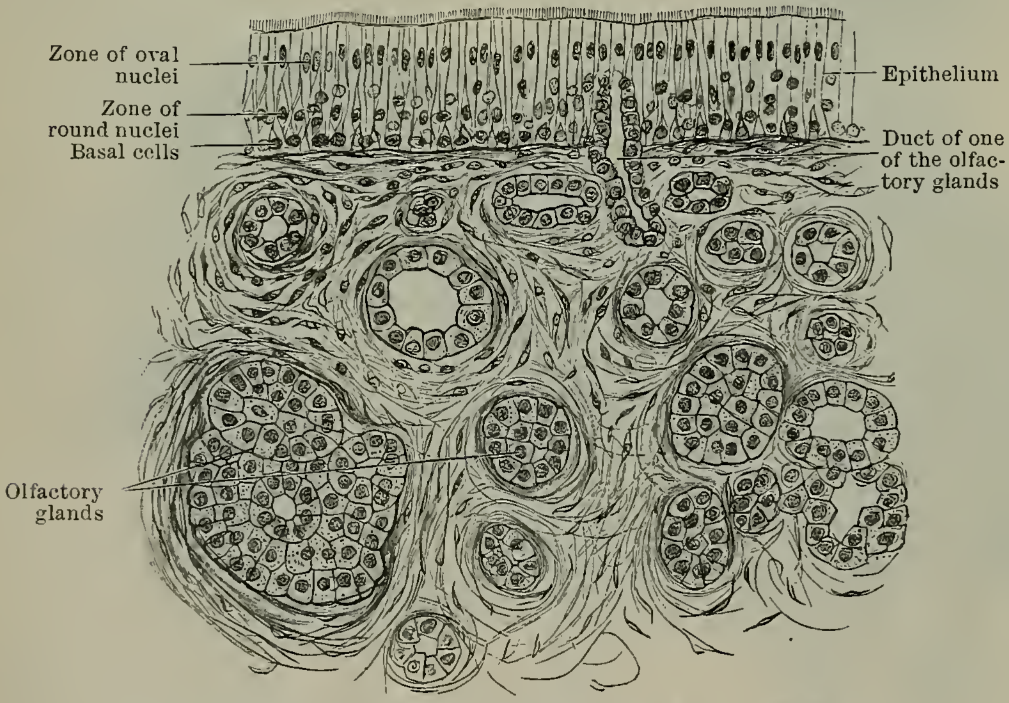

FIG. 643.—SECTION THROUGH THE OLFACTORY MUCOUS MEMBRANE.

Throughout the respiratory region the mucous membrane is covered with columnar, ciliated epithelium, interspersed amongst which are goblet or mucous cells; between the bases of the columnar cells smaller pyramidal cells are interpolated. It is highly vascular, and contains a freely anastomosing venous plexus. Many acinous glands are embedded in it, and are especially large and numerous in the posterior halves of the nasal cavities. In children a considerable amount of adenoid tissue is present.

In the olfactory region the mucous membrane is thin, yellowish in colour, and covered with non-ciliated columnar epithelium (Figs. 643, 644). Embedded in it are numerous tubular and branched **olfactory glands (glands of Bowman),** which are lined with polygonal cells, and open by fine ducts. The epithelium of the olfactory region consists of—supporting, olfactory, and basal cells (Fig. 644).

Supporting Cells. — The superficial parts of these cells are columnar in shape and contain fine granules of yellow pigment, whilst the deep portions are continued for some distance as attenuated or branched processes. These cells contain elliptical or oval nuclei, which are situated at the deep ends of the columnar parts of the cells, and form the *zone of oval nuclei.* In many animals the free surface of this columnar epithelium is covered by a thin limiting membrane.

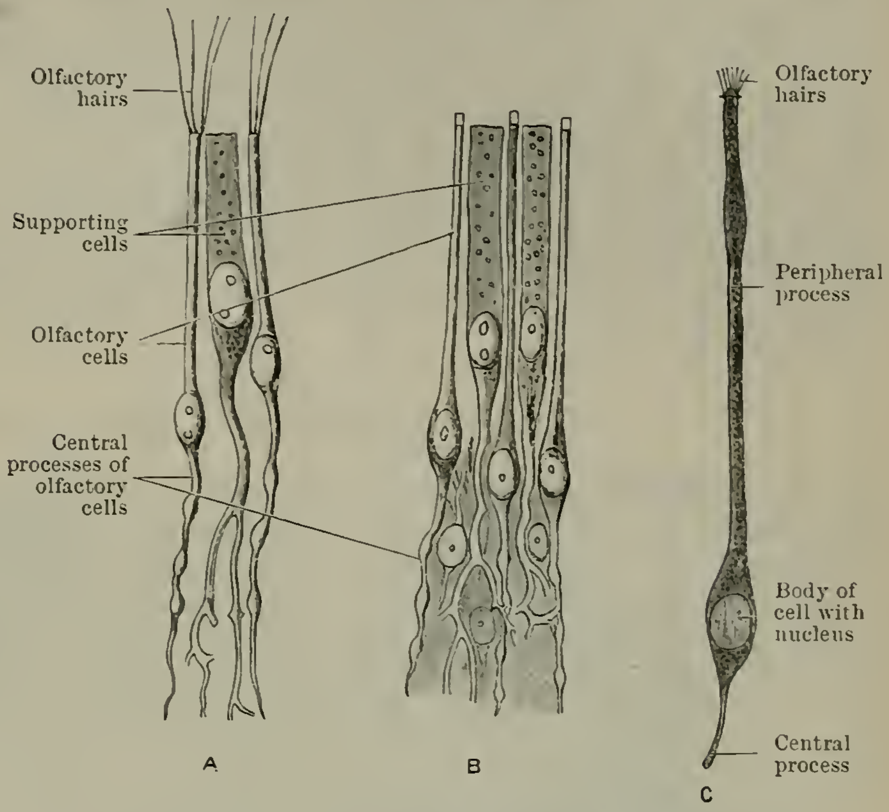

Fig. 644.—Olfactory and Supporting Cells.

A. Frog
B. Human } M. Schultze. C. Human (v. Brunn).

Olfactory Cells.—These are bipolar nerve-cells, the central processes of which are continued as the axons of the olfactory nerve-fibres. They are homologous with the nerve-cells of the spinal ganglia, but differ from them in that they retain their primitive position in the surface epithelium. The cell-bodies are spindle-shaped and are arranged in several rows between the deeper, attenuated parts of the supporting cells. Each cell-body consists of a large, spherical nucleus enveloped by a small amount of protoplasm; the nuclei form a layer of some thickness, termed the *zone of round nuclei.* The peripheral process of each olfactory cell is rod-like, and extends between the columnar portions of the supporting cells as far as their free surfaces, where it pierces the external limiting membrane and divides into a number of fine hair-like processes, named **olfactory hairs**; the central process, a delicate, beaded filament, is continued upwards as the axon of an olfactory nerve-fibre.

Basal Cells.—These cells are branched, and lie between the deep ends of the supporting and olfactory cells.

Olfactory Nerves.—The fibres of the olfactory nerves are devoid of medullary sheaths, but are provided with primitive sheaths; they arise, as stated, from the olfactory cells. They are collected into fasciculi which form a plexiform network under the mucous membrane and ascend on the medial and lateral walls of the olfactory region of the nasal cavity. They are lodged, near the base of the skull, in grooves or canals in the ethmoidal bone, and pass into the cranial cavity through the foramina in the lamina cribrosa of that bone. They enter the olfactory bulb, in the glomeruli of which they subdivide and form synapses with the dendrites of the mitral cells of the bulb.

The trigeminal nerve supplies branches of ordinary sensation to the nasal mucous membrane as follows:—The septum is chiefly supplied by the naso-palatine nerve, but its posterior part receives some filaments from the spheno-palatine ganglion and from the nerve of the pterygoid canal, and its anterior portion from the naso-ciliary branch of the ophthalmic nerve. The lateral wall is supplied—(1) by the upper nasal branches of the spheno-palatine ganglion; (2) by the lower nasal branches of the anterior palatine nerve; and in front by (3) the naso-ciliary branch of the ophthalmic nerve. The floor and the anterior part of the inferior meatus are supplied by a nasal branch of the anterior superior alveolar nerve.

Blood-vessels.—The chief artery of the nose is the spheno-palatine branch of the internal maxillary artery. This reaches the nasal cavity through the spheno-palatine foramen, and divides into—(*a*) posterior lateral nasal branches, which ramify over the meatuses and conchæ, and also send branches to the maxillary and frontal air-sinuses and the ethmoidal air-cells; and (*b*) naso-palatine, the artery of the septum. The upper portion of the cavity receives twigs from the anterior and posterior ethmoidal arteries, and the posterior part some small branches from the descending palatine artery. The nostrils are supplied by the lateral nasal branch of the external maxillary artery, and by the septal branch of the superior labial artery. The maxillary air-sinus is supplied by the infra-orbital and posterior superior alveolar arteries, whilst the sphenoidal air-sinus gets its chief supply from the spheno-palatine artery. The **veins** form a dense cavernous plexus which is well seen in the respiratory region, and especially so over the inferior nasal concha and the lower and posterior parts of the septum. The venous blood is carried in three chief directions, viz., *anteriorly* into the anterior facial vein, *posteriorly* into the pterygoid plexus through the spheno-palatine vein, and *superiorly* into the ethmoidal veins. The ethmoidal veins communicate with the ophthalmic veins and the veins of the dura mater; one ethmoidal vein passes up through the lamina cribrosa of the ethmoidal bone, and opens either into the venous plexus of the olfactory bulb or directly into one of the veins on the orbital surface of the frontal lobe of the brain. The **lymph-vessels** form an irregular network in the superficial part of the mucous membrane and communicate with the lymph-spaces which surround the branches of the olfactory nerve; they can be injected from the subdural and subarachnoid cavities. The chief lymph-vessels are directed posteriorly towards the choanæ, and are collected into two trunks, one passing to a lymph-gland in front of the epistropheus, the other to one or two lymph-glands near the greater cornu of the hyoid bone.

The Accessory Air-sinuses of the Nose.

The **accessory air-sinuses of the nose** are the frontal, ethmoidal, sphenoidal, and maxillary; they open into the nasal cavities, and are lined by mucous membrane, continuous with that of the nasal cavities.

The **frontal air-sinuses** are two in number, and are placed behind the superciliary arches; they are rarely symmetrical because the septum which separates them frequently deviates from the median plane. Their average measurements are:—height, 3·16 cm.; breadth, 2·58 cm.; depth from before backwards, 1·8 cm. Each opens, through the fronto-nasal duct, into the anterior part of the middle meatus of the nose.

The **ethmoidal air-sinuses** consist of numerous air-cavities in the labyrinths of the ethmoidal bone, and completed by the frontal, maxillary, lacrimal, sphenoidal, and palatine bones. They are separated from the orbital cavities by thin bony laminæ, and are arranged in three groups, anterior, middle, and posterior. The anterior and middle groups open into the middle meatus, and the posterior group into the superior meatus, of the nose.

The **sphenoidal air-sinuses** are two cavities in the body of the sphenoidal bone; they are rarely symmetrical, since the septum between them is often bent to one or other side of the median plane. Their average measurements are:—height, 2 cm.; width, 1·8 cm.; antero-posterior depth, 2·1 cm. Each opens into the spheno-ethmoidal recess, above the superior nasal concha.

The **maxillary air-sinuses** are pyramidal cavities in the bodies of the maxillæ. Their average measurements are:—height, opposite the first molar tooth, 3·5 cm.; width, 2·5 cm.; antero-posterior depth, 3·2 cm. In the upper part of the base of each air-sinus is an opening (*ostium maxillare*) through which it communicates with the lower part of the hiatus semilunaris in the middle meatus of the nose. An accessory ostium is frequently seen above the posterior part of the inferior nasal concha.[1]

The development of the nose is described in the section on "General Embryology."

ORGANON VISUS.

BULBUS OCULI.

The bulb of the eye (O.T. eyeball) constitutes the peripheral part of the **organ of sight**; associated with it are certain accessory structures, such as the eyelids, lacrimal apparatus, etc.

Bulbus Oculi.—The bulb of the eye is situated in the anterior part of the orbital cavity; it is protected in front by the eyelids, and is pierced behind by the optic nerve. The tendons of the ocular muscles are attached to its outer surface, and the posterior part of the bulb is enveloped by a loose membrane termed the fascia bulbi (O.T. capsule of Tenon).

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[1] The measurements of the accessory sinuses are those given by A. Logan Turner, *Accessory Sinuses of the Nose*, 1901.

The bulb of the eye is not quite spherical, being composed of the segments of two spheres, viz., an anterior, corneal segment, with a radius of about 8 mm., and a posterior, scleral segment, with a radius of about 12 mm. (Fig. 645). The anterior or corneal segment, in consequence of its shorter radius, projects in front of the scleral portion, the union of the two parts being indicated, externally, by a slight groove, the **sulcus scleræ**. The central points of the anterior and posterior curved surfaces of the bulb constitute, respectively, its **anterior** and **posterior poles**, and a straight line joining the two poles is termed the **axis oculi**; an imaginary line encircling the bulb, midway between the poles, is named the **equator**. The axes of the two bulbs are almost parallel, converging only slightly behind; but the axes of the optic nerves converge markedly behind, and, if prolonged backwards, would meet in the region of the dorsum sellæ of the sphenoidal bone. The sagittal and transverse diameters of the bulb are nearly equal—about 24 mm.; the vertical diameter is about 23·5 mm. All three diameters are rather less in the female than in the male, but the size of the bulb is fairly constant in the same sex. What are popularly described as large eyes owe their apparent size to a greater prominence of the bulb and to a wider palpebral fissure.

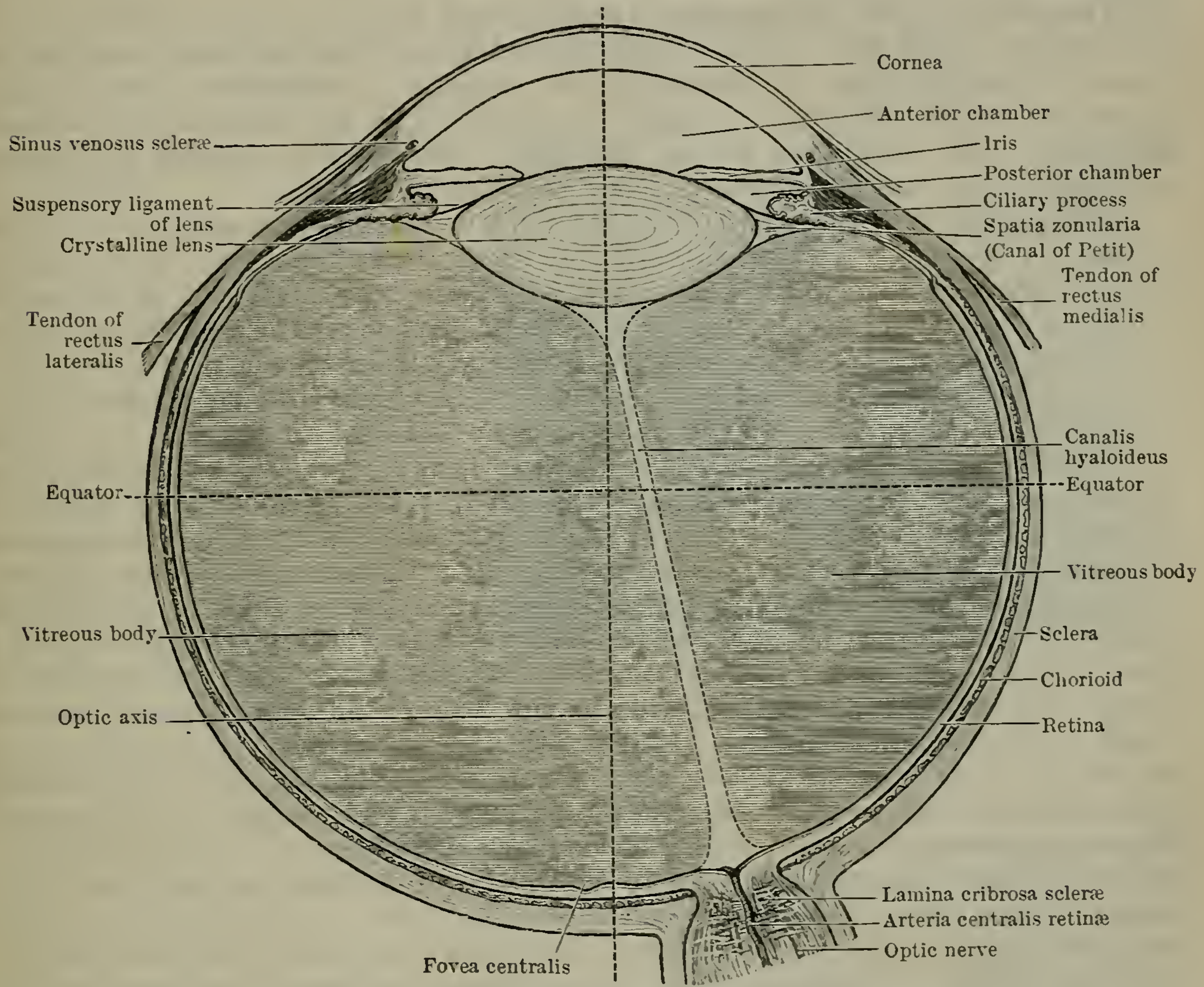

Fig. 645.—Diagram of a Horizontal Section through the Left Bulbus Oculi and the Optic Nerve (× 4).

At birth the bulb of the eye is nearly spherical and has a diameter of about 17·5 mm. By the age of puberty this has increased to 20 or 21 mm., after which it rapidly reaches its adult size. In the myopic the sagittal diameter is greater, and in the hypermetropic it is less than normal.

Fascia Bulbi.—The **fascia bulbi** is a thin fibrous tunic which envelops the bulb of the eye from the entrance of the optic nerve to the sclero-corneal junction; it forms a socket for the bulb, and separates it from the other contents of the orbital cavity. Between the fascia and the sclera is a potential **episcleral space**; this, although often described as a lymph-space, is not lined by endothelium, but is traversed by a meshwork of fine connective tissue. Around the entrance of the optic nerve the fascia bulbi is pierced by the ciliary nerves and the posterior ciliary vessels which render this part of the fascia somewhat difficult to define. The fascia is not continued backwards to form a sheath for the optic nerve. Near the equator of the bulb the fascia is perforated by the venæ vorticosæ, and the more anteriorly by the ocular muscles. The part of the fascia in front of the insertions of the recti muscles is thin; it lies between the bulbar part of the conjunctiva and the sclera, and fuses with the latter immediately behind the sclero-corneal junction.

The sheaths of the ocular muscles are thin and almost invisible posteriorly, but they become thick and opaque anteriorly, and blend with the fascia bulbi at the points where the latter is pierced by the muscles. Immediately behind these points the muscle-sheaths are united by their edges to form an **intermuscular membrane**; this membrane is best developed between the superior and lateral recti, and there passes beneath the lacrimal gland.

Offsets pass from the outer surfaces of the muscle-sheaths to the walls of the orbital cavity, and as these offsets probably check the actions of the corresponding muscles, they are named **check ligaments**; they are best developed in association with the lateral and medial recti. The outer part of the sheath of the rectus lateralis is greatly thickened anteriorly, and forms a triangular mass of tissue which constitutes the check ligament of this muscle; it is chiefly attached to the tubercle on the orbital surface of the zygomatic bone, but is also fixed to the lateral palpebral ligament and the lateral conjunctival fornix. The check ligament of the rectus medialis is of a similar shape; it is fixed to the lacrimal bone behind the posterior lacrimal crest, and to the caruncula lacrimalis and the medial conjunctival fornix. The sheath of the rectus superior blends with that of the levator palpebræ superioris, and the stratum so formed is attached to the superior conjunctival fornix; the sheath of the tendon of the obliquus superior extends as far as, and is fixed to, the fibrous pulley through which the tendon passes. A band is sometimes continued backwards and lateralwards to the floor of the orbital cavity from the sheath of the obliquus inferior; this sheath also blends with that of the rectus inferior, and the blended sheaths send forwards one thin lamella into the lower eyelid, and another to unite with the fascia bulbi. The margins of the sheath of the rectus inferior join the margins of the sheaths of the lateral and medial recti, and as the latter sheaths are fixed to the medial and lateral walls of the orbital cavity by the check ligaments, already described, a continuous band, named the **suspensory ligament** (Lockwood), is slung from side to side like a hammock beneath the bulb of the eye. The ends of this suspensory ligament blend not only with the check ligaments, but with the lateral and medial horns of the aponeurosis of the levator palpebræ superioris, and the masses of tissue thus formed are often named the **lateral** and **medial ocular retinacula.**

The wall of the bulb of the eye (Fig. 645) consists of three concentric tunics or coats; enclosed within it are three transparent refracting media. The three tunics are: (1) an outer, fibrous tunic, the **tunica fibrosa oculi**; (2) an intermediate, vascular, pigmented, and partly muscular tunic, the **tunica vasculosa oculi**; (3) an internal, nervous tunic, the **retina.** The three refracting media are named, from behind forwards, the **vitreous body**, the **crystalline lens,** and the **aqueous humour.**

TUNICA FIBROSA OCULI

The fibrous tunic of the bulb of the eye consists of an opaque, posterior part, the **sclera**, and a transparent, anterior part, the **cornea**.

Sclera.—The sclera is firm and opaque, and forms the greater part of the outer tunic. Thickest posteriorly (about 1 mm.), it thins at the equator of the bulb to

0·4 or 0·5 mm., and again increases to 0·6 mm. near the sulcus scleræ. In the child it is thinner than in the adult, and presents a bluish appearance caused by the pigment of the chorioid shining through it; in old age it assumes a yellowish tinge. The tendons of the ocular muscles are attached to it, and the fascia bulbi closely envelops it. The sclera is pierced posteriorly, by the optic nerve, the entrance for which is funnel-shaped, wide behind and narrow in front, and is situated 3 mm. to the nasal side of the posterior pole. The fibrous sheath of the nerve blends with the outer part of the sclera, while the nerve-bundles pass through a series of orifices; this perforated portion is named the **lamina cribrosa scleræ.** Around the entrance of the optic nerve are fifteen or twenty small apertures for the passage of the ciliary nerves and short ciliary arteries. The two long posterior ciliary arteries pierce the sclera, one on either side, at a little distance from the entrance of the optic nerve; near the equator are four openings, two above and two below, for the exit of veins (**venæ vorticosæ**) from the chorioid; near the sulcus scleræ it is perforated by the anterior ciliary arteries. The deep surface of the sclera is of a brownish colour, and is lined with flattened endothelial cells; between it and the chorioid is an extensive space, the **spatium perichorioideale,** traversed by the ciliary nerves and arteries just mentioned, and by a delicate meshwork of fine, pigmented, connective tissue, the **lamina fusca,** which loosely attaches the sclera to the chorioid. At the sclero-corneal junction the fibrous tissue of the sclera passes continuously into that of the cornea, and in the deeper part of this junction there is a circular canal, the **sinus venosus scleræ** (O.T. **canal of Schlemm**) (Fig. 646). When seen in a meridional section of the sclero-corneal junction, the sinus venosus scleræ appears as a narrow cleft; its outer wall is formed by the compact tissue of the sclera; its inner wall consists of a triangular mass of trabecular tissue; the apex of this triangular mass is directed forwards and is continuous with the posterior elastic lamina of the cornea. The sinus is lined with endothelium, and occasionally contains a few red blood-corpuscles. It communicates with the anterior ciliary veins, and, through the spatia anguli iridis in the trabecular tissue, with the anterior chamber of the eye.

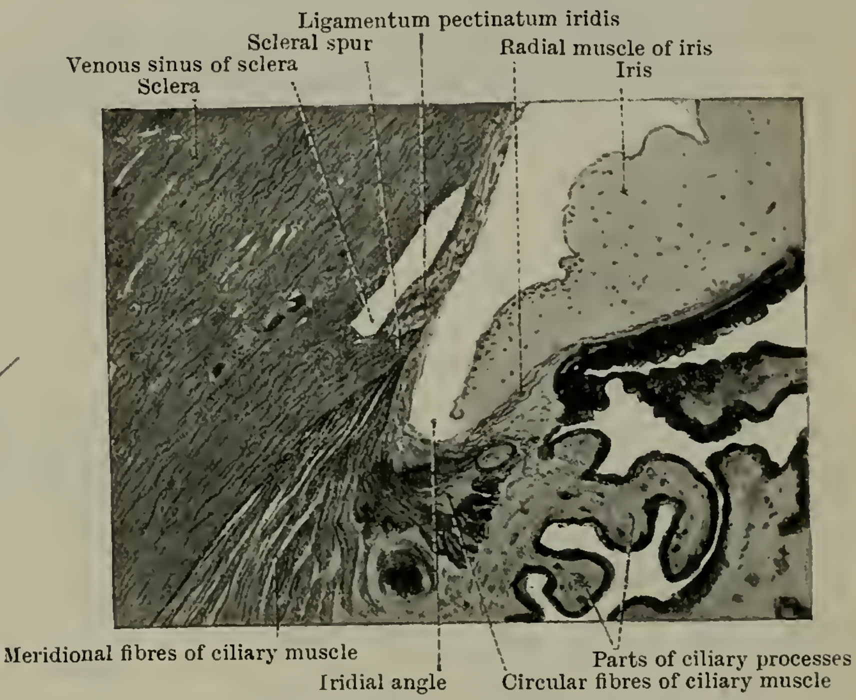
Ligamentum pectinatum iridis
Scleral spur
Radial muscle of iris
Venous sinus of sclera
Iris
Sclera
Meridional fibres of ciliary muscle
Iridial angle
Parts of ciliary processes
Circular fibres of ciliary muscle

Fig. 646.—Section of Iridial Angle. (Arthur Thomson.)

Structure.—The sclera consists of bundles of white fibrous tissue, together with some fine elastic fibres, the bundles forming equatorial and meridional layers, which interlace with one another. Numerous spaces containing connective tissue cells and migratory cells exist between the fibres. Pigmented cells are plentiful in the lamina fusca, and a few are found in the tissue of the sclera near the entrance of the optic nerve and in the region of the sclero-corneal junction.

Vascular and Nervous Supply.—The sclera receives its blood-supply from the short posterior ciliary and the anterior ciliary arteries; its veins open into the venæ vorticosæ and anterior ciliary veins. The cell-spaces probably play the part of lymph-vessels; they communicate with the perichorioidal and episcleral spaces. The nerves of the sclera are derived from the ciliary nerves, which, after losing their medullary sheaths, pass between the fibrous bundles; their exact mode of ending is not known.

Cornea.—The **cornea** is transparent and forms the anterior part of the outer tunic; its index of refraction is from 1·33 to 1·35; the thickness of its central part is about ·95 mm., that of its peripheral part, about 1·19 mm. Its anterior surface is covered with a stratified epithelium, continuous with that of the conjunctiva; its posterior surface is directed towards the anterior chamber of the eye and is in contact with the aqueous humour. The degree of curvature of the cornea varies in different individuals; it is greater in youth than in old age, and is, as a rule, slightly greater in the vertical than in the horizontal plane; it diminishes from the centre to the circumference of the cornea, and is less on the nasal than on the temporal side of the anterior pole. The outline of the anterior surface of the cornea is almost circular, measuring 11 mm. vertically and 11·9 mm. transversely; that of the posterior surface is circular and has a diameter of 13 mm. The arc of the cornea is equal to about one-sixth of the total circumference of the bulb of the eye.

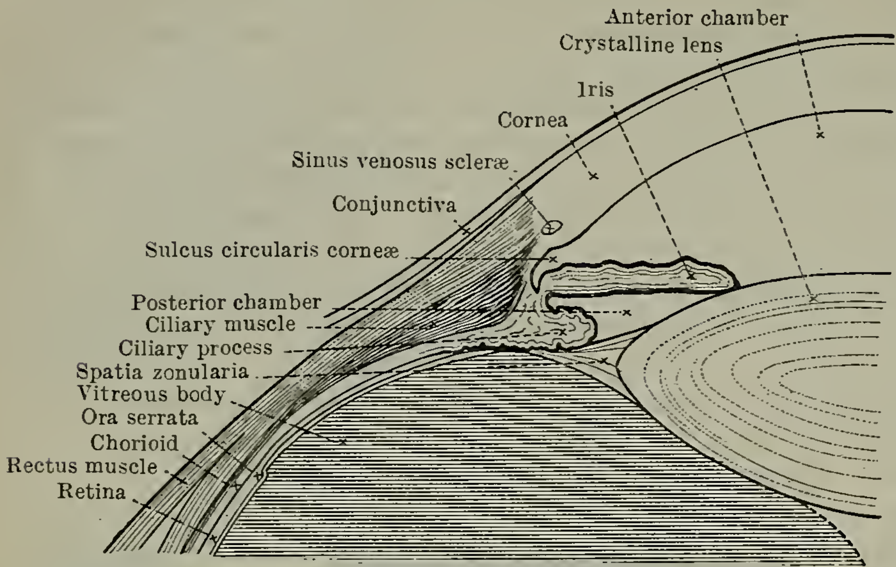

Fig. 647.—Section of a Portion of the Bulb of the Eye, showing the Sulcus Circularis Corneæ.

The tissue of the cornea is continuous posteriorly with that of the sclera, the line of union being known as the **sclero-corneal junction**. Directly in front of this junction the inner surface of the cornea projects in the form of a rounded rim; behind this rim, in the interval between the sclero-corneal junction and the attachment of the iris, is a groove, the **sulcus circularis corneæ** (Arthur Thomson)[1] (Fig. 647). The outer wall of this sulcus is composed of a stratum of trabecular tissue placed on the inner side of the sinus venosus scleræ (Fig. 647). Between this trabecular tissue and the front of the circumference of the iris is a narrow recess which on section appears as an acute angle; it is named the **filtration angle** or **angle of the iris.**

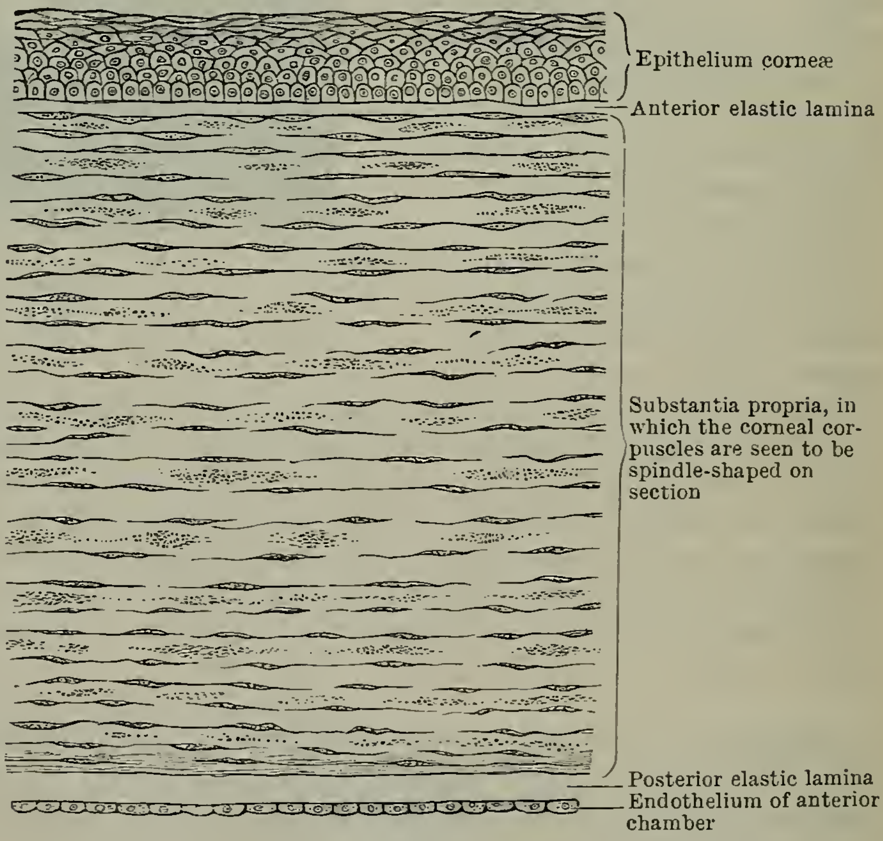
Epithelium corneæ
Anterior elastic lamina
Substantia propria, in which the corneal corpuscles are seen to be spindle-shaped on section
Posterior elastic lamina
Endothelium of anterior chamber

Fig. 648.—Vertical Section of Cornea (magnified).

Structure.—The cornea consists, from before backwards, of the following strata, (Fig. 648):—

1. Epithelium corneæ.
2. Anterior elastic lamina.
3. Substantia propria.
4. Posterior elastic lamina.
5. Endothelium of anterior chamber.

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[1] *Atlas of the Eye*, Clarendon Press, Oxford, 1912.

1. The **epithelium corneæ** is continuous with the epithelium covering the free surface of the conjunctiva, and consists of six or eight strata of nucleated cells. Deepest of all is a single layer of perpendicularly arranged columnar cells, the flattened bases of which rest on the anterior elastic lamina, while their opposite ends are round and contain the nuclei. Superficial to this layer are three or four strata of polygonal cells, most of which exhibit finger-like processes joining with the corresponding processes of neighbouring cells; the more superficial layers consist of squamous cells. The thickness of this stratified epithelium is about 45 μ at the centre, and about 80 μ at the periphery, of the cornea.

2. The **anterior elastic lamina**, from 19-20 μ thick, is merely a differentiation of the anterior part of the substantia propria, from which it is difficult to separate; it is not stained yellow by picrocarmine, thus differing from true elastic tissue. Its degree of development varies in different animals.

3. The **substantia propria** presents, in a fresh condition, a homogeneous appearance; but, with the assistance of reagents, it is seen to consist of modified connective tissue, with a few elastic fibres. An amorphous interstitial substance binds the fibres into bundles, and, in turn, cements the bundles into lamellæ which are flattened from before backwards. The fibres of any one lamella cross those of adjacent lamellæ almost at right angles, while the superimposed lamellæ are joined by sutural fibres and by amorphous substance. Between the lamellæ are the **cell-spaces** or **lacunæ** of the cornea—irregularly stellate in shape, and communicating freely with each other by means of fine canaliculi. The corneal cells are contained in these lacunæ, without, however, completely filling them, the remainder of the lacunæ being occupied by lymph. The cells are nucleated, flattened, and star-like, and their branched processes join those of neighbouring cells in the canaliculi. Lymph-cells are also found in the cell-spaces.

After middle age a grayish opaque ring, 1·5 to 2 mm. in breadth, is frequently seen near the periphery of the cornea; it is termed the **arcus senilis**, and results from a deposit of fat granules in the lamellæ and corneal cells.

4. The **posterior elastic lamina** is a clear homogeneous membrane, covering the posterior surface of the substantia propria and having a thickness of 6-8 μ at the centre and 10-12 μ at the periphery of the cornea. Less firmly attached to the substantia propria than the anterior elastic lamina, it may be stripped off, when it will be found to roll up with its attached surface inwards. Between the ages of twenty and thirty years small wart-like projections appear on its deep surface, near its periphery, and these increase in size and number as age increases, so that in old people the membrane may attain a thickness of 20 μ. At the sclero-corneal junction the posterior elastic lamina splits into bundles of fine fibres which interlace and form the triangular area of trabecular tissue already referred to (p. 804), and which is usually spoken of under the name of the **ligamentum pectinatum iridis**. The spaces between the trabeculæ are termed the **spatia anguli iridis** (O.T. **spaces of Fontana**), and are lined with endothelium prolonged from the endothelium of the anterior chamber. They communicate internally with the filtration angle and externally with the sinus venosus scleræ, and form important channels through which fluid may filter from the anterior chamber into the sinus and thence into the anterior ciliary veins. When the trabecular tissue of the ligamentum pectinatum iridis is followed backwards most of its fibres are seen to be attached to the anterior surface of an inwardly directed rim of scleral tissue; in a meridional section this rim appears as a triangular projection, and is named the **scleral spur**. A few fibres of the trabecular tissue are carried past the apex of the scleral spur on to the inner surface of the origin of the meridional fibres of the ciliary muscle, and, running behind the filtration angle, are prolonged into the iris (Fig. 646), where they are directly continuous with the fibres of the dilatator pupillæ muscle (Arthur Thomson).[1]

5. The **endothelium of the anterior chamber** consists of a single stratum of nucleated, flattened, polygonal cells, which present a fibrillar structure and are continued as a lining to the spatia anguli iridis; this layer of endothelium is also reflected on to the anterior surface of the iris.

Vascular and Nervous Supply of the Cornea.—In the fœtus the cornea is traversed, almost as far as its centre, by capillaries; but in the adult it is devoid of blood-vessels, except at its margin. The capillaries of the conjunctiva and sclera pass into this marginal area for a distance of about 1 mm., where they end in loops. The rest of the cornea is nourished by the lymph which percolates into its cell-spaces and canaliculi.

The nerves of the cornea are derived from the ciliary nerves. Around its periphery they form an annular plexus, from which nerve-fibres pass into the cornea, where, after a distance of 1 or 2 mm., they lose their medullary sheaths and ramify in the substantia propria, forming the fundamental or stroma plexus. Fibres extend from this plexus through the anterior elastic lamina and form a subepithelial plexus, from which fine filaments ramify between the epithelial cells as far as the superficial layers. From the annular and stroma plexuses fibrils pass to the substantia propria and come into close relation with the corneal cells.

TUNICA VASCULOSA OCULI.

The vascular and pigmented tunic of the bulb of the eye comprises, from behind forwards, the chorioid, the ciliary body, and the iris (Fig. 645).

Chorioidea.—The **chorioid** intervenes between the sclera and the retina, reaching as far forwards as the ora serrata of the latter (p. 809). It is dark brown or black in colour, and is thicker behind than in front; posteriorly it is pierced by the optic nerve, and is there firmly attached to the sclera. Its outer surface is flocculent and is loosely connected to the sclera by the lamina fusca; its inner surface is smooth and is adherent to the pigmented layer of the retina.

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[1] *Op. cit.*

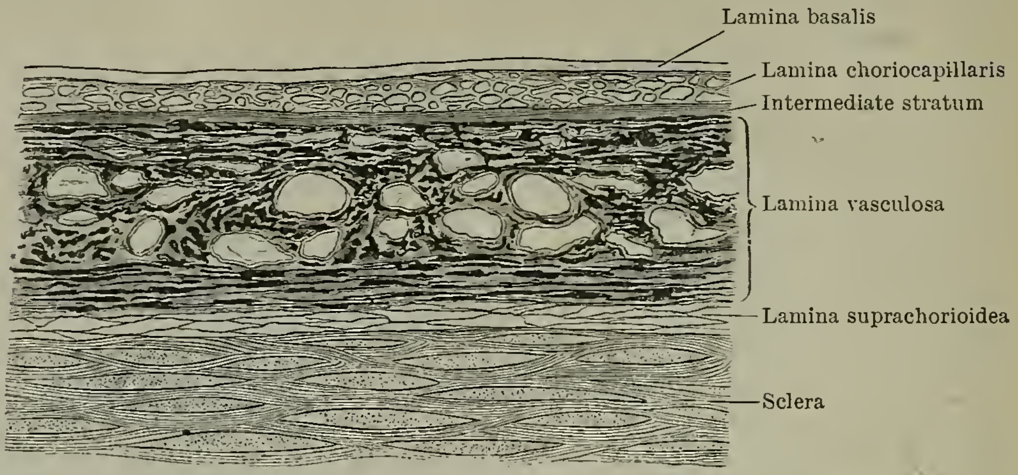

Fig. 649.—Vertical Section of Chorioid and Inner Part of Sclera.

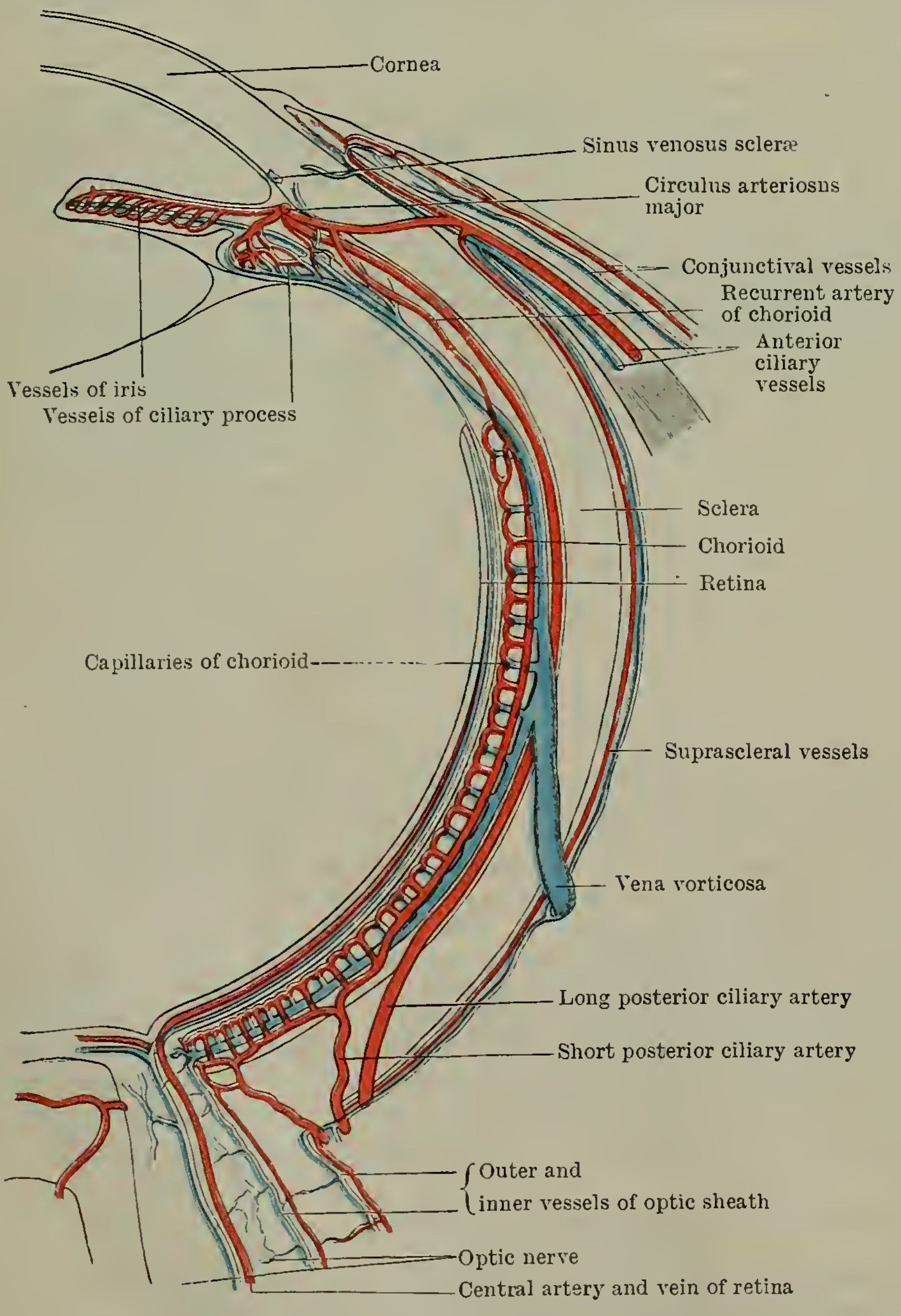
Cornea
Sinus venosus scleræ
Circulus arteriosus major
Conjunctival vessels
Recurrent artery of chorioid
Anterior ciliary vessels
Vessels of iris
Vessels of ciliary process
Sclera
Chorioid
Retina
Capillaries of chorioid
Suprascleral vessels
Vena vorticosa
Long posterior ciliary artery
Short posterior ciliary artery
Outer and inner vessels of optic sheath
Optic nerve
Central artery and vein of retina

Fig. 650.—Diagram of the Circulation in the Eye. (Leber.)

Structure.—The chorioid consists of a loose connective tissue, embedded in which are blood-vessels and branched, pigmented cells; from without inwards it consists of three layers, (*a*) the lamina suprachorioidea; (*b*) the proper tissue of the chorioid; and (*c*) the lamina basalis (Fig. 649).

The **lamina suprachorioidea** resembles the lamina fusca of the sclera, and consists of a series of fine non-vascular lamellæ, each containing a delicate network of elastic fibres, amongst which are stellate, pigmented cells, and amœboid cells. The spaces between the laminæ are lined with endothelium, and together form the spatium perichorioideale, already referred to (p. 803).

The **proper tissue of the chorioid** consists of blood-vessels and numerous pigmented cells, supported by connective tissue, elastic fibres, and some non-striped muscular fibres. Its outer part contains the larger blood-vessels, and is named the **lamina vasculosa**. Its inner portion is composed of a close network of capillaries embedded in a finely granular or almost homogeneous tissue, and is termed the **lamina choriocapillaris**. These two laminæ are joined by a thin **intermediate stratum** consisting of a network of delicate elastic fibres.

Vascular and Nervous Supply of the Chorioid.—The arteries of the chorioid are derived from the short posterior ciliary vessels which pierce the sclera around the entrance of the optic nerve, and form a wide-meshed plexus in the lamina vasculosa. The circular muscular coats of the arteries are well developed, and longitudinal muscular fibres also are present in the larger branches. The veins, destitute of muscular tissue, are superficial to the arteries; they are surrounded by perivascular lymph-sheaths and converge to form whorls, which open into the venæ vorticosæ (p. 803). In the tissue between the blood-vessels are numerous stellate, flattened, and pigmented cells.

Tapetum.—In many animals a brilliant iridescence is seen on the postero-lateral part of the chorioid; to this the name **tapetum** is applied. Absent in man, it may be due, as in the horse, to a markedly fibrous condition of the stratum intermedium (tapetum fibrosum), or as in the seal, to the presence of five or six layers of flattened iridescent cells (tapetum cellulosum), lying immediately outside the lamina choriocapillaris.

Corpus Ciliare.—The **ciliary body** connects the chorioid to the circumference of the iris (Fig. 651), and comprises three zones, (*a*) the orbiculus ciliaris, (*b*) the ciliary processes, and (*c*) the ciliary muscle.

The **orbiculus ciliaris** is a zone, about 4 mm. wide, immediately adjoining the chorioid; it exhibits numerous radially arranged ridges.

Processus Ciliares.—The **ciliary processes**, about seventy in number, form a circle of radial thickenings, each of a somewhat triangular shape; the base of the triangle is directed forwards, towards the equator of the lens, while the apex is continuous behind with three or four of the ridges of the orbiculus ciliaris. They vary in size, the largest having a length of 2-5 mm.

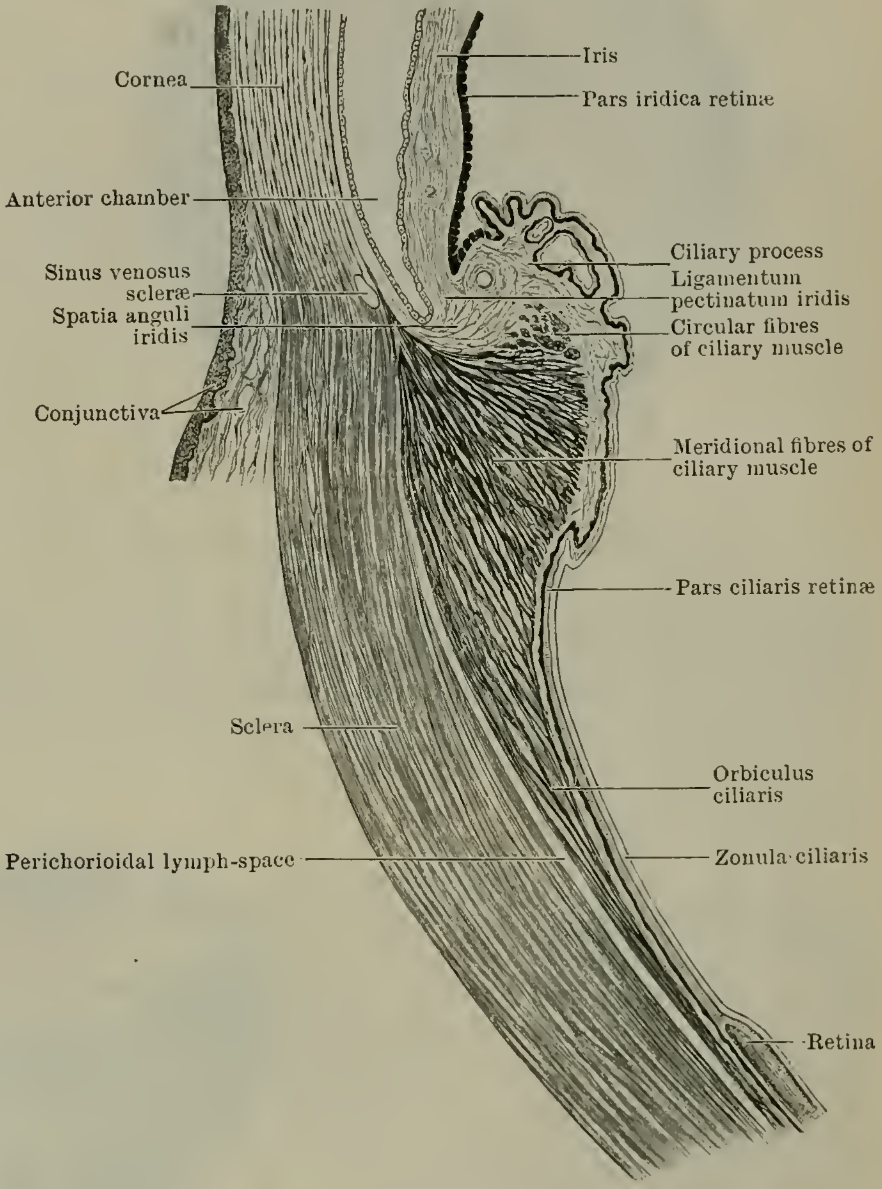

Fig. 651.—Section through Ciliary Region of the Bulb of the Eye.

Structure.—The structure of the orbiculus ciliaris and ciliary processes is similar to that of the chorioid, but the capillaries are larger and more tortuous, and there is no lamina choriocapillaris. The deep surface of the ciliary processes is covered by two strata of columnar epithelium, the anterior layer of which is pigmented; these two strata are continued forwards from the retina and constitute the **pars ciliaris retinæ**; this epithelium is invaginated to form more or less tubular glands.

M. Ciliaris.—The **ciliary muscle** is triangular on horizontal or vertical section, and consists of two sets of fibres—meridional and circular (Fig. 651). The **meridional fibres** arise from the scleral spur, and radiate backwards, to be attached to the ciliary processes and orbiculus ciliaris; the **circular fibres** form a triangular zone behind the filtration angle, close to the periphery of the iris. When the ciliary muscle contracts the chorioid is drawn forwards and the lens becomes more convex, owing to the relaxation of its suspensory ligament (p. 813). Considerable individual differences exist as to the degree of development of the two portions of the ciliary muscle; the meridional fibres are always more numerous than the circular fibres, the latter being absent or rudimentary in myopic eyes, but well developed, as a rule, in hypermetropic eyes.

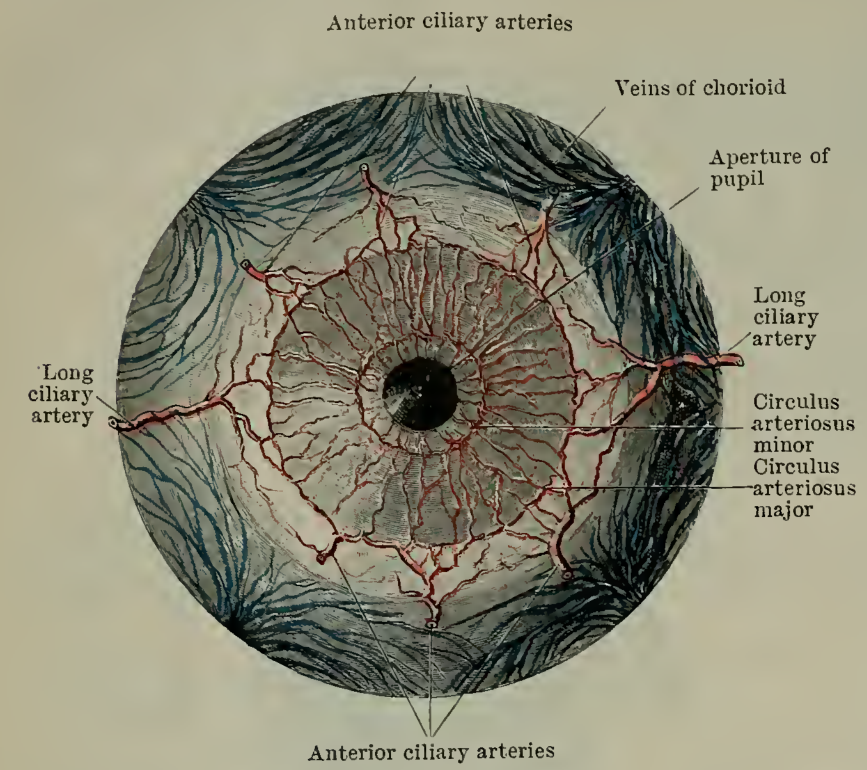
Anterior ciliary arteries
Veins of chorioid
Aperture of pupil
Long ciliary artery
Long ciliary artery
Circulus arteriosus minor
Circulus arteriosus major
Anterior ciliary arteries

FIG. 652.—BLOOD-VESSELS OF IRIS AND ANTERIOR PART OF CHORIOID, viewed from the front (Arnold).

Iris.—The iris forms a contractile diaphragm in front of the lens, and is pierced, a little to the nasal side of its centre, by an almost circular aperture, the **pupil**, which, during life, is continually varying in size in order to regulate the amount of light admitted into the interior of the bulb. It partially divides the space between the cornea and lens into two portions, which are filled by the aqueous humour, and are named, respectively, the **anterior and posterior chambers** of the eye. The iris is thinnest at its peripheral or ciliary margin which is directly continuous with the ciliary body, and, through the medium of the ligamentum pectinatum iridis, with the posterior elastic lamina of the cornea. Its pupillary or free margin forms the circumference of the pupil, and rests upon the anterior surface of the capsule of the lens.

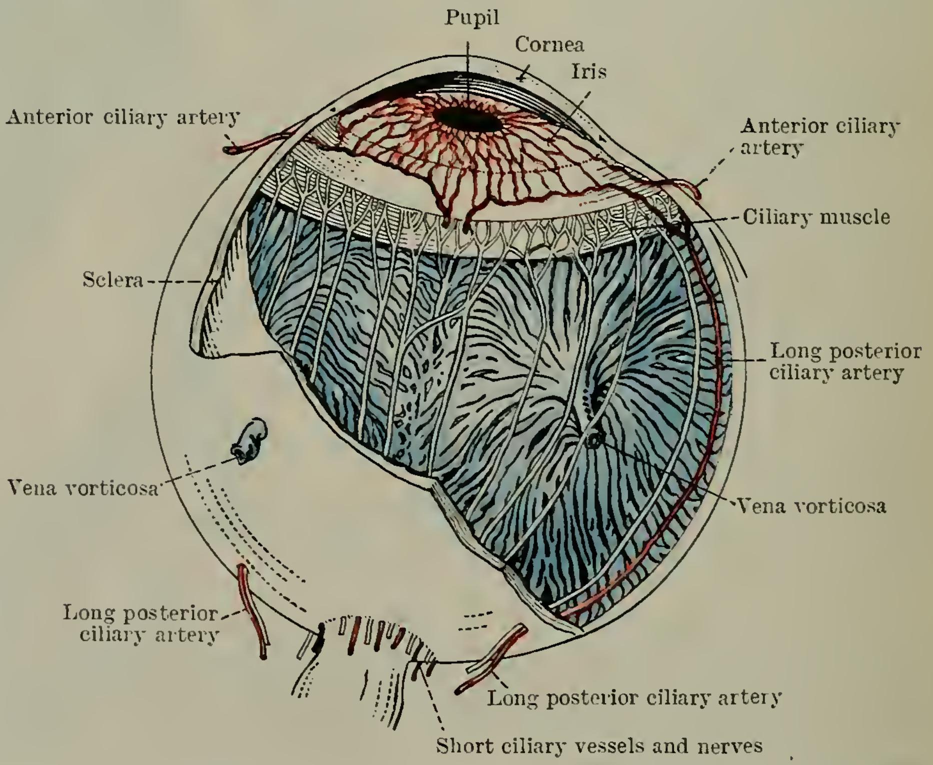
Pupil
Cornea
Iris
Anterior ciliary artery
Anterior ciliary artery
Ciliary muscle
Sclera
Long posterior ciliary artery
Vena vorticosa
Vena vorticosa
Long posterior ciliary artery
Long posterior ciliary artery
Short ciliary vessels and nerves

FIG. 653.—DISSECTION OF THE EYEBALL SHOWING THE VASCULAR TUNIC AND THE ARRANGEMENT OF THE CILIARY NERVES AND VESSELS.

The colour of the eye depends on the arrangement of the pigment in the iris; in the blue eye the pigment is limited to the posterior surface of the iris, but in the brown or black eye it is also scattered throughout its stroma; in the albino the pigment is absent.

The pupil is closed, during the greater part of fœtal life, by a thin, vascular membrane, the **membrana pupillaris**, continuous with the pupillary margin of the iris. Its vessels are derived from the vessels of the iris and the vessels of the capsule of the lens; they converge towards the middle of the membrane, near which they form loops so as to leave the central part non-vascular. About the seventh month the vessels begin to be obliterated, from the centre towards the circumference; and this is followed by a thinning and absorption of the membrane, which becomes perforated by the aperture of the pupil. This perforation gradually enlarges, and at birth the membrane has entirely disappeared; in exceptional cases it persists.

Structure.—On the anterior surface of the iris is a layer of flattened endothelium, placed on a basement-membrane, and continuous with the endothelium of the anterior chamber. Depressions or crypts are seen here and there in which the endothelium and basement-membrane are absent, and are, by some, regarded as stomata, through which the lymph-vessels of the iris communicate with the cavity of the anterior chamber. The posterior surface of the iris is covered with a basement-membrane, on which are placed two layers of columnar, pigmented epithelium, continuous with the pars ciliaris retinæ, and termed the **pars iridica retinæ**. The **stroma iridis**, or proper tissue of the iris, consists of delicate connective tissue and elastic fibres, with pigmented cells, blood-vessels, nerves and non-striped muscular fibres.

The **non-striped muscular fibres** of the iris are arranged in two sets: (*a*) circular, (*b*) radial. The **circular fibres** form a band, the **m. sphincter pupillæ**, around the pupillary aperture; by the contraction of these fibres the size of the pupil is lessened. The **radial fibres** constitute the **m. dilatator pupillæ** and radiate from the sphincter to the ciliary margin of the pupil. Many anatomists maintain that the radial fibres, in man and most mammals, are elastic, not muscular.

Vascular Supply.—The **arteries of the iris** (Fig. 652) are derived from the long ciliary and the anterior ciliary arteries. The long ciliary arteries, two in number, pierce the sclera on the medial and lateral sides of the optic nerve respectively, and extend forwards, between the sclera and chorioid, towards the ciliary margin of the iris. There each artery divides into a superior and an inferior branch, and the resulting four branches anastomose in the form of a circle, termed the **circulus arteriosus major.** This circle is joined by a varying number of anterior ciliary arteries, derived from the lacrimal and muscular branches of the ophthalmic artery, and, after supplying the ciliary muscle, sends converging branches towards the aperture of the pupil, where a second circle, the **circulus arteriosus minor,** is formed. The **veins** proceed towards the ciliary margin of the iris, and communicate with the veins of the ciliary processes and with the sinus venosus scleræ. The convergence of the blood-vessels towards the aperture of the pupil gives a striated appearance to the anterior surface of the iris.

The **nerves of the chorioid and iris** (Fig. 653) are derived from the long and short ciliary nerves. The former, two or three in number, are branches of the naso-ciliary nerve; the latter, from eight to fourteen in number, are derived from the ciliary ganglion. Piercing the sclera around the entrance of the optic nerve, the ciliary nerves traverse the perichorioidal lymph-space, where they form a plexus, rich in nerve-cells, from which filaments are supplied to the blood-vessels of the chorioid. In front of the ciliary muscle a second plexus, also rich in nerve-cells, is formed; this supplies the ciliary muscle and sends filaments into the iris, as far as its pupillary margin, for the supply of its muscular fibres and blood-vessels. The sphincter pupillæ and the ciliary muscle are supplied by the oculo-motor nerve, the dilatator pupillæ by the sympathetic.

RETINA.

The **retina**, or nervous tunic of the eyeball, is a soft, delicate membrane, in which the fibres of the optic nerve are spread out. It consists of two strata, (*a*) an outer, pigmented layer, attached to the chorioid; and (*b*) an inner nervous lamina, the retina proper, in contact with the hyaloid membrane of the vitreous body, but attached to it only around the entrance of the optic nerve and in the region of the ciliary processes. Expanding from the entrance of the optic nerve, the retina appears to end, a short distance behind the ciliary body, in a wavy border, the **ora serrata** (Fig. 654). There its nervous elements cease and the membrane becomes suddenly thinned, but a delicate continuation of it is prolonged over the posterior surfaces of the ciliary body and iris. This continuation consists of the pigmented layer, together with a layer of columnar epithelium, and constitutes the **pars ciliaris retinæ** and **pars iridica retinæ**, already referred to (p. 809). The portion behind the ora serrata is termed the **pars optica retinæ**, and its thickness gradually diminishes from 0·4 mm. near the entrance of the optic nerve, to 0·1 mm. at the ora serrata. It presents, near the posterior pole of the eye, a small, oval yellowish spot, the **macula lutea**, the greatest diameter of which is transverse. The central part of the macula is depressed and is named the **fovea centralis.** About 3 mm. to the nasal side and slightly below the level of the posterior pole is a whitish, circular disc, the **optic disc**, which corresponds with the entrance of the optic nerve, and has a diameter of about 1·5 mm. The circumference of the optic disc is slightly raised and is named the **papilla nervi optici**, while its depressed central portion is termed the **excavatio papillæ nervi optici** (**O.T. optic cup**). The optic disc consists merely of nerve-fibres; it is insensitive to light, and is named the "blind spot."

The nervous layer of the retina is transparent during life, but becomes opaque and of a grayish colour soon after death. If an animal be kept in the dark before the removal of its eyeball, the retina presents a purple tinge, due to the presence of a colouring matter named **rhodopsin** or **visual purple**, which is rapidly bleached on exposure to sunlight. This colouring matter is absent from the macula lutea, and absent also over a narrow zone, 3-4 mm. in width, near the ora serrata.

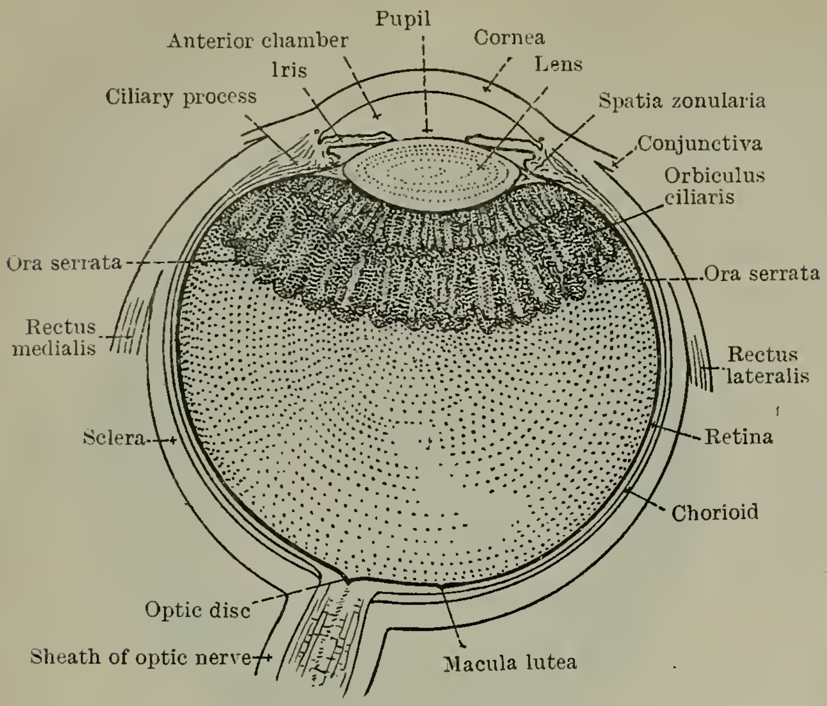

Fig. 654.—A Section of the Bulbus Oculi showing the Ora Serrata (semidiagrammatic).

Structure of the Retina (Figs. 655, 656, 657).—The nervous elements of the retina are supported by non-nervous or **sustentacular fibres**, and are arranged in seven layers; the pigmented layer consists of a single stratum.

The layers from within outwards, *i.e.* from vitreous body to chorioid, are:

1. Stratum opticum or layer of nerve-fibres.
2. Ganglionic or nerve-cell layer.
3. Inner molecular or inner plexiform layer.
4. Inner nuclear layer or layer of inner granules.
5. Outer molecular or outer plexiform layer.
6. Outer nuclear layer or layer of outer granules.
7. Layer of rods and cones.
8. Stratum pigmenti.

1. **Stratum Opticum or Layer of Nerve-fibres.**—Most of the fibres of this stratum are centripetal, and are direct continuations of the axons of the cells in the ganglionic layer; a few are centrifugal and ramify in the inner molecular or inner nuclear layers of the retina.

2. **Ganglionic or Nerve-cell Layer.**—The cells of this stratum vary in size; they are oval or piriform in shape, and form a single layer, except at the macula lutea, where several strata are present. Each cell contains a large nucleus, and gives off, from its inner surface, an axon which is continued as a fibre of the stratum opticum. From the outer surface of each cell numerous dendrites arise, and form arborisations in the inner molecular layer. The cells may be divided into uni-stratified, multi-stratified, and diffuse, according as their dendrites ramify in one or in several strata of the inner molecular layer, or extend throughout nearly its whole thickness.

3. **Inner Molecular or inner Plexiform Layer.**—This is constituted chiefly by the interlacement of the dendrites of the cells of the ganglionic

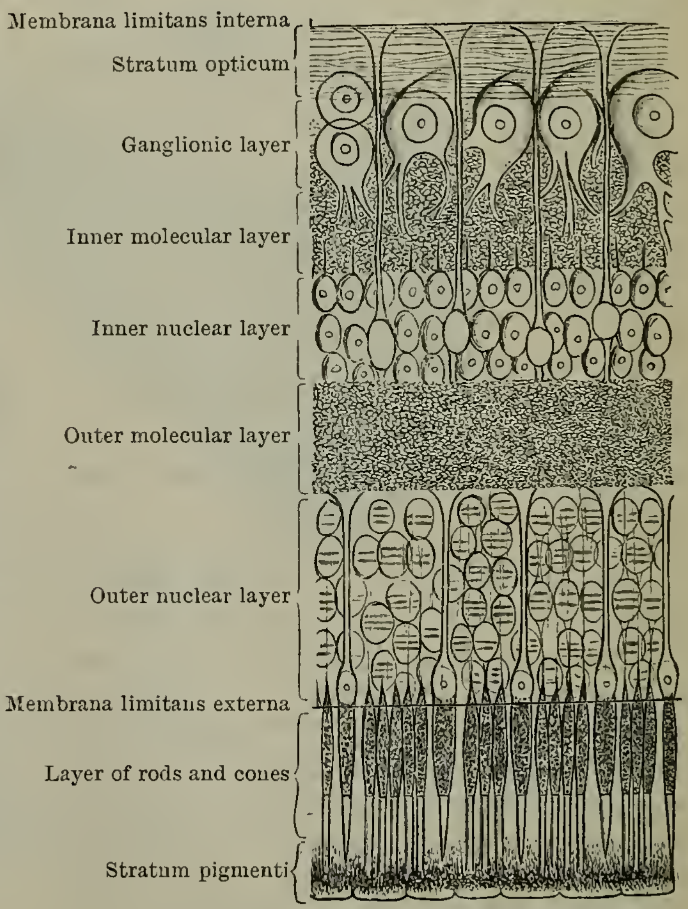

Fig. 655.—Diagrammatic Section of the Human Retina (modified from Schultze).

layer with those of the inner nuclear layer. It sometimes contains horizontal cells, the branched processes of which ramify in it.

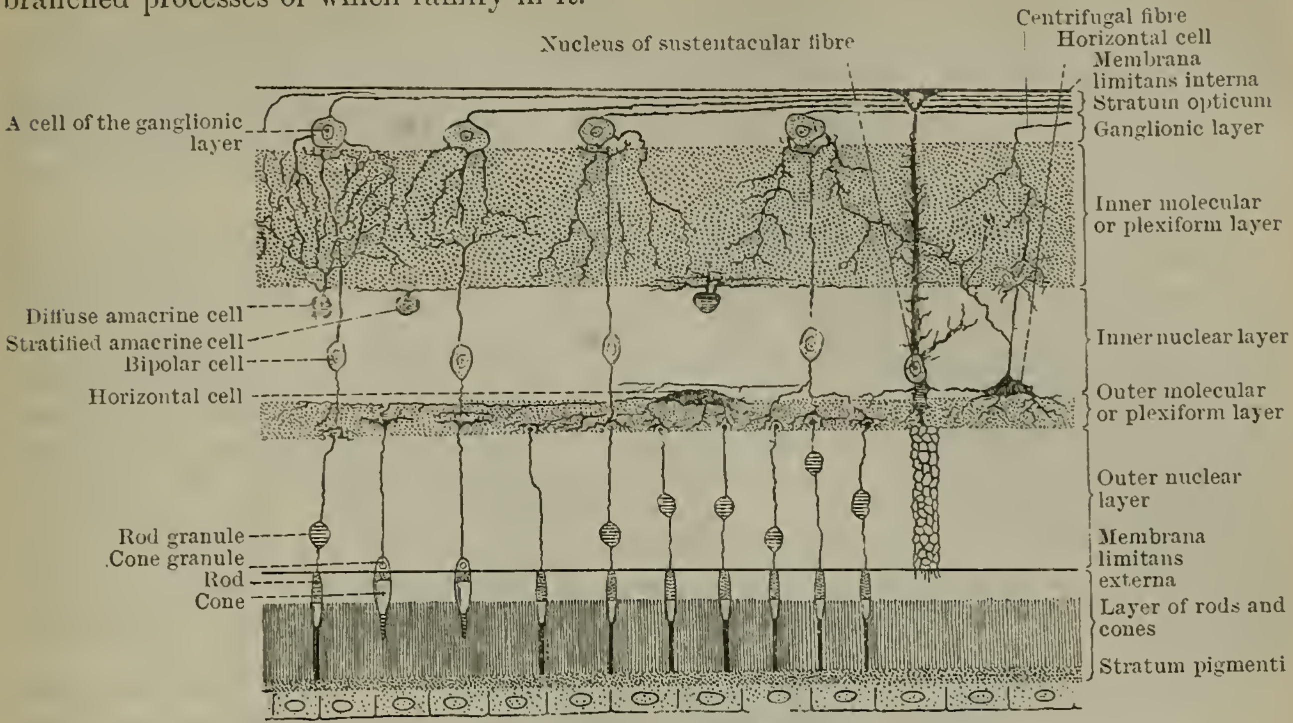

FIG. 656.—A PLAN OF THE RETINAL NEURONS. (After Cajal.)

4. **Inner nuclear Layer or Layer of inner Granules.**—This consists of numerous cells which may be divided into, (*a*) bipolar cells, (*b*) horizontal cells, and (*c*) amacrine cells.

(*a*) The **bipolar cells**, by far the most numerous, are fusiform and nucleated. They are divided into rod bipolars and cone bipolars, and each gives off an external and internal process. The external processes of the **rod bipolars** end in arborisations around the button-like ends or spherules of the rod fibres; their internal processes end in branches which mostly become applied to the cells of the ganglionic layer. The external processes of the **cone bipolars** end in flattened arborisations in the outer molecular layer, in contact with the ramifications of the foot-plates of the cone fibres; their internal processes ramify in one or other of the five strata of the inner molecular layer.

(*b*) The **horizontal cells** are of two varieties: (1) small, flattened, star-like cells, lying immediately internal to the outer molecular layer, and sending a tuft of dendrites outwards, towards the bases of the cone fibres, while their axons are directed horizontally, for a variable distance; (2) large, irregular cells, lying internal to the above and ending in finger-like ramifications in the outer molecular layer. Their axons run horizontally for some distance, and end, in extensive arborisations, under the spherules of the rod fibres.

(*c*) The **amacrine cells** are situated in the innermost part of the inner nuclear layer; their processes ramify in the inner molecular layer, it may be in one stratum (stratified cells) or in several strata (diffuse cells).

5. **Outer Molecular or outer Plexiform Layer.**—This is constituted by the interlacement of the dendrites of the bipolar and horizontal cells, just described, with the spherules of the rod fibres and the ramifications of the foot-plates of the cone fibres. It is divisible into two strata: (*a*) *external*, indicating the contact of the rod bipolars with the spherules of the rod fibres; (*b*) *internal*, the line of contact between the cone bipolars and the branches of the cone fibres.

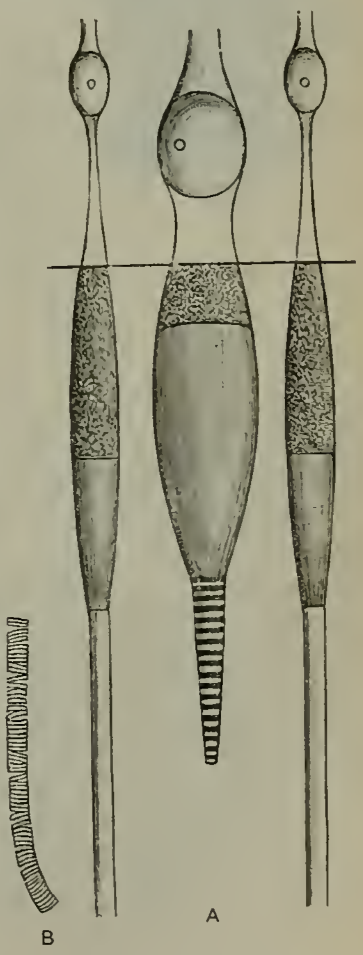

FIG. 657.

A, A cone and two rods from the human retina (modified from Max Schultze); B, Outer part of rod separated into discs.

6. **Outer Nuclear Layer or Layer of outer Granules.**—This is made up of clear granules which somewhat resemble those of the inner nuclear layer, and are divisible into two kinds: (*a*) cone granules, (*b*) rod granules. The **cone granules** are the larger, and each contains an oval nucleus; they lie immediately inside the

outer limiting membrane, through which they are continuous with the cones of the next layer. Each is prolonged internally as a straight fibre; in the outer molecular layer this fibre expands to form a foot-plate, from which several horizontal fibrils are given off. The **rod granules** are far more numerous than the cone granules, and each contains a small oval nucleus, which, in some animals, is transversely striated. Their external processes are continuous, through the outer limiting membrane, with the rods of the next layer, while their internal processes end in the outer molecular layer as free, unbranched spherules amongst the arborisations of the rod bipolars.

7. **Layer of Rods and Cones.**—This consists of two sets of structures, viz., **rods** and **cones**. Except at the macula lutea the rods are far more numerous than the cones, and assume the form of elongated cylinders, while the cones are shorter than the rods, and taper externally to fine points. Each rod and cone consists of two segments—inner and outer. The inner segment of the rod only slightly exceeds the outer in diameter, whereas the inner segment of the cone greatly exceeds the outer in diameter. The inner segments of both rods and cones have an affinity for staining reagents, and each consists of a basal homogeneous portion and an outer longitudinally striated part, the proportion of the latter to the former being greater in the cones than in the rods. The outer segments have not the same affinity for reagents, but tend to break transversely into numerous discs (Fig. 657, B). The colouring matter, *rhodopsin*, already referred to, is found only in the outer segments of the rods, the terminal parts of which extend into the layer of pigmented epithelium.

8. **Stratum Pigmenti.**—This consists of a single stratum of cells which, on surface view, are hexagonal (Fig. 658), their outer flattened surfaces being firmly attached to the chorioid. When seen in profile the outer part of each cell contains a large oval nucleus and is devoid of pigment, while the inner portion is filled with pigment and extends as a series of thread-like processes amongst the outer segments of the rods and cones. When the eye is in the dark the pigment accumulates near the outer part of the cell, but when the eye is exposed to light the pigment streams in between the rods and cones.

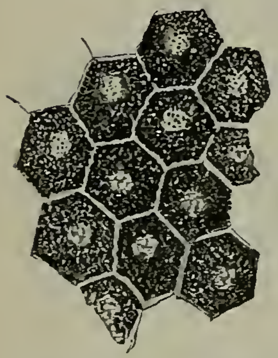

FIG. 658. — STRATUM PIGMENTI OF HUMAN RETINA (viewed from the surface).

Sustentacular Fibres of the Retina.—These form a framework for the support of the nervous structures (Fig. 656). They begin at the inner surface of the nerve-fibre layer in single or forked expanded bases, by the apposition of which a delicate membrane, the **membrana limitans interna**, is formed. In the ganglionic layer they give off a few side branches, and in the inner nuclear layer supply ramifications amongst the inner granules for their support; in this part of each fibre there is an oval nucleus. In the outer nuclear layer they break up into a network of fibrils which surround the rod and cone granules and fibres, and end at the bases of the rods and cones in a delicate membrane, the **membrana limitans externa**.

Structure of the Macula Lutea and Fovea Centralis.—The yellow colour of the macula is due to the presence of pigment in the inner layers of the retina. At the circumference of the macula the nerve-fibre layer is greatly thinned and the rods are few in number; the ganglionic layer, on the other hand, is thickened and may contain from seven to nine strata of cells, while the outer granular layer also is thicker and its granules have an oblique direction. At the fovea centralis the retina is much thinned, since here its nerve-fibre and ganglionic layers are absent and its other strata greatly attenuated. The stratum pigmenti, on the other hand, is thicker and its pigmentation more pronounced. The cone nuclei are situated some distance internal to the outer limiting membrane. There are no rods, and the cones, closely crowded together, are narrower and their outer segments more elongated than elsewhere. The fovea centralis and macula lutea are spoken of by physiologists as the "region of distinct vision."

At the ora serrata the nervous layers of the retina suddenly cease; the layer of rods and cones ends a little behind the margin of the ora serrata; the other nervous strata persist as far as its margin. In front of the ora serrata the retina is prolonged over the ciliary processes in the form of two layers of cells: (*a*) an inner layer of columnar epithelium, and (*b*) an outer, consisting of the stratum pigmenti, the two forming the pars ciliaris retinæ. The same layers are prolonged over the back of the iris, where both are pigmented and form the pars iridica retinæ.

Vessels of the Retina (Fig. 659).—The retina is supplied by the **arteria centralis retinæ**, a branch of the ophthalmic artery; it pierces the sheath of the optic nerve about 2 cm. behind the bulb of the eye, and makes its appearance in the centre of the optic papilla.

There it divides into an upper and a lower branch, and each of these again bifurcates into a medial or nasal, and a lateral or temporal, branch. The resulting four branches ramify towards the periphery of the retina, and are named the superior and inferior temporal and the superior and inferior nasal arteries. The temporal arteries pass laterally above and below the macula lutea, to which they give small branches; these do not, however, extend as far as the fovea centralis, which is devoid of blood-vessels. The macula also receives two small arteries (superior and inferior macular) directly from the stem of the arteria centralis. The larger vessels run in the nerve-fibre layer near the membrana limitans interna and form two capillary networks, one in the nerve-fibre layer, and another in the inner nuclear layer. The inner network arises directly from the arteries, and sends numerous small branches to form the outer network, from which the veins take origin. The vessels do not penetrate deeper than the inner nuclear layer, nor do the arteries anastomose, except through the capillary plexuses. The veins follow the course of the arteries; they have no muscular coats, but consist merely of a layer of endothelial cells, outside which is a perivascular lymph-sheath, surrounded by delicate retiform tissue.

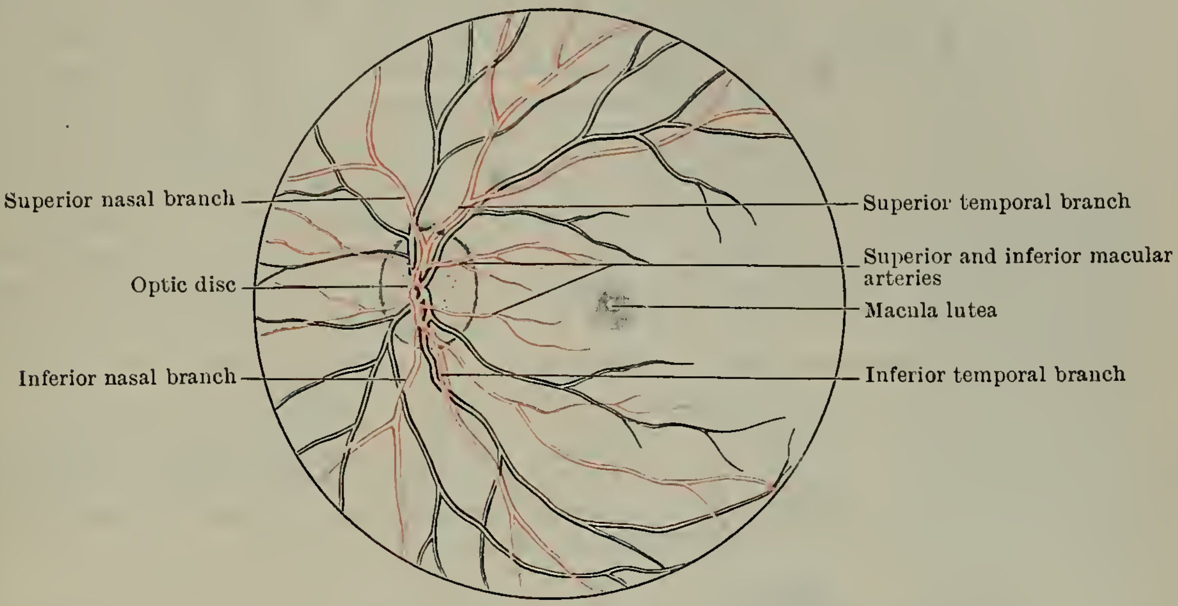

Fig. 659.—Blood-vessels of the Retina.

REFRACTING MEDIA.

Corpus Vitreum.—The **vitreous body** is a transparent, jelly-like substance situated between the crystalline lens and the retina, and occupying the posterior four-fifths of the bulb of the eye (Fig. 645). In front it presents a deep concavity, the **hyaloid fossa** (O.T. **fossa patellaris**), for the reception of the posterior convexity of the lens. It is enclosed within a thin transparent membrane, the **membrana hyaloidea**, which is in contact with the membrana limitans interna of the retina, and is adherent to it at the entrance of the optic nerve. The portion of the membrana hyaloidea in front of the ora serrata is thickened and strengthened by radial fibres, and is termed the **zonula ciliaris**. Situated behind the ciliary body, the zonula is radially folded and presents a series of alternating furrows and elevations. The ciliary processes are received into, and are firmly adherent to, the furrows, with the result that, if removed, some of their pigment remains attached to the zonula. The elevations of the zonula are not attached to the interciliary depressions, but are separated by a series of lymph-spaces named the **recessus cameræ posteriores**; these may be regarded as diverticula of the posterior chamber with which they communicate. Near the equator of the lens the zonula ciliaris splits into two chief layers: (*a*) a thin posterior lamina, which lines the hyaloid fossa, and (*b*) a thicker anterior layer, the **suspensory ligament** of the lens

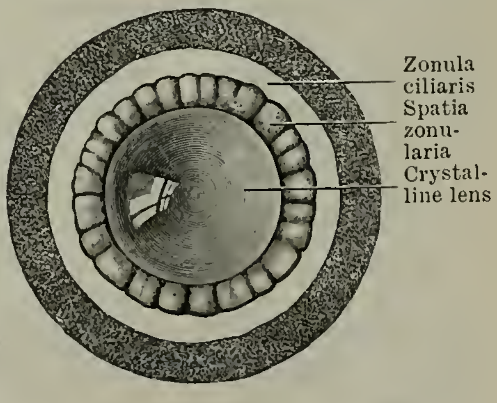

Fig. 660.—The Spatia Zonularia distended and viewed from the Front (enlarged).

(Fig. 654), which blends with the front of the lens capsule a short distance from the equator of the lens. Scattered fibres of this ligament are also attached to the lens capsule at the equator and to the regions immediately anterior and posterior to it. By this suspensory ligament the lens is retained in position, and its convexity varies inversely with the degree of tension of the ligament. The ciliary muscle, by pulling forward the ciliary processes and the attached zonula ciliaris, relaxes the ligament, and thus allows the lens to become more convex. Behind the suspensory ligament, a sacculated lymph-space surrounds the equator of the lens; it is named the **spatia zonularia** (O.T. **canal of Petit**), and may be easily inflated on introducing a fine blow-pipe through the suspensory ligament (Fig. 660). In the fœtus an artery, the **arteria hyaloidea**, runs forwards from the arteria centralis retinæ through the vitreous body, for the supply of the capsule of the lens. Its position, in the adult, is represented by a lymph-channel, termed the **canalis hyaloideus** of Stilling (Fig. 645); the presence of this canal can be demonstrated by shaking up the vitreous body in a solution of picrocarmine, when some of the pigment may be seen to enter the canal (Anderson Stuart[1]).

When the vitreous body is treated by a weak solution of chromic acid it presents a series of concentric, peripherally arranged striæ, together with numerous radial striæ. Between these the more fluid part lies, and it frequently contains vacuolated amœboid cells scattered through it. The vitreous body consists of 98·4 per cent of water, having in solution about 1·4 per cent of sodium chloride and traces of extractives and albumen.

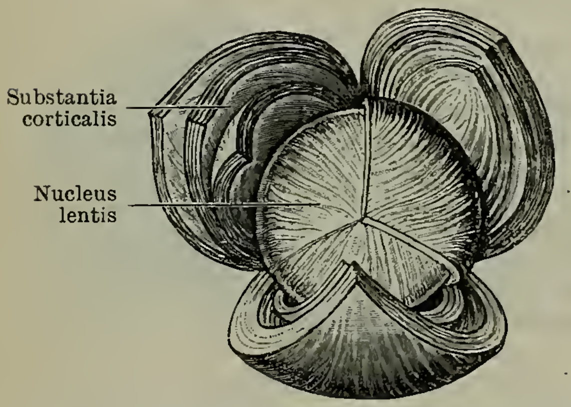

FIG. 661.—LENS HARDENED IN FORMALIN AND DISSECTED TO SHOW ITS CONCENTRIC LAMINÆ (enlarged).

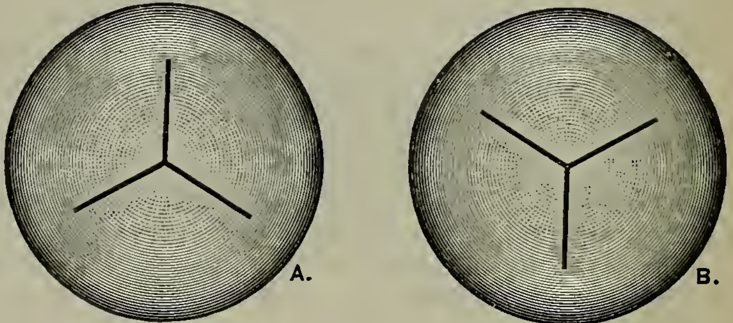

FIG. 662.—DIAGRAMMATIC REPRESENTATION OF THE RADIAL LINES OF THE FŒTAL LENS.

A, Seen from the front; B, From behind.

Lens Crystallina.—The **crystalline lens** lies in front of the vitreous body and behind the iris. It is a biconvex, transparent body (Fig. 662), enclosed in a thin, transparent, homogeneous capsule, the *capsule of the lens.* The central points of its anterior and posterior surfaces are termed respectively its **anterior** and **posterior poles**; a line joining the poles is known as its **axis**; its peripheral circumference is named the **equator.** Its axial measurement is 4 mm., and its transverse diameter from 9 to 10 mm. Its anterior surface is less convex than the posterior and is in contact with the pupillary margin of the iris; the central part of this surface corresponds with the aperture of the pupil and is directed towards the anterior chamber; the peripheral part is separated from the iris by the aqueous humour of the posterior chamber. The posterior surface of the lens is more convex than the anterior, and occupies the hyaloid fossa of the vitreous body. The curvatures of the surfaces of the lens, especially that of the anterior surface, are constantly varying, during life, for the purpose of focussing on the retina near or distant objects.

Structure.—The **substantia lentis** consists of a soft outer part, the **substantia corticalis,** easily crushed between the finger and thumb, and of a dense central part, the **nucleus lentis.** The refractive index of the substantia corticalis is about 1·4; that of the nucleus lentis about 1·45. Faint radial lines run from the anterior and posterior poles of the lens towards its equator. In the fœtus they are three in number, and form angles of 120° with each other (Fig. 662). From the anterior pole one ray ascends vertically and the other two diverge downwards, whilst from the posterior pole one ray descends vertically and the other two diverge upwards. In the adult the rays may be increased to six or more. They represent the free edges of a corresponding number of septa which dip into the substance of the lens, and along which the extremities of the different groups of lens fibres come into contact, and are attached by a clear, amorphous substance. The lens, when hardened, exhibits a series of concentrically arranged laminæ (Fig. 661), superimposed like the scales of an onion and attached to each other by a clear, amorphous substance. Each lamina is split along the radiating lines, and consists of a series of hexagonal, riband-like fibres, the **fibræ lentis**, which are adherent to each other by their margins; the fibres of the deeper laminæ are small and serrated, but non-nucleated; while those of the superficial coats are large and nucleated, but non-serrated. The fibres extend in a curved manner from the rays on the anterior surface to the rays on the posterior surface, but no fibre extends from pole to pole. Fibres which start at or near one pole end at or near the equator on the opposite surface, and *vice versa*, while the intervening fibres take up intermediate positions. Between the substantia lentis and the anterior part of the capsule there is a layer of nucleated columnar cells, the **epithelium lentis**. Towards the equator the cells of this epithelium become gradually elongated and transformed into lens fibres, which, when fully formed, lose all trace of their nuclei, except in the more superficial laminæ. Each lens fibre represents, therefore, a greatly elongated columnar cell (Fig. 663).

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[1] T. P. Anderson Stuart, *Journal of Anatomy and Physiology,* vol. xxv.

In the fœtus the lens is soft, of a pinkish colour, and nearly spherical; in old age it becomes somewhat flattened, and assumes a yellowish tint.

Cameræ Oculi (Fig. 645).—As already stated (p. 808), the space between the cornea and the lens is divided by the iris into two unequal parts, viz., the camera oculi anterior, and the camera oculi posterior. These are filled with the **aqueous humour**, and, in the adult, communicate freely through the aperture of the pupil; in the fœtus they are separated by the membrana pupillaris. The **camera oculi anterior** or **anterior chamber** is bounded in front by the cornea, behind by the iris and lens, whilst peripherally it communicates with the spatia anguli iridis. The **camera oculi posterior** or **posterior chamber** is triangular on section, and is bounded in front by the iris, behind by the circumferential part of the lens and its suspensory ligament; the base of the triangle corresponds with the broad, anterior extremities of the ciliary processes. It communicates with the recessus cameræ posteriores and spatia zonularia.

The aqueous humour has a refractive index of about 1·336, and consists of about 98 per cent of water, with 1·4 per cent of sodium chloride, and traces of albumen.

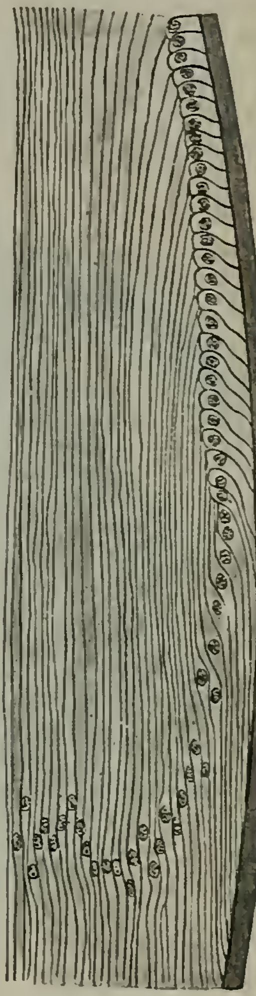

Fig. 663.

Section through the Equator of the Lens.

Showing the gradual transition of the epithelium into lens fibres. (After Babuchin.)

SUPERCILIA.

The **supercilia** or **eyebrows** are two arched eminences of thickened skin which surmount the orbits, and are covered by short stout hairs. Deep to the skin are the interlacing fibres of the frontalis, corrugator, and orbicularis oculi muscles, whilst between these and the galea aponeurotica is a layer of fatty and areolar tissue, which is thickest in the lower part of the eyebrow.

PALPEBRÆ.[1]

The **palpebræ** or **eyelids** are two movable curtains situated in front of the bulb of the eye, and named, from their positions, **superior** and **inferior**. The superior is the larger, and the more movable, being provided with an elevator muscle, the *m. levator palpebræ superioris*. The interval between the eyelids is termed the **palpebral fissure** (rima palpebrarum), and measures transversely about 30 mm., but varies considerably in different individuals and in different races. When the eye is open the fissure is elliptical in shape, but when closed it assumes the form of a transverse slit, which lies on a level with the lower margin of the cornea. The two eyelids meet at the extremities of the fissure, and form the **lateral** and medial commissures. Their free margins are flattened, and their points of meeting are named the medial and lateral *angles* or *canthi.* The free margins are surmounted by eyelashes, from the lateral angle to a point about 6 mm. from the medial angle —a point indicated by a small papilla, the **papilla lacrimalis.** Medial to this papilla the margins are rounded and destitute of eyelashes, and form the upper and lower boundaries of a triangular space, termed the **lacus lacrimalis,** which is occupied by a small pink body, the **caruncula lacrimalis.** The caruncula consists of a small island of modified skin, and contains sebaceous glands, fine hairs and one or more acinotubular glands. Posteriorly the lids are lined with mucous membrane, the conjunctiva, and are in contact with the bulb of the eye, except near the medial commissure, where there intervenes a vertical fold of conjunctiva, the **plica semilunaris conjunctivæ,** which in many animals contains a plate of cartilage.

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[1] For further details of the structure of the eyelids, lacrimal apparatus, etc., the reader is referred to *The anatomy of the human orbit and accessory organs of vision*, by S. Ernest Whitnall, 1921.

Structure.—In each eyelid there is a plate of condensed fibrous tissue, which gives consistence and shape to the lid, and is termed the **tarsus.** In front of the tarsus are the fibres of the orbicularis oculi muscle and the skin, while embedded in the posterior surfaces of the tarsi, and covered by the conjunctiva, are numerous modified sebaceous glands, named the **tarsal glands.** The superior tarsus is larger than the inferior, and of a half oval shape, its greatest vertical diameter measuring about 10 or 11 mm. Its upper margin is thin and convex, and is continuous with the deep lamella (the non-striped muscle of Müller) of the aponeurosis of the levator palpebræ superioris muscle, while its lower edge is thick and straight. The inferior tarsus is a narrow plate, with a nearly uniform vertical diameter of about 5 mm.; its lower edge is united to the orbital septum.

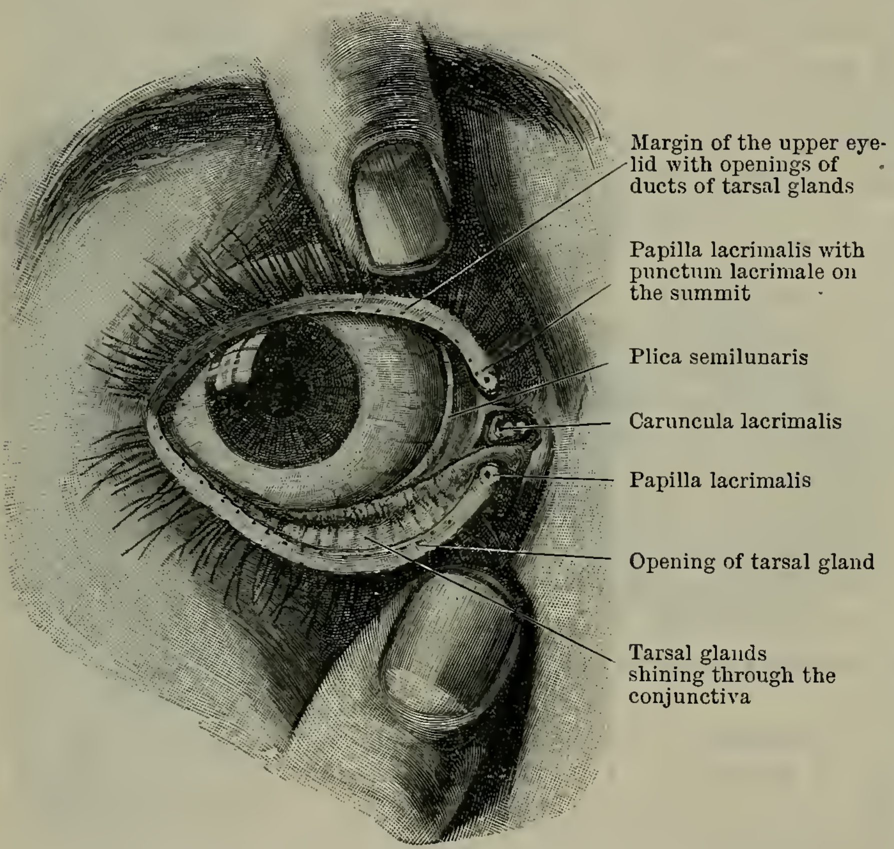
Margin of the upper eyelid with openings of ducts of tarsal glands
Papilla lacrimalis with punctum lacrimale on the summit
Plica semilunaris
Caruncula lacrimalis
Papilla lacrimalis
Opening of tarsal gland
Tarsal glands shining through the conjunctiva

Fig. 664.—Eyelids slightly everted to show the Conjunctiva (enlarged).

In the commissures of the eyelids the ends of the tarsi unite to form the lateral and medial palpebral ligaments which fix the tarsi to the wall of the orbital cavity. The **lateral tarsal ligament** is thin; it connects the lateral ends of the tarsi to a small tubercle on the orbital surface of the zygomatic bone, and is separated from the lateral palpebral raphe by a narrow cleft which may contain a few lobules of the lacrimal gland. The *lateral palpebral raphe* is formed by the interlacing ends of the palpebral fibres of the orbicularis oculi, strengthened by the underlying orbital septum; " it does not represent the lateral termination of the tarsal plates as is erroneously described " (Whitnall). The **medial palpebral ligament** (O.T. tendo oculi) is a strong fibrous band, continuous with the medial ends of the tarsi. It is fixed to the upper one-half of the anterior lacrimal crest, and to the adjacent part of the frontal process of the maxilla; it is also adherent to the lacrimal fascia (p. 820) which roofs over the lacrimal fossa. The upper part of the medial palpebral ligament is thin, and blends with the periosteum; the lower part is thick, and ends inferiorly in a free edge. The orbicularis oculi arises from the greater part of the anterior surface of the ligament. Superficial to the ligament are the angular artery and vein: deep to it is the upper one-half of the lacrimal sac. Close to its origin from the tarsal plates, the medial palpebral ligament gives off a posterior thin lamella, which passes behind the lacrimal fossa, clothes the anterior surface of the pars lacrimalis muscle, and is fixed to the posterior lacrimal crest.

The eyelids are further strengthened by a membranous sheet, named the **orbital septum,** which extends into them from the margin of the base of the orbit where it is continuous with the periosteum. In the upper eyelid this septum fuses with the superficial lamella of the aponeurosis of the levator palpebræ superioris; in the lower eyelid it is thin, and blends with the anterior surface of the inferior tarsus. It is perforated by the vessels and nerves which pass from the orbital cavity to the face or scalp.

The skin covering the eyelids is thin, and is continuous, at their free margins, with their conjunctival lining. It contains numerous small sudoriferous glands and fine hairs, the latter being provided with sebaceous follicles. Branched pigment-cells are present in the cutis, and pigment exists also in the deep layers of the epidermis. The subcutaneous tissue is loose and devoid of fat, and in it are found the fibres of the orbicularis oculi muscle—a small separate slip of which, termed the **ciliary bundle** or **muscle of Riolan**, occupies the margin of the lids behind the eyelashes.

The **glandulæ tarsales** (O.T. **Meibomian glands**) are elongated sebaceous glands with numerous lateral offshoots (acini); they are embedded in the tarsi, and are filled with cubical epithelium. There are from twenty-five to thirty in the upper eyelid, and from twenty to twenty-five in the lower; they open by small ducts, about 1 mm. in length, along the lid margins, behind the eyelashes. The ducts are lined with cubical epithelium, placed on a basement-membrane; in the mouths of the ducts the epithelium is stratified. Between the eyelashes and the muscle of Riolan are two or three rows of modified sudoriferous glands, termed the **glands of Moll**.

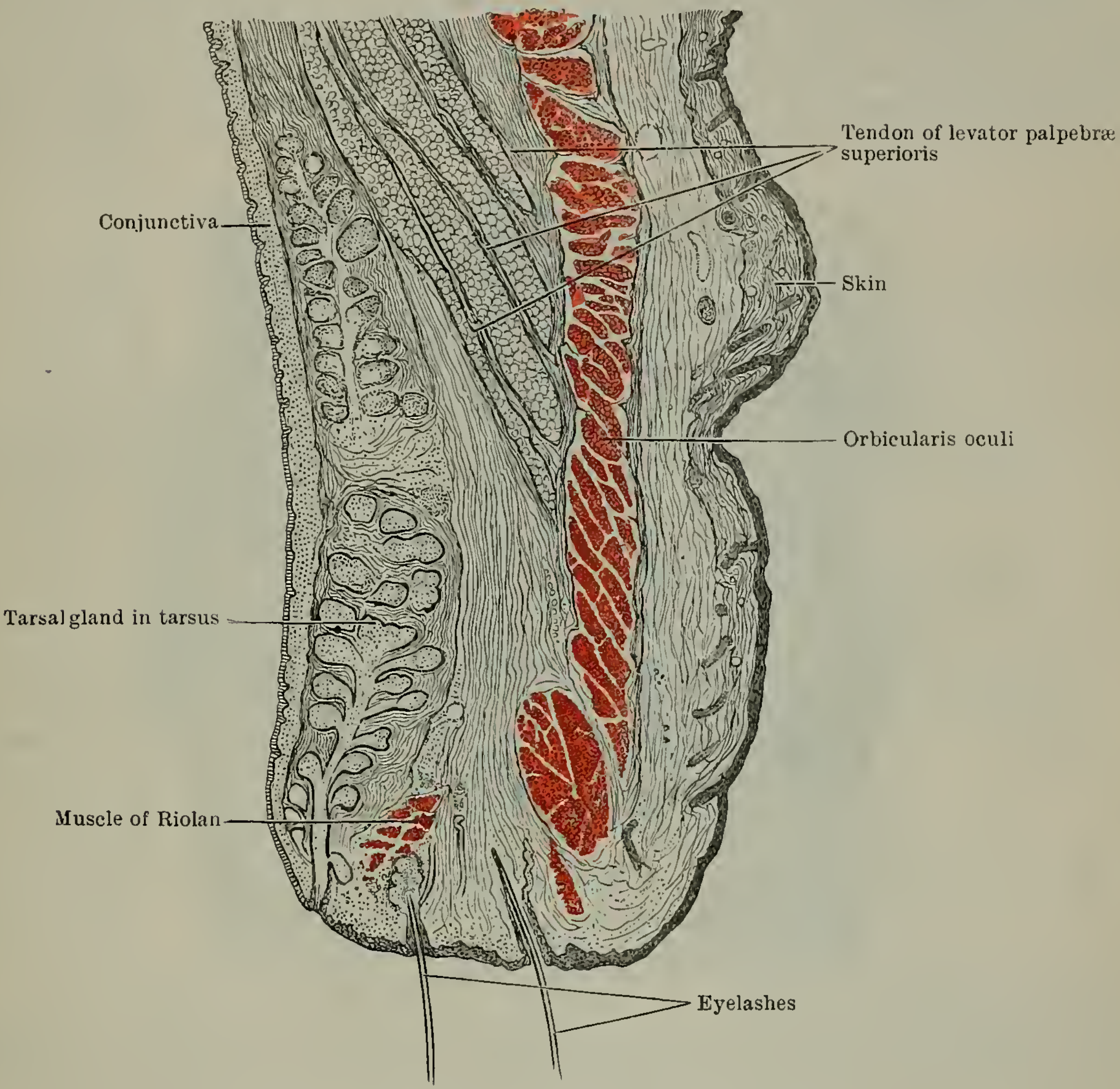

FIG. 665.—SAGITTAL SECTION THROUGH SUPERIOR EYELID.

H. Müller described a layer of non-striped muscle in each eyelid: in the superior eyelid it extends from the aponeurosis of the levator palpebræ superioris to the upper tarsus (p. 816); in the inferior eyelid it arises from the sheath of the obliquus inferior and divides into two lamella, one ending in the bulbar conjunctiva, the other in the lower eyelid.

The eyelashes are curved, short hairs which project from the free margins of the eyelids; in the upper eyelid they are curved upwards, and are longer and more numerous than those in the lower eyelid, which are bent downwards.

Conjunctiva.—The **conjunctiva** is the mucous membrane which clothes the deep surfaces of the eyelids, and is reflected, from them, on to the front of the bulb of the eye; the line of reflection is known as the **conjunctival fornix**, which in different regions is referred to as the superior, inferior, lateral or medial fornix. The part on the eyelids is termed the **tunica conjunctiva palpebrarum**, that on the bulb of the eye the **tunica conjunctiva bulbi**. The tunica conjunctiva palpebrarum is highly vascular, and intimately adherent to the tarsi. It is covered with a layer of columnar epithelial cells, beneath the bases of which are small flattened cells; near the upper and lower fornices a number of acino-tubular glands, much more plentiful in the upper than in the lower eyelid, open on its free surface; these glands are structurally identical with the lacrimal gland. The tunica conjunctiva bulbi is thinner than the tunica conjunctiva palpebrarum. A short distance behind the sclero-corneal junction it blends with the fascia bulbi, which separates it from the sclera. On the cornea the conjunctiva is represented merely by the epithelium corneæ (p. 805). The plica semilunaris conjunctivæ has already been referred to (p. 816).

Vessels and Nerves.—The chief **arteries** of the eyelids are the superior and inferior palpebral branches of the ophthalmic artery; these pierce the orbital septum above and below the medial palpebral ligament, and run lateralwards in the corresponding lid near its free margin; the lower eyelid also receives twigs from the external maxillary artery. At the lateral palpebral commissure they anastomose with each other and with twigs from the lacrimal, superficial temporal, and transverse facial arteries, and in this way a primary arch is formed in either lid. Secondary smaller arches are found, one above the primary arch in the upper lid, and another below that of the lower lid, while the upper lid receives branches also from the supra-orbital and frontal arteries. The **veins** are arranged in two sets: (*a*) subconjunctival or retrotarsal, opening into the muscular tributaries of the ophthalmic veins, and (*b*) pretarsal, opening into the angular and superficial temporal veins. The **lymph-vessels**, like the veins, form pre- and retrotarsal networks, which communicate with each other through the tarsal plates. The lymph is drained chiefly into the anterior auricular and parotid lymph-glands, but partly, by vessels which accompany the anterior facial vein, into the submaxillary lymph-glands. The **sensory nerves** of the eyelids are supplied by the trigeminal nerve—the upper lid chiefly by the supra-orbital and supra-trochlear branches of the ophthalmic nerve; the lower, by the infra-orbital branch of the maxillary nerve. The region of the lateral commissure receives some filaments from the lacrimal nerve, that of the medial from the infra-trochlear nerve. These sensory nerves form a marginal plexus behind the orbicularis oculi muscle. The levator palpebræ superioris muscle is supplied by the oculo-motor nerve and the non-striped fibres of the eyelids by the sympathetic.

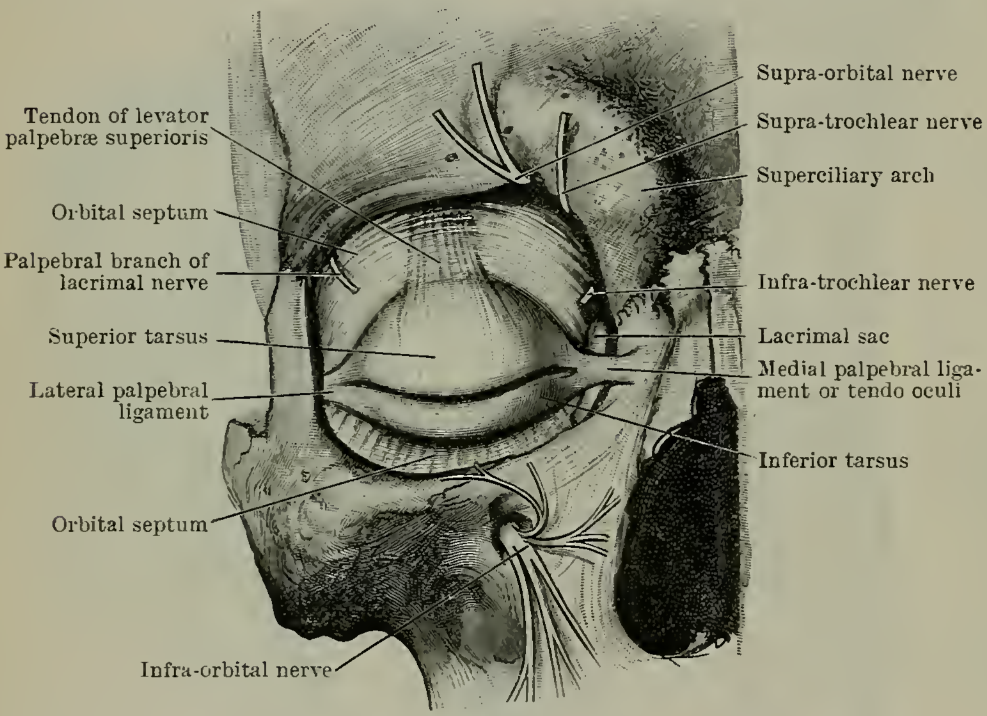

FIG. 666.—DISSECTION OF THE RIGHT EYELID. The orbicularis oculi has been removed.

APPARATUS LACRIMALIS.

The **lacrimal apparatus** consists of: (1) the lacrimal gland, which secretes the tears; and (2) the lacrimal ducts, lacrimal sac and naso-lacrimal duct, through which they are conveyed into the nasal cavity.

Glandula Lacrimalis.—The **lacrimal gland** (Fig. 667) is of about the size and form of an almond; it is situated in the upper and lateral part of the orbital cavity, and consists of two portions—superior and inferior—imperfectly separated from each other by the aponeurosis of the levator palpebræ superioris muscle. The **glandula lacrimalis superior** is firm, and much larger than the inferior; it measures transversely about 20 mm., and sagittally from 12 to 14 mm. It occupies the fossa on the medial surface of the zygomatic process of the frontal bone. The anterior part of its ocular surface lies on the aponeurosis of the levator palpebræ superioris, but the posterior part, which is continuous with the glandula lacrimalis inferior, lies on the fascial expansion which passes from the sheath of the rectus superior to that of the rectus lateralis, whereby it is separated from the fascia bulbi. The **glandula lacrimalis inferior**, from one-half to one-third the size of the glandula lacrimalis superior, consists of small, loosely aggregated lobules; it lies below and in front of the orbital portion, and projects into the posterior part of the upper eyelid, where its deep surface is in contact with the palpebral conjunctiva. The ducts draining the glandula superior are from three to five in number; they pass between the lobules of the glandula inferior, and open at the upper and lateral part of the fornix conjunctivæ superior. The ducts of the glandula inferior number from three to nine; some of them join those from the glandula superior, while others open separately at the fornix conjunctivæ superior. In close relation with the conjunctival fornices (especially the superior fornix) are numerous small *accessory lacrimal glands*, the secretion from which may serve to moisten the conjunctiva after the extirpation of the two main parts of the gland.

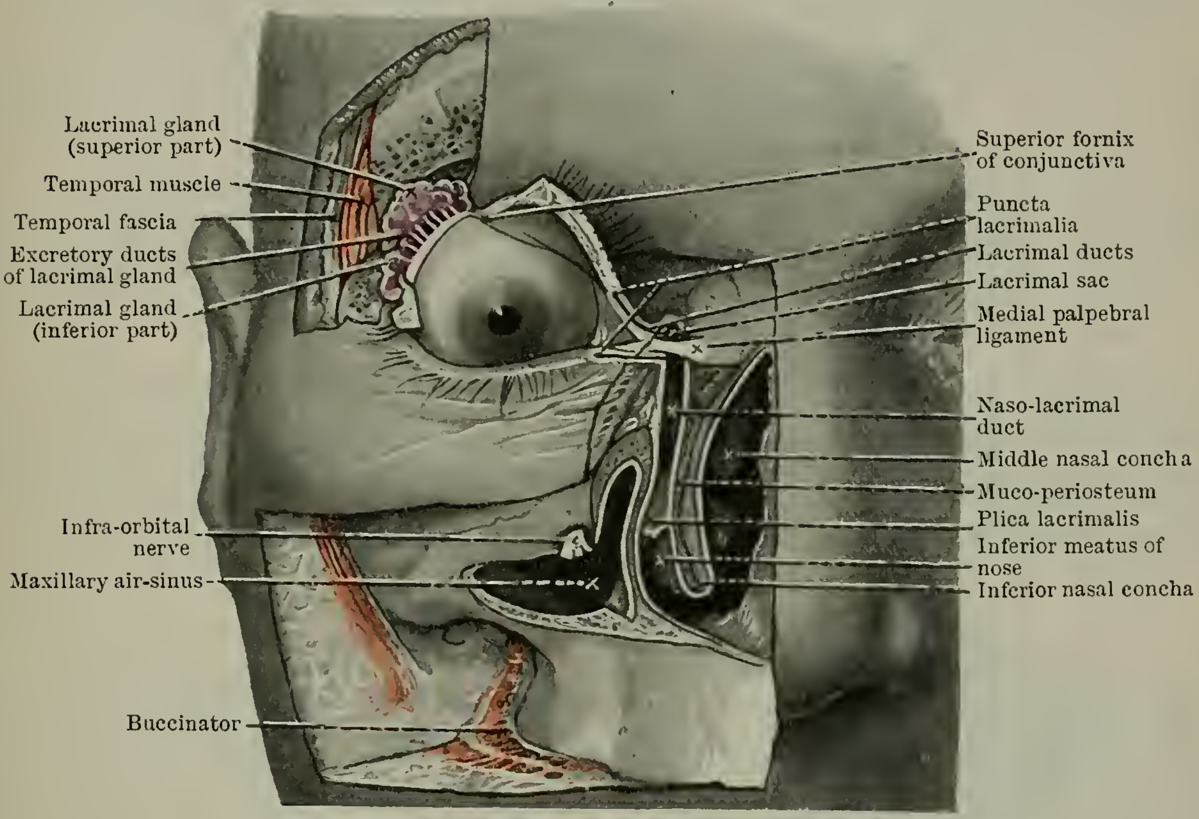

FIG. 667.—DISSECTION TO SHOW THE LACRIMAL APPARATUS.

Structure.—The structure of the lacrimal gland resembles that of the parotid gland; it is supplied by the sympathetic, lacrimal, and facial nerves, and by the lacrimal artery; its veins open into the ophthalmic vein.

Ductus Lacrimales.—The **lacrimal ducts** (Fig. 667), one in either eyelid commence in minute orifices, termed *puncta lacrimalia,* situated at the apices of the papillæ lacrimales (p. 816), and are directed along the medial parts of the margins of the eyelids, above and below the lacus lacrimalis; each duct is about 10 mm. long. The superior duct at first ascends for a short distance and then inclines downwards; the inferior duct descends for a short distance and then runs horizontally; at the angles they are dilated into ampullæ. The two ducts open close together into the lateral and front part of the lacrimal sac, a little above its middle; sometimes they open into a pouch-like dilatation of the sac, termed the *sinus of Maier.* The ducts are lined with stratified epithelium placed on a basement-membrane, outside which is a layer of striped muscular fibres continuous with the lacrimal part of the orbicularis oculi. These muscular fibres are arranged somewhat spirally around the ducts, but at the base of each papilla lacrimalis they are circular in direction and form a species of sphincter. On contraction they probably serve to empty the contents of the lacrimal ducts into the lacrimal sac.

The **saccus lacrimalis** and **ductus nasolacrimalis** together form the passage by which the tears are conveyed from the lacrimal ducts to the nasal cavity.

The **lacrimal sac** (Figs. 666, 667) is the upper part of the passage, and measures about 12 mm. in length; its upper part is flattened from side to side, and may be likened to the end of a quill pen seen sideways. It lies in the lacrimal fossa or groove formed by the lacrimal bone and the frontal process of the maxilla; its upper end is closed; its lower end is continued into the naso-lacrimal duct. At the junction of the sac and duct a fold of mucous membrane, named the *valve of Beraud,* together with a laterally directed pouch, the *sinus of Arlt,* are sometimes present. A fascia, continuous with the orbital periosteum, and named by Whitnall the **lacrimal fascia**, stretches from the anterior to the posterior lacrimal crest, and roofs over the lacrimal fossa; there is usually a minute plexus of veins between this fascia and the lacrimal sac. The medial palpebral ligament lies in front of the upper one-half of the lacrimal sac, and the pars lacrimalis muscle behind it; the lower one-half of the sac is below these two structures. The anterior ethmoidal air-cells lie on the medial or nasal side of the upper part of the lacrimal fossa.

The **naso-lacrimal duct** (Fig. 667) is about 18 mm. long, and has a diameter of from 3 to 4 mm. Rather narrower in the middle than at its extremities, it is directed downwards and slightly backwards, and opens into the inferior meatus of the nose at the junction of its anterior one-fourth with its posterior three-fourths, *i.e.* a distance of about 30 mm. from the posterior boundary of the nostril. Its lower orifice is very variable in form and position; it is frequently guarded by a fold of mucous membrane, termed the **plica lacrimalis (Hasneri)**. The mucous membrane of the duct is thrown into inconstant folds, several of which have been described as valves. Its epithelium is columnar and in part ciliated.

The nerves of the lacrimal ducts and sac are derived from the infra-trochlear branch of the naso-ciliary nerve; the lower part of the naso-lacrimal duct receives a branch from the anterior superior alveolar nerve. The arteries of the lacrimal sac and naso-lacrimal duct are derived from the palpebral branches of the ophthalmic artery, the angular branch of the external maxillary artery, and the infra-orbital branch of the internal maxillary artery. The veins of the naso-lacrimal duct are large, and form a well-marked venous plexus.

Development of the Eye.

The retina and optic nerve are developed from a hollow outgrowth of the fore-brain, termed the **optic vesicle** (pp. 38 and 54). This extends towards the side of the head, and its connexion with the brain is gradually elongated to form the **optic stalk**. The ectoderm overlying the optic vesicle becomes thickened, invaginated, and finally cut off as a hollow island of cells, which is named the **lens vesicle**. This vesicle indents the outer and lower part of the optic vesicle, converting it into a cup (**optic cup**), which is lined by two layers of cells continuous with each other at the margin of the cup. The inner of these layers, thicker than the outer, is named the **retinal layer**, and becomes differentiated into the nervous and supporting elements of the retina; while the outer, named the **pigmentary layer**, forms the stratum pigmenti. The edge of the optic cup extends in front of the equator of the lens, and bounds the future aperture of the pupil. In front of the lens, and also opposite its equator, the retinal layer is thin, and is represented only by a stratum of columnar cells which becomes closely applied to the pigmentary layer, the two forming the pars ciliaris and pars iridica retinæ. The indentation of the optic cup extends as a groove for some distance along the postero-inferior aspect of the optic stalk, forming what is termed the **chorioidal fissure** (Fig. 669). Through this fissure mesoderm passes inwards between the lens and the retina to form a part of the vitreous body, while the arteria centralis retinæ also becomes enclosed in it and so gains its future position in the centre of the optic nerve. The arteria centralis is prolonged forwards from the porus opticus through the vitreous body, as a cone of branches, as far as the back of the lens. By the fifth or sixth month all these branches have disappeared except one, the **arteria hyaloidea**, which persists until the last month of fœtal life, when it also atrophies, leaving only the **canalis hyaloideus** to indicate its position.

The vitreous body is developed between the optic cup and the lens, and is derived partly from ectoderm and partly from mesoderm. It consists primarily of a series of fine protoplasmic fibres which project from the cells of the retinal layer of the cup and form a delicate reticular tissue. At first these fibres are seen in relation to the whole of the optic cup, but later they are limited to the ciliary region, where by a process of condensation they appear to form the zonula ciliaris of the hyaloid membrane. When the mesoderm enters the cup through the chorioidal fissure it unites with this reticular tissue to form the vitreous body.

The lens, at first in contact with the ectoderm from which it is derived, is soon separated from it by mesoderm, and then consists of a rounded vesicle with epithelial walls. The anterior wall remains as a single layer of cells—the anterior lens epithelium of the adult; the cells of the posterior wall become elongated into lens fibres, and by the forward growth of these the cavity of the vesicle is obliterated. This elongation into lens fibres is greatest at the centre of the lens, while near the equator the fibres are shorter, and here the gradual transition between the anterior epithelium and the lens fibres is seen (Fig. 663). The lens becomes enveloped in a vascular tunic, which receives its vessels from the arteria centralis retinæ and from the vessels of the iris. The front part of this tunic forms the membrana pupillaris which disappears before birth (p. 808).

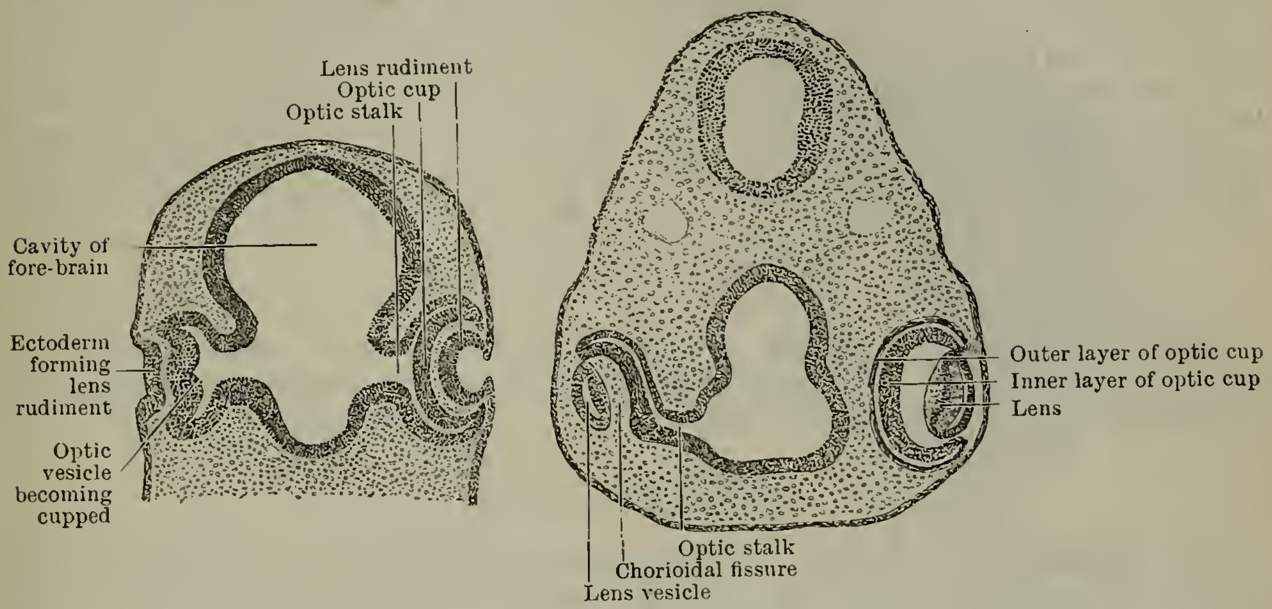

FIG. 668.—SECTIONS THROUGH PORTIONS OF THE HEADS OF FŒTAL RABBITS, to illustrate the connexion of the optic cup with the fore-brain, and the invagination of the ectoderm to form the lens.

The hollow optic stalk becomes solid by the thickening of its walls, and, acquiring nerve-fibres, is transformed into the optic nerve. These nerve-fibres are mostly centripetal, and are the axons of the ganglionic nerve-cells of the retina; but a few are centrifugal and arise from nerve-cells in the brain. The further development of the retina resembles, in certain respects, that of the spinal medulla.

Cameron states (*Journ. Anat. and Physiol.*, vol. xxxix.) that in the early stages of the development of the inner or retinal layer of the optic cup all the structures, described by His as being present in the spinal medulla of the human embryo, are to be found, viz., (*a*) spongioblasts, (*b*) germinal cells, and (*c*) neuroblasts.

The spongioblasts undergo ramification and form a network or myelospongium, and also give rise to the inner and outer limiting membranes; the latter is next the original cavity of the optic vesicle, and therefore corresponds to the inner limiting membrane of the spinal medulla. The spongioblasts also form the groundwork of the inner and outer molecular or plexiform layers into which the processes of the neuroblasts grow and arborise.

The germinal cells are always situated beneath the external limiting membrane, and by their division give rise to the neuroblasts. The first-formed neuroblasts are larger than those of succeeding generations, and are found in the site of the future ganglionic layer. The germinal cells in the middle of the convexity of the retinal cup cease to divide at an early stage of development, and become directly transformed into the rod and cone cells from which the rods and cones develop as processes; hence these structures appear first over the middle of the convexity of the retina.

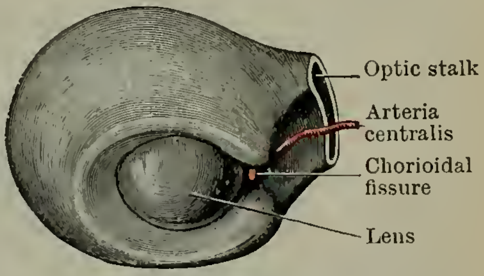

FIG. 669.—OPTIC CUP AND LENS VIEWED FROM BEHIND AND BELOW, to show formation of chorioidal fissure and enclosure of the arteria centralis retinæ (from model by Ziegler).

The molecular layers make their appearance as plexuses of myelospongium. The internal molecular layer is first developed at the centre of the retinal cup. The rod and cone fibres, and the outer processes of the bipolar cells of the internal nuclear layer, grow into and arborise within the external molecular layer.

The condensed mesoderm surrounding the optic cup becomes the sclera and chorioid. In the portion of the mesoderm which lies in front of the lens a cleft appears, and divides it into a thick anterior and a thin posterior layer. The former becomes the substantia propria of the cornea; the latter, the stroma of the iris and anterior part of the vascular tunic of the lens. The fissure represents the future camera oculi anterior, and its lining cells form the endothelium of this chamber.

The **eyelids** arise as two integumentary folds above and below the cornea, each being covered on both its surfaces by the ectoderm. By the third month the edges of the folds meet and unite, the eyelids being only permanently opened shortly before birth; in many animals they are not opened until after birth. The ectoderm forms the epithelium of the conjunctiva and the epithelium corneæ. It is also invaginated at the margins of the eyelids to form the hair-follicles and the lining cells of the tarsal glands and glands of Moll, and, at the fornix conjunctivæ superior, to form the lining cells of the alveoli and ducts of the lacrimal gland.

The **lacrimal sac** and **naso-lacrimal duct** are developed along the line of the furrow which separates the maxillary from the lateral nasal process. This furrow is lined by ectodermal cells, and these cells, after the meeting and fusion of the lips of the furrow, proliferate and form a solid rod which is embedded in the mesoderm. By the breaking down and disintegration of its central cells, this rod becomes hollowed out to form the lacrimal sac and the naso-lacrimal duct, the lower end of the latter remaining closed until near the end of fœtal life. The **lacrimal ducts** are developed as secondary buds of cells which extend lateralwards from the upper end of the solid rod, and which subsequently undergo canalisation. The **caruncula lacrimalis** is formed from a small part of the margin of the lower eyelid, which is cut off by the growth of the inferior lacrimal duct.

ORGANON AUDITUS.

The **ear** or **auditory organ** (Fig. 670) consists of three portions—external, middle, and internal; the peripheral terminations of the acoustic nerve are distributed within the internal portion.

EXTERNAL EAR.

The **external ear**[1] includes—(*a*) the auricula, attached to and projecting from the side of the head; and (*b*) the external acoustic meatus leading inwards from the most depressed part of the auricula to the tympanic membrane.

Auricula.

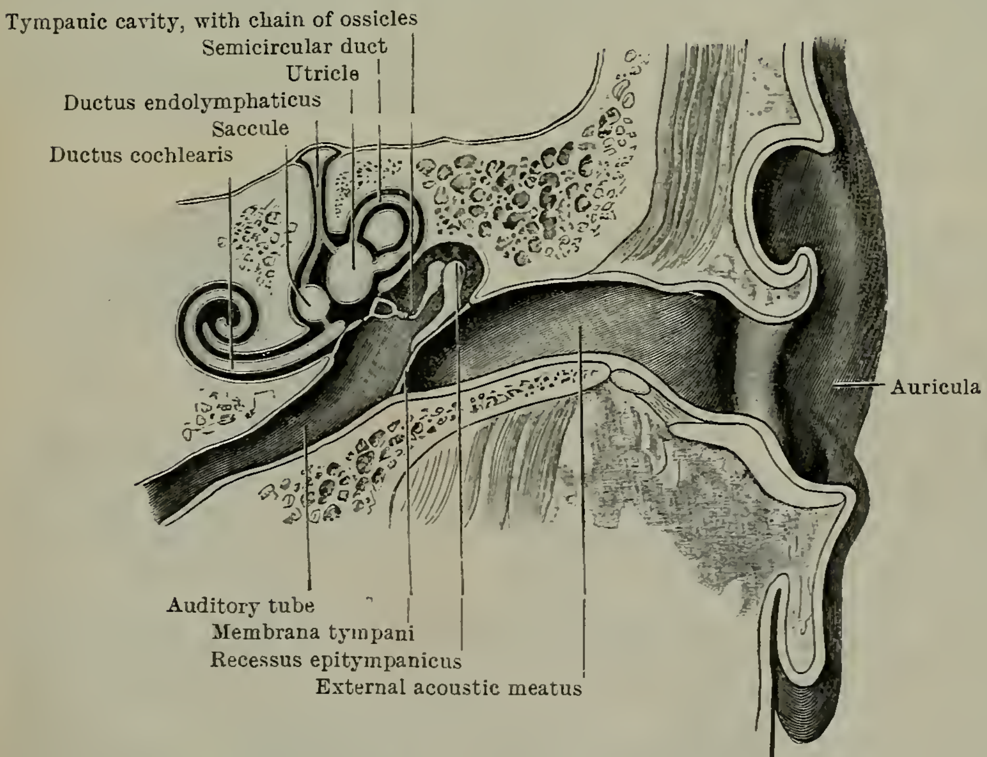

Fig. 670.—Diagrammatic View of the Organ of Hearing.

The **auricula** (O.T. **pinna**) (Fig. 671) forms an angle (cephalo-auricular angle) of about 30° with the side of the head. Its lateral surface is irregularly concave, but has several well-marked elevations and depressions. The deepest of the depressions, the **concha auriculæ**, is situated near the middle of the auricula; it is divided by a ridge, the **crus helicis**, into an upper, smaller portion, termed the **cymba conchæ**; and a lower, larger portion, the **cavum conchæ**; the latter leads into the external acoustic meatus. Anteriorly, the crus helicis is continuous with the **helix** or margin of the auricula, which is incurved in the greater part of its extent, and is directed at first upwards, and then backwards and downwards, to become gradually lost in the upper part of the lobule. Near the point where the helix begins to descend a small tubercle, the **tuberculum auriculæ (Darwini)**, is often seen. In front of the descending part of the helix is a second elevation, the **antihelix**, which divides superiorly into two limbs, termed the **crura**

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[1] Although it is usual to speak of the external, the middle, and the internal ear, it would be more correct to use the terms external, middle, and internal *portions* of the ear.

antihelicis; between the crura is a triangular depression, the **fossa triangularis.** The elongated furrow between the helix and antihelix is named the **scapha.** The concavity of the concha is overlapped in front by a tongue-like process, the **tragus,** and below and behind by a triangular projection, the **antitragus**; the notch, directed downwards and forwards between these two processes, is named the **incisura intertragica.** The tragus consists really of two tubercles, the upper of which constitutes the **tuberculum supratragicum** of His, and is separated from the helix by a groove, the **sulcus auris anterior.** The **lobule** is situated below the incisura intertragica, and is the most dependent part of the auricle.

The medial or cranial surface of the auricula is also irregular, and presents elevations corresponding to the depressions on its lateral surface, *e.g.* **eminentia scaphæ, eminentia conchæ, eminentia triangularis,** etc.

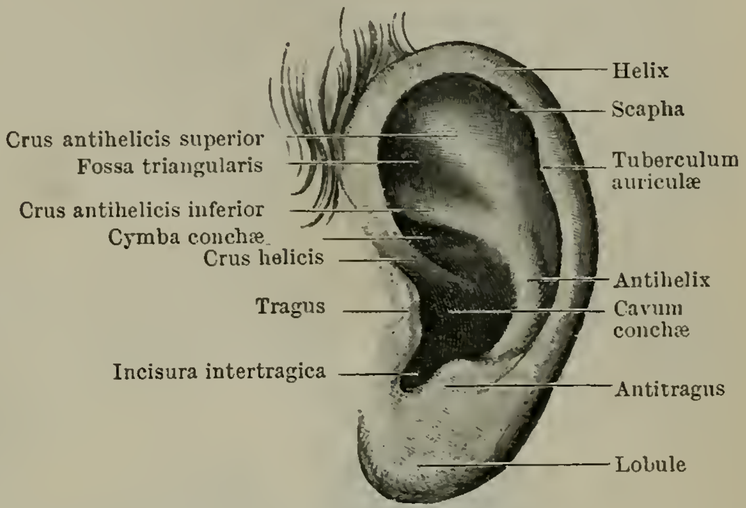

FIG. 671.—VIEW OF LATERAL SURFACE OF LEFT AURICULA (one-half natural size).

The auricula, usually smaller and more finely modelled in the female than in the male, presents great variations in size and shape in different individuals. In the new-born child its length is about one-third of that of the adult; in old age it increases slightly in length and breadth.

The **cephalo-auricular angle** may be absent, as in those cases where the skin of the head passes directly on to the lateral surface of the auricula, or it may be increased to nearly a right angle, so that the lateral surface of the auricula looks directly forwards. The **tuberculum auriculæ,** the significance of which was recognised by Darwin, is a somewhat triangular prominence which projects forwards when the helix is well rolled over, but backwards and upwards when the incurving of the helix has been arrested. More frequently present in men than in women, it is of developmental interest since it is well marked at the sixth month of fœtal life, when the entire auricula resembles that of the adult macaque monkey. The **lobule** may be small and sessile or considerably elongated; it may adhere to the skin of the cheek, or its lower end may be divided.

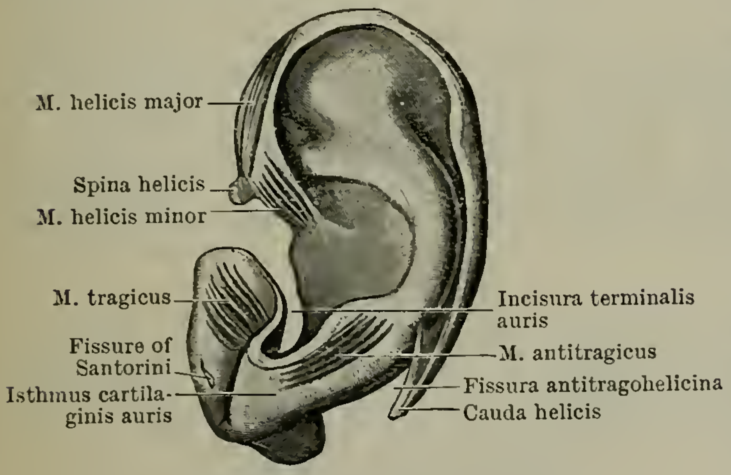

FIG. 672.—LATERAL SURFACE OF CARTILAGE OF THE AURICULA (one-half natural size).

Structure of the Auricula.—The skin covering the auricle is thin and smooth, and is prolonged, in the form of a tube, as a lining to the external acoustic meatus. On the lateral surface of the auricula, it adheres firmly to the subjacent perichondrium. Strong hairs are present on the tragus and antitragus, and also in the incisura intertragica, forming the **barbula hirci,** which guard the entrance to the concha; soft downy hairs are found over the greater part of the auricula and point towards the tuberculum auriculæ. Sebaceous glands, present on both surfaces of the auricle, are most numerous in the concha and fossa triangularis. Sudoriferous glands are found on the medial surface; few or none on the lateral surface.

The greater part of the auricula consists of a lamella of yellow fibro-cartilage, the **cartilago auriculæ**; the cartilage is, however, absent from the lobule, which is composed of fat and connective tissue. When laid bare, the cartilage (Figs. 672, 673) presents, in an exaggerated condition, all the inequalities of the auricula, and is prolonged medially to form the cartilaginous part of the external acoustic meatus. The cartilage of the helix projects anteriorly as a conical eminence, the **spina helicis,** and ends behind in a tail-like process, the **cauda helicis,** which is separated from the lower part of the antitragus by the **fissura antitrago-helicina.** The cartilage of the auricula is continuous with that of the external acoustic meatus by a narrow isthmus, the **isthmus cartilaginis auris,** measuring from 8 to 9 mm. in breadth. The isthmus corresponds laterally with the deepest part of the incisura intertragica, and medially it forms the outer boundary of a deep fissure, the **incisura terminalis auris,** which separates the cartilage of the meatus from that of the concha. The upper edge of the tragus fits into an angle below the crus helicis. Two additional fissures are usually present, one in the tragus and another behind the spina helicis.

On the cranial surface of the cartilage (Fig. 673) the eminences produced by the concha and fossa triangularis are separated by the **sulcus antihelicis transversus**, corresponding with the crus antihelicis inferior. The eminentia conchæ is crossed horizontally by a groove, the **sulcus cruris helicis**, and almost vertically by a slight ridge, the **ponticulus**; to the latter the m. auricularis posterior is attached.

Ligaments of the Auricula.—The cartilage of the auricula is fixed to the temporal bone by two extrinsic ligaments, an *anterior*, stretching from the spina helicis and tragus to the zygomatic process, and a *posterior*, from the eminentia conchæ to the mastoid portion. Small intrinsic ligaments pass between individual parts of the auricula.

Muscles of the Auricula.—The muscles of the auricula are divisible into two groups, *extrinsic* and *intrinsic*. The extrinsic muscles connect the auricula to the skull and scalp, and are described in the section on Myology. The intrinsic muscles are confined to the auricula and are six in number, four on its lateral and two on its cranial or medial surface.

(*a*) *On the lateral surface* (Fig. 672)—

1. **M. helicis major** passes upwards from the spina helicis along the ascending part of the helix. 2. **M. helicis minor** covers the crus helicis. 3. **M. tragicus**, quadrangular in shape, consists of fibres running vertically over the greater part of the tragus. Some of its fibres are prolonged upwards to the spina helicis and constitute the **m. pyramidalis.** 4. **M. antitragicus** covers the antitragus and runs obliquely upwards and backwards to the antihelix and cauda helicis.

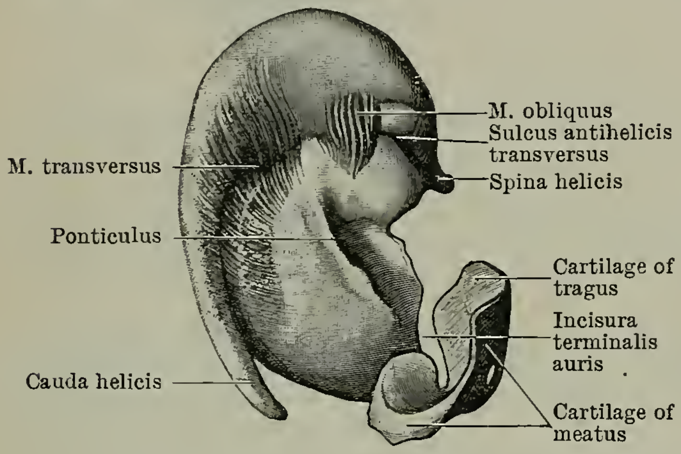

FIG. 673.—MEDIAL SURFACE OF THE CARTILAGE OF THE AURICULA (one-half natural size).

(*b*) *On the medial surface* (Fig. 673)—

1. **M. transversus auriculæ** consists of scattered fibres, which stretch from the eminentia conchæ to the eminentia scaphæ. 2. **M. obliquus auriculæ** (Tod) comprises a few fasciculi, which run obliquely or vertically across the sulcus antihelicis transversus.

A small stylo-auricularis muscle sometimes extends from the root of the styloid process to the cartilage of the meatus.

Vessels of the Auricula.—The arteries of the auricula are derived—(*a*) from the superficial temporal artery, which sends two or three branches to the lateral surface; and (*b*) from the posterior auricular artery, which gives three or four branches to the medial surface. From the branches of the posterior auricular artery two sets of twigs pass to the lateral surface, one turning round the free margin of the helix, and the other passing through small fissures in the cartilage. The **veins** from the lateral surface open into the superficial temporal vein; those from the medial surface chiefly join the posterior auricular vein, but some communicate with the mastoid emissary vein. The **lymph-vessels** take three directions, viz.: (*a*) forwards to the parotid lymph-glands, and especially to the anterior auricular lymph-gland in front of the tragus; (*b*) downwards to the lymph-glands which accompany the external jugular vein, and to the lymph-glands under the sterno-cleidomastoideus; and (*c*) backwards to the posterior auricular lymph-glands.

Nerves of the Auricula.—The muscles of the auricula are supplied by the facial nerve. The skin receives its sensory nerves from—(*a*) the great auricular nerve, which supplies nearly the whole of the medial surface, and sends filaments in company with the branches of the posterior auricular artery to the lateral surface; (*b*) the auriculo-temporal nerve, which supplies the tragus and ascending part of the helix; (*c*) the lesser occipital nerve, which sends a branch to the upper part of the medial surface.

MEATUS ACUSTICUS EXTERNUS.

The **external acoustic meatus** (Figs. 670, 674) is the passage leading from the concha to the membrana tympani. Its length, measured from the bottom of the concha, is about 24 mm.; from the level of the tragus it is about 35 mm. On account of the obliquity of the membrana tympani the anterior and inferior walls of the meatus are longer than the posterior and superior. The meatus consists of an external portion, the **pars cartilaginea**, about 8 mm. in length; and an internal portion, the **pars ossea**, about 16 mm. in length. The entire meatus forms a somewhat S-shaped bend (Fig. 675), and may be divided into three portions—external, intermediate, and internal; each is directed medialwards, but, in addition, the external part is inclined forwards and slightly upwards; the intermediate, backwards; and the internal, the longest, forwards and slightly downwards. On transverse section the canal is seen to be elliptical, its greatest diameter having an inclination downwards and backwards. Widest at its lateral end, it becomes somewhat narrower at the medial end of the pars cartilaginea; once more expanding in the lateral portion of the pars ossea, it is again constricted near the medial end of the latter, where its narrowest part, or **isthmus**, is found at a distance of about 19 mm. from the bottom of the concha. The medial end of the meatus is nearly circular and is closed by the membrana tympani.

Bezold gives the diameters of the meatus as follows:—

	Greatest.	Least.
At the commencement of the pars cartilaginea . .	9·08 mm.	6·54 mm.
At the end ,, ,, ,, ...	7·79 mm.	5·99 mm.
At the commencement of the pars ossea . . .	8·67 mm.	6·07 mm.
At the end ,, ,, ,, . . .	8·13 mm.	4·60 mm.

The lumen of the pars cartilaginea is influenced by the movements of the mandible, being increased when that bone is depressed. This can be verified by inserting a finger into the meatus, and then alternately opening and shutting the mouth.

The condyle of the mandible lies in front of the pars ossea; between the condyle and the pars cartilaginea a portion of the parotid gland is sometimes present. Behind the pars ossea, and separated from it by a thin plate of bone, are the mastoid air-cells.

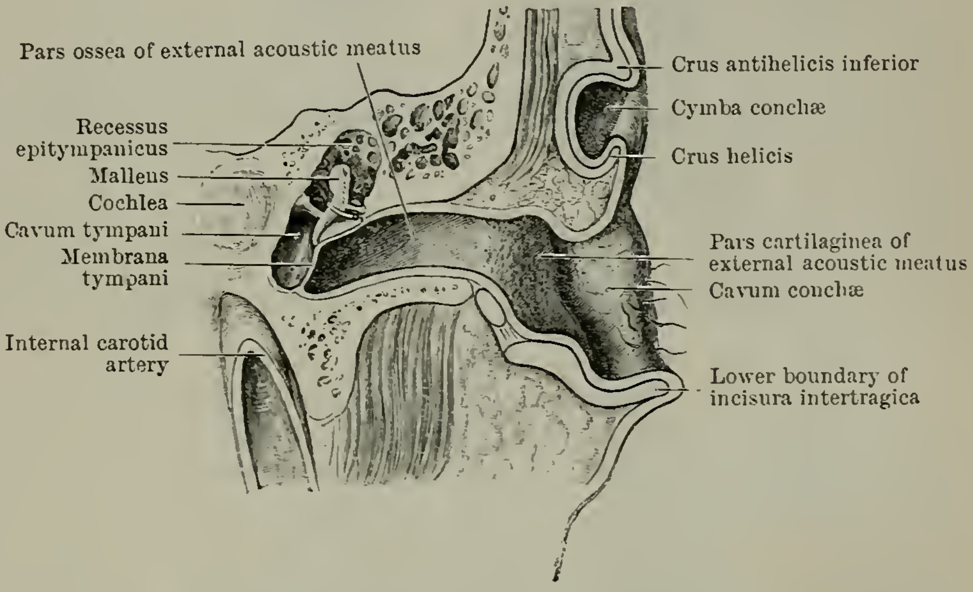
Pars ossea of external acoustic meatus
Recessus epitympanicus
Malleus
Cochlea
Cavum tympani
Membrana tympani
Internal carotid artery
Crus antihelicis inferior
Cymba conchæ
Crus helicis
Pars cartilaginea of external acoustic meatus
Cavum conchæ
Lower boundary of incisura intertragica

Fig. 674.—Frontal Section of Right Ear; Anterior Half of Section, viewed from behind (natural size).

Structure of the Meatus.—The cartilage of the meatus, directly continuous with that of the auricula, is folded on itself to form a groove, opening upwards and backwards, the margins of which are connected by fibrous tissue. The medial end of the cartilaginous part of the meatus is firmly fixed to the lateral margin of the bony meatus; its lateral end is continuous with the cartilage of the tragus (p. 672). Two fissures exist in the anterior portion of the pars cartilaginea, and are filled by fibrous tissue. In the lateral part of the meatus the cartilage forms about three-fourths of the circumference of the tube; but near the medial end of the pars cartilaginea it forms only a part of the anterior and lower boundaries.

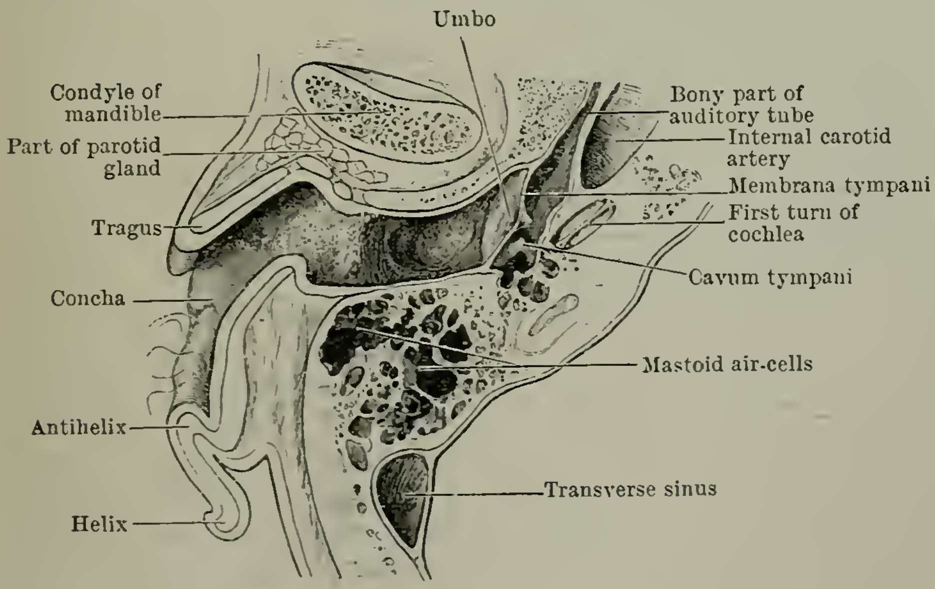

Fig. 675.—Horizontal Section through Right Ear; Upper Half of Section, viewed from below (natural size).

The pars ossea of the external acoustic meatus is described on p. 198. In the new-born child it is represented by an incomplete ring of bone, the **annulus tympanicus**, together with a small portion of the squama temporalis, which articulates with, and bridges the interval between, the ends of the annulus superiorly. In the concavity of the annulus is a groove, the **sulcus tympanicus**, in which the circumference of the membrana tympani is fixed. On the medial surface of the anterior part of the annulus, a little below its free end, a groove, the **sulcus malleolaris**, is directed downwards and forwards. It transmits the anterior process and the anterior ligament of the malleus, the tympanic artery, and the chorda tympani nerve. It is limited above by a ridge, the **crista spinarum** (Henle), which ends in front and behind in a spinous process (**spina tympanica anterior et posterior**). Below the sulcus malleolaris there is a second, less prominent ridge, the **crista tympanica** (Gruber), which subsequently unites with a process of the tegmen tympani, and so shuts off the canalis musculotubarius from the petrotympanic fissure. A **fibrous tympanic plate** (Symington) intervenes between the annulus tympanicus and the cartilage of the meatus, and into this plate the bony ring extends. The bony outgrowth does not, however, proceed uniformly from the whole of circumference of the annulus, but occurs most rapidly from its anterior and posterior parts. These outgrowths fuse about the end of the second year of life, so as to surround a foramen (**foramen of Huschke**) in the floor of the meatus; this foramen is usually closed by the fifth year, but persists until adult life in about 19 per cent. of skulls (Bürkner).

The lumen of the meatus in the new-born child is extremely small: its outer part is funnel-shaped; its inner is a mere slit, bounded below by the fibrous tympanic plate and above by the obliquely placed membrana tympani.

The external acoustic meatus is lined by skin, and the latter also covers the outer surface of the membrana tympani. The skin is thick in the pars cartilaginea, and contains fine hairs and sebaceous glands, the latter extending for some distance along the postero-superior wall of the pars ossea. In the subcutaneous tissue of the pars cartilaginea are numerous enlarged sudoriferous glands; they constitute the **glandulæ ceruminosæ** and secrete the ear wax or cerumen.

Vascular and Nervous Supply of the External Acoustic Meatus.—The external acoustic meatus receives its blood-supply from the posterior auricular and superficial temporal arteries, and from the deep auricular branch of the internal maxillary artery, the last distributing some minute twigs to the membrana tympani. The **veins** open into the external jugular and internal maxillary veins, and into the pterygoid venous plexus, while the **lymph-vessels** have a similar mode of termination to those of the auricula. **Sensory nerves** are supplied to the meatus by the auriculo-temporal branch of the trigeminal nerve and by the auricular branch of the vagus nerve.

CAVUM TYMPANI OR MIDDLE EAR.

The **tympanic cavity** is a small air-chamber in the temporal bone, between the membrana tympani and the lateral wall of the internal ear or labyrinth (Figs. 674, 676). It is lined with mucous membrane, and contains a chain of ossicles,—malleus, incus, and stapes,—which reaches from its lateral to its medial wall, and transmits the vibrations of the membrana tympani across the cavity to the internal ear. Attached to the ossicles are several ligaments and two small muscles.

The tympanic cavity consists of (*a*) the **tympanum proper**, or **atrium**, lying medial to the membrana tympani; and (*b*) the **recessus epitympanicus**, or **attic**, lying above the level of the membrana tympani and containing the greater part of the incus and the upper half of the malleus. Including the attic, the vertical and antero-posterior diameters of the cavity are each about 15 mm. The distance between its lateral and medial walls is about 6 mm. above and 4 mm. below, while at its central part, owing to the bulging of the two walls towards the cavity, it is only from 1·5 to 2 mm.

The tympanic cavity communicates, behind, with the tympanic antrum, and through this with the mastoid air-cells; in front, with the nasal part of the pharynx, through the auditory (Eustachian) tube. It is enclosed by six walls, tegmental, jugular, labyrinthic, mastoid, carotid, and membranous.

Paries Tegmentalis.—The **tegmental wall** or **roof** of the tympanic cavity (Fig. 676) is formed by a thin plate of bone, the **tegmen tympani**, constituting a portion of the anterior surface of the petrous part of the temporal bone. It extends backwards so as to cover the tympanic antrum, and forwards, to form a roof for the semicanal for the tensor tympani muscle. It separates the tympanic cavity and antrum from the middle fossa of the cranial cavity, and may contain a few air-cells, whilst occasionally it is partly deficient. In the child its lateral edge corresponds with the petro-squamous suture, traces of which can generally be seen in the adult bone.

Paries Jugularis.—The **jugular wall** or **floor** of the tympanic cavity is narrower than the tegmental wall, and consists of a thin plate of bone which separates the tympanic cavity from the fossa jugularis; anteriorly, it ascends and is continuous with the posterior wall of the carotid canal. The inner orifice of the canal which transmits the tympanic nerve is placed near the junction of the jugular and labyrinthic walls.

Paries Labyrinthica.—The **labyrinthic** or **medial wall** of the tympanic cavity is formed by the lateral wall of the internal ear (Fig. 676). It presents—(1) a rounded eminence, the **promontory**, caused by the outward projection of the first coil of the cochlea; its surface is marked by small grooves which lodge the tympanic plexus of nerves. (2) An oval or somewhat reniform opening, the **fenestra vestibuli**, which is situated above and behind the promontory, with its long axis directed antero-posteriorly; this fenestra is 3 mm. long and 1·5 mm. broad and, in the macerated bone, leads into the vestibule of the osseous labyrinth, but, in the recent state, is closed by the base or foot-plate of the stapes, surrounded by its **ligamentum annulare.** (3) An elevation, the **prominentia canalis facialis**, which is situated above the fenestra vestibuli, in the recessus epitympanicus; this elevation indicates the position of the upper part of the **canalis facialis** (O.T. **aqueduct of Fallopius**), which contains the facial nerve. (4) The **septum canalis musculotubarii** (O.T. **processus cochleariformis**), which extends backwards, above the anterior end of the fenestra vestibuli, where it makes a sharp lateral curve, and forms a pulley over which the tendon of the tensor tympani muscle plays. (5) A funnel-shaped recess, situated behind and below the promontory, and almost hidden by its overhanging edge, leads to an irregularly oval opening, termed the **fenestra cochleæ**; in the macerated bone this fenestra opens into the cochlea, but in the recent state is closed by the **membrana tympani secundaria**; this membrane is bent angularly along

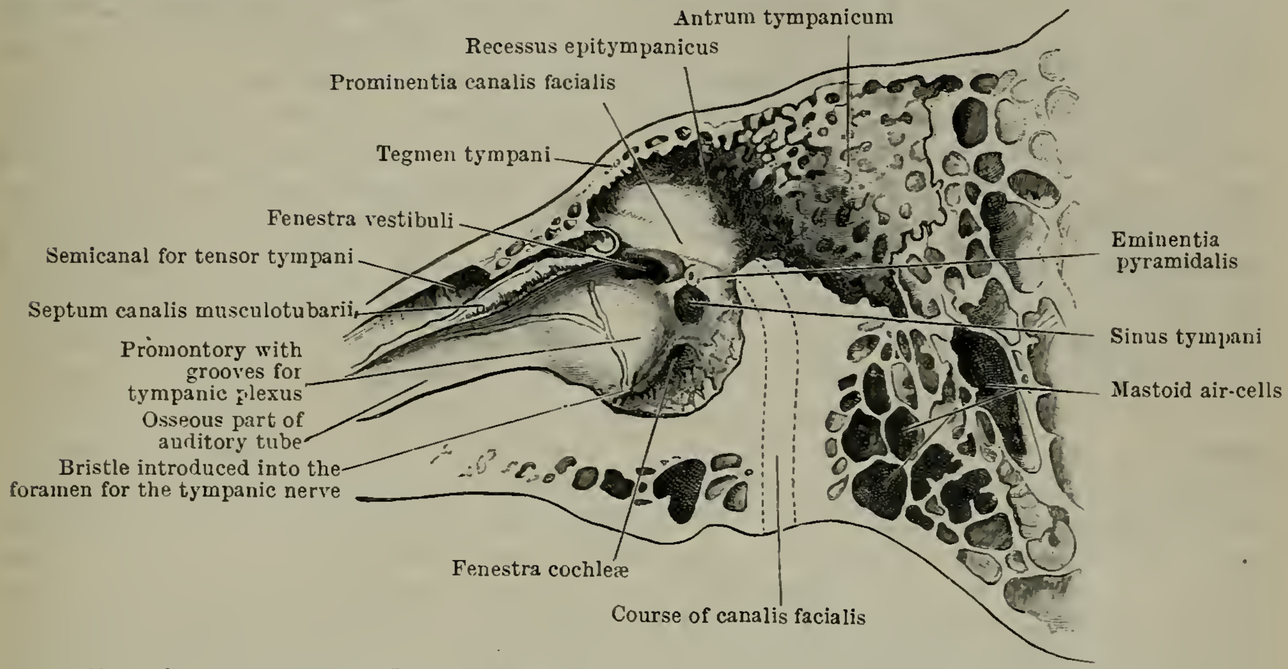
Antrum tympanicum
Recessus epitympanicus
Prominentia canalis facialis
Tegmen tympani
Fenestra vestibuli
Semicanal for tensor tympani
Septum canalis musculotubarii
Promontory with grooves for tympanic plexus
Osseous part of auditory tube
Bristle introduced into the foramen for the tympanic nerve
Fenestra cochleæ
Course of canalis facialis
Eminentia pyramidalis
Sinus tympani
Mastoid air-cells

FIG. 676.—SECTION THROUGH LEFT TEMPORAL BONE, showing labyrinthic wall of tympanic cavity, etc.

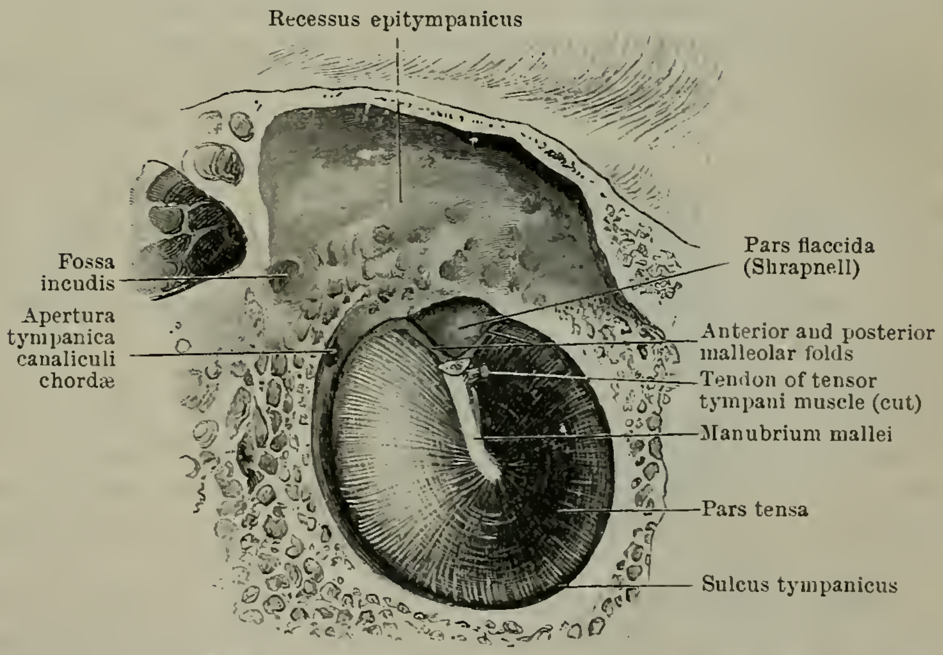
Recessus epitympanicus
Fossa incudis
Apertura tympanica canaliculi chordæ
Pars flaccida (Shrapnell)
Anterior and posterior malleolar folds
Tendon of tensor tympani muscle (cut)
Manubrium mallei
Pars tensa
Sulcus tympanicus

FIG. 677.—LEFT MEMBRANA TYMPANI AND RECESSUS EPITYMPANICUS, viewed from within. The head and neck of the malleus have been removed to show the pars flaccida and the malleolar folds. × 3.

a line joining its antero-inferior two-thirds with the postero-superior one-third; and consists of three layers: (*a*) a *lateral* layer, continuous with the mucous lining of the tympanum, and containing a network of capillaries; (*b*) an *intermediate* fibrous layer (membrana propria); (*c*) a *medial* layer, continuous with the epithelial lining of the labyrinth. (6) Between the fenestra vestibuli and the fenestra cochleæ, and below the pyramid, is a small depression, the **sinus tympani**, which indicates the position of the ampullated end of the posterior semicircular canal, and is perforated by one or two minute foramina for blood-vessels.

Paries Mastoidea.—The **mastoid** or **posterior wall** of the tympanic cavity presents, from above downwards: (1) a round or triangular opening, which leads from the recessus epitympanicus into the **tympanic antrum** (Fig. 676); (2) a depression, the **fossa incudis**, situated in the postero-inferior part of the recessus epitympanicus (Fig. 677), for the reception of the end of the short crus of the incus; (3) a minute conical bony projection, the **eminentia pyramidalis** (Fig. 676), the summit of which is perforated by a round aperture for the passage of the tendon of the stapedius muscle. From this aperture a minute canal is continued downwards and backwards in front of the facial canal, and frequently opens, by a minute orifice, on the base of the skull in front of the stylo-mastoid foramen; it communicates with the facial canal by one or two small foramina, which transmit the vessels and the nerve to the stapedius muscle; a minute spicule of bone often unites the eminentia pyramidalis to the upper part of the promontory; (4) a small aperture, the **apertura tympanica canaliculi chordæ** (Fig. 677), which is situated close to the posterior edge of the membrana tympani, nearly on a level with the upper end of the manubrium mallei; (5) a rounded eminence, the **prominentia styloidea**, is sometimes seen below the last, and is caused by the upward and forward prolongation of the styloid process.

Paries Carotica.—The **carotid** or **anterior wall** of the tympanic cavity is narrowed in its transverse diameter by the approximation of the lateral and medial boundaries of the tympanic cavity, and in its vertical diameter by the descent of the tegmen tympani and the ascent of the carotid canal. It presents (Fig. 676) two parallel semicanals, one above the other, separated by a thin lamella of bone, the **septum canalis musculotubarii** (O.T. **processus cochleariformis**). These run forwards on the lateral wall of the carotid canal and open in the angle between the squama and the petrous part of the temporal bone. The higher and smaller semicanal is termed the **semicanalis m. tensoris tympani**, and lies immediately below the tegmen tympani. It has a diameter of about 2 mm., and extends on to the medial wall of the tympanic cavity above the anterior part of the fenestra vestibuli. The lower and larger semicanal gradually increases in diameter from before backwards, and is named the **semicanalis tubæ auditivæ**; it forms the bony part of the auditory tube. Below the orifice of the auditory tube the anterior part of the tympanic cavity is separated from the ascending portion of the carotid canal by a thin plate of bone in which there are sometimes gaps or deficiencies. This plate is perforated by the carotico-tympanic canal, which transmits the carotico-tympanic nerve from the sympathetic plexus on the carotid artery to the tympanic plexus. The auditory tube is described on p. 831.

Paries Membranacea.—The **membranous** or **lateral wall** of the tympanic cavity is formed almost entirely by the membrana tympani (Fig. 677), which closes the medial end of the external acoustic meatus, and is fixed throughout the greater part of its circumference in a groove, the **sulcus tympanicus**. The bony ring containing this sulcus is deficient superiorly, where it exhibits a small notch, the **notch of Rivinus**. On a level with the upper edge of the membrane, and in front of the ring of bone in which it is fixed, is the medial end of the **petrotympanic fissure**. This transmits the tympanic branch of the internal maxillary artery, and lodges the anterior process and anterior ligament of the malleus. Close to the medial end of the fissure is the **iter chordæ anterius** through which the chorda tympani nerve leaves the tympanic cavity.

Membrana Tympani.—The **tympanic membrane** is an elliptical disc, its greatest diameter, 9 to 10 mm., being directed from above, downwards and forwards; its least diameter is from 8 to 9 mm. It is placed very obliquely, and forms an angle of about 55° with the lower and anterior walls of the external acoustic meatus; it is said to be more oblique in cretins and deaf mutes, and more perpendicular in musicians.

The portion of the membrane which is fixed in the sulcus tympanicus is considerably thickened, and is named the **annulus fibrocartilagineus.** It is prolonged from the anterior and posterior ends of the notch of Rivinus to the processus lateralis of the malleus, as two ligamentous bands, the **anterior** and **posterior malleolar folds.** A small triangular portion of the membrane (Fig. 677) situated above these folds is thin and lax, and constitutes the **pars flaccida** (O.T. **membrane of Shrapnell**); whilst the main portion of the membrane is tightly stretched and is termed the **pars tensa.** A small orifice, sometimes seen in the pars flaccida, is probably either a pathological condition or has been produced artificially during manipulation. The manubrium mallei is firmly fixed to the medial surface of the membrana tympani, the central portion of which is drawn towards the tympanic cavity so that the lateral surface of the membrane is concave. The point of greatest convexity of the membrane corresponds with the lower end of the manubrium mallei, and is named the **umbo membranæ tympani.**

Structure.—The membrana tympani consists of three layers: (1) a lateral, the stratum cutaneum; (2) an intermediate, the membrana propria; (3) a medial, the stratum mucosum.

The **stratum cutaneum** is continuous with the skin of the external acoustic meatus, and consists of a thin layer of cutis covered with epidermis. The cutis is thickest near the circumference, and the epidermis near the centre, of the membrane.

The **membrana propria** consists of two sets of fibres: (*a*) a *lateral*, the stratum radiatum, situated immediately under the stratum cutaneum, and radiating from the manubrium mallei to the annulus fibrocartilagineus; (*b*) a *medial*, the stratum circulare, the fibres of which are numerous near the circumference, but scattered and few in number near the centre of the membrane (Fig. 677). The radial fibres are curved with their convexities directed towards the external acoustic meatus. Both radial and circular fibres are absent from the pars flaccida, which consists only of the cutaneous and mucous strata. In addition to the radial and circular fibres, there exists, next the stratum mucosum, a series of *dendritic* or *branched fibres* (Gruber), which are best developed in the posterior part of the membrane.

The **stratum mucosum** is continuous with the mucous lining of the tympanic cavity. It is thickest over the upper part of the membrane, and is covered with pavement epithelium.

Otoscopic Examination of the Membrana Tympani (Fig. 678).—The membrana tympani, in the living, is of a "pearl-gray" colour, but may present a reddish or yellowish tinge; the posterior segment is usually clearer than the anterior. At the antero-superior part, close to its periphery, a whitish point appears as if projecting towards the meatus; this is the processus lateralis of the malleus. Passing downwards and backwards from this point to the umbo is a ridge caused by the manubrium mallei, the lower end of which appears rounded. Two ridges, corresponding with the malleolar folds, extend from the processus lateralis of the malleus, one forwards and upwards, the other backwards and upwards. Behind, and near the lower end of the manubrium mallei, is a reddish or yellowish spot, due to the promontory of the medial wall of the tympanic cavity shining through. If the membrane is very transparent, the long crus of the incus may be visible behind the upper part of the manubrium mallei, and reaching downwards as far as its middle. From the lower end of the manubrium mallei, the "cone of light" or "luminous triangle" extends downwards and forwards, its apex being directed towards the handle; this triangle varies in size in different people.

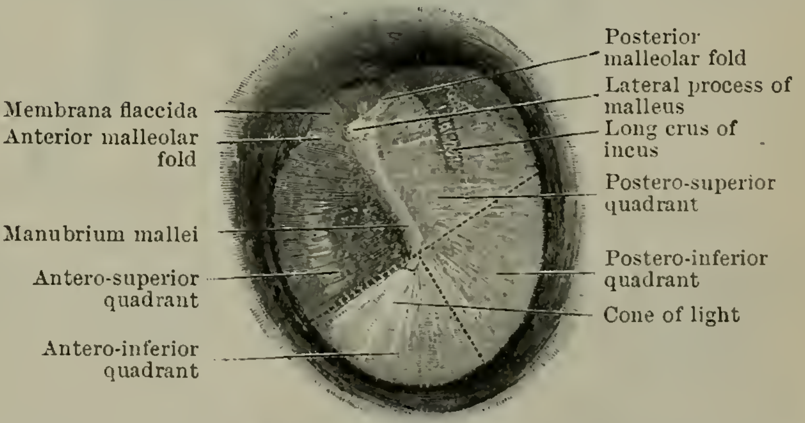

Fig. 678.—Left Tympanic Membrane (as viewed from the external acoustic meatus). × 3.

A line prolonging the manubrium downwards divides the membrane into two parts, while another, drawn at right angles to this through the umbo, subdivides it into quadrants, viz., postero-superior, postero-inferior, antero-superior, and antero-inferior; this subdivision is useful in enabling the otologist to localise and describe accurately the seat of lesions in the membrane.

Vascular and Nervous Supply of the Membrana Tympani.—The arteries of the tympanic membrane are arranged in two sets, one on the cutaneous and another on the mucous surface; they anastomose by means of small branches which pierce the membrane, especially near its periphery. The first set is derived chiefly from the deep auricular branch of the internal maxillary artery; those on the mucous surface are small and proceed from the anterior tympanic branch of the internal maxillary artery, and from the stylo-mastoid branch of the posterior auricular artery. The veins from the cutaneous surface open into the external jugular vein; those from the mucous surface partly into the venous plexus on the auditory tube, and partly into the transverse sinus and veins of the dura mater. The **lymph-vessels**, like the blood-vessels, are arranged in two sets, cutaneous and mucous, which, however, communicate freely with each other. Kessel has described as lymph-vessels the spaces between the branches of Gruber's dendritic fibres. The lateral surface of the membrane receives its **nerves** from the auriculo-temporal branch of the trigeminal nerve and from the auricular branch of the vagus nerve; the medial surface, from the tympanic branch of the glossopharyngeal nerve.

ANTRUM TYMPANICUM ET CELLULÆ MASTOIDEÆ.

Antrum Tympanicum.—The **tympanic antrum** (O.T. **mastoid antrum**) is an air-space situated behind the epitympanic recess. In the adult its average length is from 12 to 15 mm., its height from 8 to 10 mm., and its width from 6 to 8 mm.

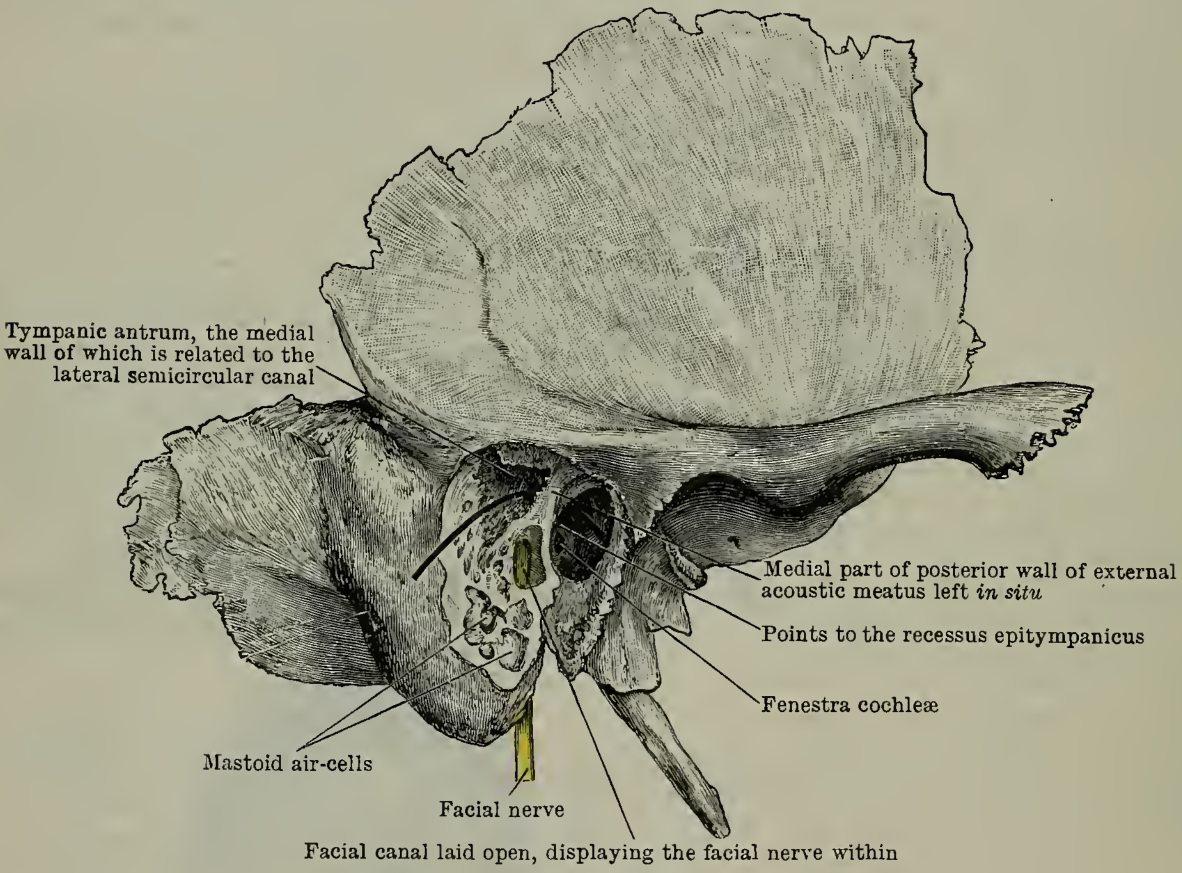
Tympanic antrum, the medial wall of which is related to the lateral semicircular canal
Medial part of posterior wall of external acoustic meatus left *in situ*
Points to the recessus epitympanicus
Fenestra cochleæ
Mastoid air-cells
Facial nerve
Facial canal laid open, displaying the facial nerve within

FIG. 679.

Preparation to display the position and relations of the tympanic antrum. The greater part of the posterior wall of the external acoustic meatus has been removed, leaving only a bridge of bone at its medial extremity; under this a bristle is displayed, passing from the tympanic antrum to the cavity of the tympanum.

Its roof is formed by the tegmen tympani, and its floor and medial wall by the pars petrosa and pars mastoidea of the temporal bone; laterally it is closed by the part of the squama temporalis which lies below the supramastoid crest. It communicates with the epitympanic recess by a triangular or rounded opening, on the medial wall of which, immediately above and behind the canalis facialis, is a smooth convexity indicating the position of the ampullated ends of the superior and lateral semicircular canals.

At birth the lateral wall of the antrum has a thickness of only 1-2 mm., but by the ninth year this has increased to about 10 mm. Coincident with the growth of the mastoid process the mastoid air-cells are developed downwards and backwards as diverticula from the antrum, and present the greatest possible variation in different skulls.

Cellulæ Mastoideæ.—The **mastoid air-cells** may be large, comparatively few in number, and involve the whole mastoid process, in which case the compact bone surrounding them is very thin, and the innermost air-cells are separated from the transverse sinus by a transparent lamella which, in some instances, is partly deficient. Sometimes the air-cells are small, and invade only a portion of the process, the remainder consisting of diploëtic tissue; occasionally a solid mastoid process is met with. The air-cells are not always limited to the mastoid portion of the temporal bone, but may extend forwards over the roof of the meatus, upwards towards the squama temporalis, and medially towards the temporo-occipital suture; occasionally they invade the pars jugularis of the occipital bone. The tympanic antrum and the mastoid air-cells are lined with thin mucous membrane, continuous with that of the tympanic cavity; the deep surface of the mucous membrane is fixed to the periosteum; its free surface is covered with a layer of flattened, non-ciliated epithelium.

Tuba Auditiva.

The **auditory tube** (O.T. **Eustachian tube**) leads from the tympanic cavity to the nasal part of the pharynx, and transmits air to the former, in order that the pressures on the medial and lateral surfaces of the membrana tympani may be equalised; it may also serve to convey mucous secretion from the tympanic cavity. Its **tympanic orifice** (Fig. 676) opens into the anterior part of the tympanic cavity, below the semicanal for the tensor tympani muscle. The tube is directed downwards and medialwards, and ends on the lateral wall of the nasal part of the pharynx by a wide **pharyngeal orifice** (Fig. 642, p. 797). It is about 35 mm. in length, and forms with the horizontal plane an angle of 30° to 40°, and with the sagittal plane an angle of about 45°. It consists of—(*a*) an antero-medial part, the **pars cartilaginea tubæ auditivæ**, about 25 mm. long; and (*b*) a postero-lateral part, the **pars ossea tubæ auditivæ**, about 10 mm. long. The cartilaginous part inclines downwards a little more than the osseous portion, and forms with it a wide angle. The lumen of the tube is widest at the pharyngeal orifice, narrowest at the junction of the bony and cartilaginous portions, forming here the **isthmus**; the lumen of the tube gradually increases from the isthmus to the tympanic orifice. The pars ossea occupies the angle between the tympanic and petrous parts of the temporal bone, and is separated from the tensor tympani muscle by the septum canalis musculo-tubarii; medial to it is the carotid canal. The pars cartilaginea consists partly of cartilage and partly of fibrous membrane. The cartilage is an elongated triangular plate, the apex of which is firmly attached to the medial end of the pars ossea, while the base is free, and forms a projection above and behind on the pharyngeal orifice. The upper part of this cartilaginous plate is bent lateralwards, so as to produce a furrow which is converted into a canal by the membranous lamina of the tube. On transverse section, therefore, the cartilage presents two laminæ continuous with each other superiorly (Fig. 680): (*a*) *lamina medialis*, broad and thick; and (*b*) *lamina lateralis*, thin and hook-shaped. At the pharyngeal orifice the lamina medialis forms the entire medial wall of the tube, but it gradually diminishes in breadth on approaching the isthmus tubæ. Fissures are often seen in the cartilage; sometimes it is divided into several pieces, or accessory islands may be observed in the roof, floor, or membranous lamina.

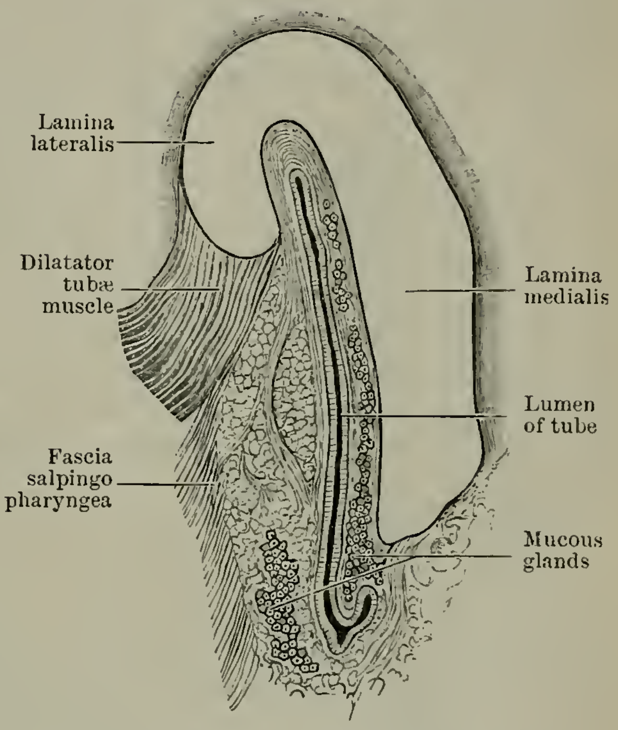

Fig. 680.—Transverse Section of the Cartilaginous Part of the Auditory Tube.

The upper and medial surfaces of the medial lamina are firmly fixed to the base of the skull, in the **sulcus tubæ auditivæ**, between the great wing of the sphenoidal bone and the petrous part of the temporal bone. Extending forwards on to the root of the pterygoid process this sulcus ends at a projection, the **processus tubarius**, on the medial pterygoid lamina. The tensor veli palatini muscle lies on the lateral side of the tube and receives some fibres of origin from its lamina lateralis; these fibres constitute the **dilatator tubæ muscle** (Rüdinger). On the medial side of the cartilage are the levator veli palatini muscle and the mucous membrane of the pharynx. The **membranous lamina** consists of a strong fibrous membrane, stretching between the two edges of the cartilage, and so completing the lower and lateral walls of the tube. Its lower part is thickened and forms the **fascia salpingopharyngea** of Tröltsch, which gives origin to some of the fibres of the tensor veli palatini muscle. Between this fascia and the mucous lining of the tube is a layer of fatty tissue.

The **pharyngeal orifice** of the auditory tube, triangular or oval in shape, is situated on the lateral wall of the nasal part of the pharynx, the centre of the opening being on a level with the posterior end of the inferior nasal concha. It is bounded above and behind by a pad, the **torus tubarius**, produced by the base of the cartilage, which there abuts against the mucous membrane; the posterior part of the torus is very prominent and forms the anterior boundary of the **recessus pharyngeus**. Prolonged downwards from the posterior part of the torus is a fold of the mucous membrane, the **plica salpingopharyngea**, which covers the small salpingopharyngeus muscle. An indistinct fold, the **plica salpingopalatina**, extends from the upper part of the torus to the palate.

The tube is opened, during deglutition, by the dilatator tubæ and salpingopharyngeus muscles. The former springs superiorly from the lateral lamina of the tube, and blends inferiorly with the tensor veli palatini. When the dilatator tubæ contracts, the lateral lamina of the cartilage and the membranous lamina of the tube are drawn lateralwards and forwards. Some anatomists believe that the entire tensor veli palatini acts chiefly as a dilator of the tube, and Rüdinger named it the abductor tubæ. Blakeway[1] thinks that contraction of the tensor veli palatini is more likely to close than open the tube. The salpingopharyngeus muscle draws downwards and backwards the medial lamina, increasing the angle between it and the lateral lamina. Some difference of opinion exists as to the precise action of the levator veli palatini; probably it assists in opening the tube.

Mucous Membrane.—The mucous lining of the tube is continuous behind with that of the tympanic cavity, and in front with that of the nasal part of the pharynx. In the pars ossea it is thin and firmly fixed to the bony wall; in the pars cartilaginea it is loose and thrown into longitudinal folds. Numerous mucous glands open into the tube near its pharyngeal orifice, and here also there is a considerable amount of adenoid tissue, which constitutes the "tube-tonsil" of Gerlach. This adenoid tissue is continuous with that of the nasal part of the pharynx, and, like it, is especially well developed in children. The lumen of the tube is lined with ciliated columnar epithelium.

Vessels and Nerves.—The auditory tube receives its blood-supply from the ascending pharyngeal and middle meningeal arteries, and from the artery of the pterygoid canal. Its veins drain into the pterygoid venous plexus. Its sensory nerves are derived from the tympanic plexus and from the pharyngeal branch of the spheno-palatine ganglion.

The auditory tube of the child differs considerably from that of the adult; its lumen is relatively wider, its direction more horizontal, and its pars ossea relatively shorter. Kunkel states that its pharyngeal orifice is below the level of the hard palate in the fœtus; at birth it is level with the palate, whilst at the fourth year it is 3 to 4 mm., and in the adult 10 mm., above it. In the child the pharyngeal orifice forms a narrow fissure, and its cartilage projects less towards the middle line.

OSSICULA AUDITUS.

The **auditory ossicles**, three in number, form an articulated column connecting the lateral with the medial wall of the tympanic cavity; they are named, from without inwards, the malleus, incus, and stapes. The first is attached to the medial surface of the membrana tympani; the last is fixed within the circumference of the fenestra vestibuli.

The **malleus** (Fig. 681, B, D), the largest of the three auditory ossicles, is from 8 to 9 mm. long, and consists of a head, a neck, a manubrium, and two processes, anterior and lateral.

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[1] *Journal of Anatomy and Physiology*, vol. xlviii.

The head and neck are situated in the epitympanic recess; the lateral process and the manubrium are fixed to the medial surface of the membrana tympani; the anterior process is directed forwards, towards the petro-tympanic fissure, to which, in the adult, it is connected by ligamentous fibres. The **head**, somewhat rounded, is smooth and convex above and in front; on its posterior surface is a facet for articulation with the body of the incus. This facet is more or less elliptical in form, but is constricted near the middle; an oblique ridge, corresponding with the constriction, divides the facet into two parts—an upper and larger, directed backwards, and a lower and lesser, directed medialwards. Opposite the lower part of the constriction the inferior edge of the facet is very prominent, and is continued upwards into the oblique ridge just referred to; it forms a tooth-like process, the **spur** or **cog-tooth** of the malleus. On the back of the head, below this spur, is an oblique crest, the **crista mallei**, to which the lateral ligament of the malleus is attached. The **neck** is the slightly constricted portion immediately below the head. Its lateral surface is directed towards the membrana flaccida; its medial surface is crossed by the chorda tympani nerve. The **manubrium** or **handle** projects downwards, backwards, and medialwards from the neck, and forms with the long axis of the head an angle of 126° to 150°. Its upper part is flattened from before

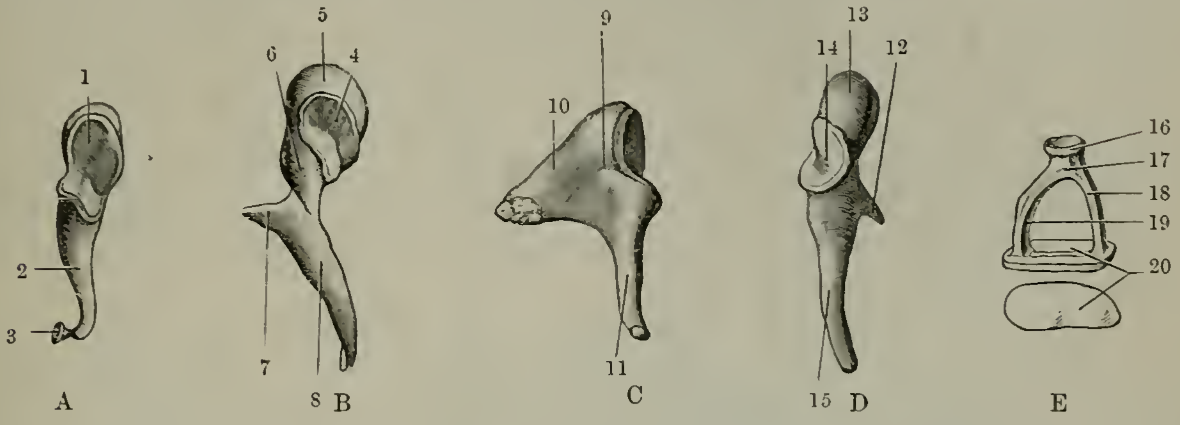

FIG. 681.—AUDITORY OSSICLES OF LEFT EAR (enlarged about three times).

A, Incus, seen from the front; B, Malleus, viewed from behind; C, Incus, and D, Malleus, seen from medial aspect; E, Stapes.

1. Body of incus, with articular surface for head of malleus.
2. Crus longum of incus.
3. Processus lenticularis of incus.
4. Articular surface for incus.
5. Head of malleus.
6. Neck of malleus.
7. Processus lateralis of malleus.
8. Manubrium mallei.
9. Body of incus.
10. Crus breve of incus.
11. Crus longum of incus.
12. Processus anterior of malleus.
13. Head of malleus.
14. Facet for incus.
15. Manubrium mallei.
16. Head of stapes.
17. Neck of stapes.
18. Crus anterius of stapes.
19. Crus posterius of stapes.
20. Base of stapes.

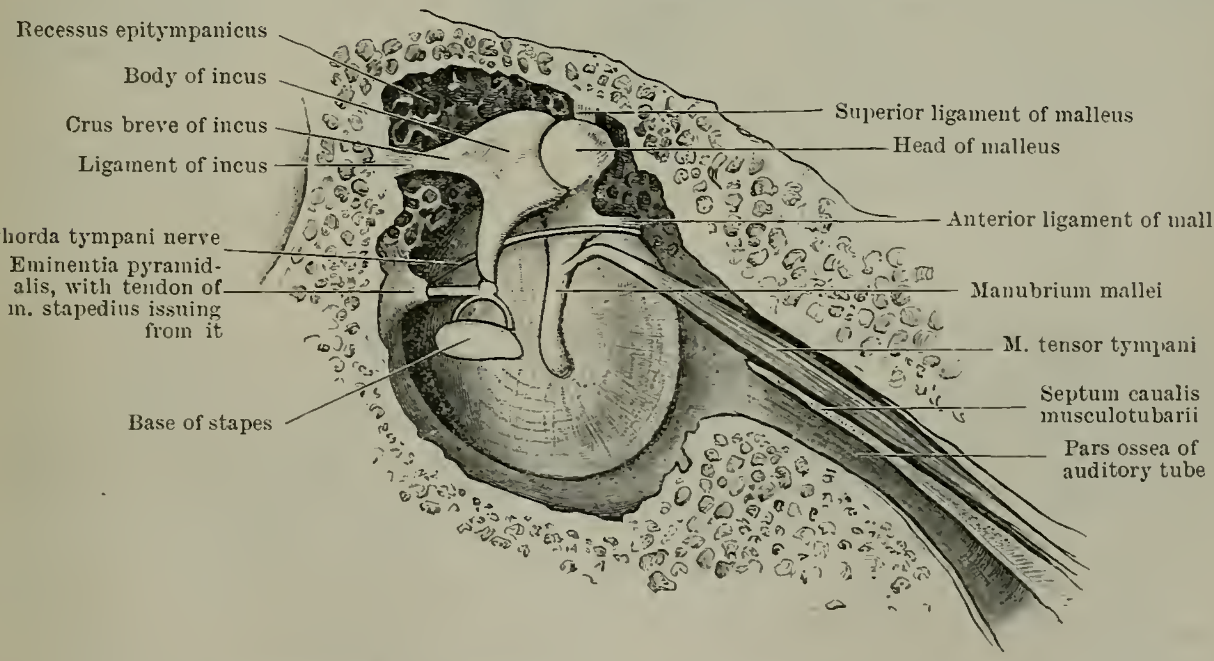
Recessus epitympanicus
Body of incus
Crus breve of incus
Ligament of incus
Chorda tympani nerve
Eminentia pyramidalis, with tendon of m. stapedius issuing from it
Base of stapes
Superior ligament of malleus
Head of malleus
Anterior ligament of malleus
Manubrium mallei
M. tensor tympani
Septum canalis musculotubarii
Pars ossea of auditory tube

FIG. 682.—LEFT MEMBRANA TYMPANI AND CHAIN OF AUDITORY OSSICLES (seen from the medial aspect). × 3.

backwards, but the lower part is twisted on itself, so that its surfaces look lateralwards and medialwards; the lower end is slightly curved, the concavity being directed forwards and lateralwards. The manubrium is fixed, by its periosteum and by a layer of cartilage to the membrana propria of the tympanic membrane. On the medial surface of the manubrium, near its upper end, is a slight projection for the attachment of the tendon of the tensor tympani muscle. The **processus anterior**, a slender spicule, springs from the front of the neck and is directed forwards, towards the petro-tympanic fissure. In the fœtus this is the longest process of the malleus, but in the adult it usually assumes the form of a small projection, since its anterior part is replaced by ligamentous tissue. The **processus lateralis** is a conical eminence, and may be looked upon as the upper end of the manubrium projected lateralwards; it is fixed to the upper part of the membrana tympani by a layer of cartilage, and to the ends of the notch of Rivinus by the anterior and posterior malleolar folds.

The **incus** (Fig. 681, A, C) resembles a premolar tooth with widely divergent roots. It consists of a body, a crus longum, and a crus breve; the crura form with each other an angle of 90° to 100°. The body and crus breve are situated in the epitympanic recess. On the **body** is a more or less saddle-shaped surface for articulation with the head of the malleus. This surface is directed forwards, and its lower part is hollowed out for the accommodation of the cog-tooth of the malleus; in front of this hollow it is prominent and spur-like. The **crus breve** is thick, pyramidal in shape, and projects horizontally backwards; its apex, covered with cartilage, is received into the fossa incudis in the postero-inferior part of the epitympanic recess. The **crus longum** projects downwards into the tympanic cavity, where it lies parallel with, but 1·25 mm. behind and medial to, the manubrium mallei. Its lower end is bent medialwards and narrowed to form a short neck, on the end of which is a small knob of bone, the **processus lenticularis**, for articulation with the head of the stapes.

The **stapes** (Fig. 681, E) consists of a head, a neck, two crura, and a base. The **head**, directed lateralwards, is concave for articulation with the processus lenticularis of the incus. The **neck** is slightly constricted, and from it the two crura spring; the tendon of the stapedius is inserted into the posterior surface of the neck. The **crus anterius** is shorter and less curved than the **crus posterius**. Diverging from each other, the crura are directed medialwards and are attached—one near the anterior, the other near the posterior end of the base. The **base** almost completely fills the fenestra vestibuli, and, like it, is somewhat oval or reniform, its anterior end being the more pointed. In the recent condition a membrane fills the arch formed by the crura and the base, the crura being grooved for its reception.

In the child the crura of the stapes are less curved than in the adult, and the opening between them and the base is nearly triangular.

Articulations of the Auditory Ossicles.—The joint between the head of the malleus and the body of the incus is diarthrodial, and may be described as one of reciprocal reception. It is surrounded by an articular capsule, from the inner surface of which a wedge-shaped meniscus projects into the joint-cavity and incompletely divides it. The joint between the processus lenticularis of the incus and the head of the stapes is of the nature of an enarthrosis and is surrounded by an articular capsule. An interarticular cartilage has been described as occurring in this joint, but some observers deny the presence of a synovial cavity and regard the articulation as a syndesmosis, the articular surfaces being held together by fibrous tissue.

Ligamenta Ossiculorum Auditus.—The malleus is attached to the walls of the tympanic cavity by anterior, superior, and lateral ligaments (Fig. 682). The **anterior ligament** consists of two portions: (*a*) the *band of Meckel*, which is attached to the base of the processus anterior, and passes forwards, through the petro-tympanic fissure, to reach the spina angularis of the sphenoidal bone; it was formerly described as the laxator tympani muscle; (*b*) a firm bundle of fibres, the *anterior ligament of Helmholtz*, which extends from the spina tympanica anterior (p. 826) to the anterior surface of the malleus, above the base of the processus anterior. The **superior ligament** stretches from the head of the malleus to the roof of the epitympanic recess. The **lateral ligament** is short and fan-shaped; its fibres converge from the posterior half of the edge of the notch of Rivinus to the crista mallei. The posterior part of this ligament is strong and constitutes the *posterior ligament of Helmholtz*; it forms, together with the anterior ligament of the malleus, the axis around which the malleus rotates, and the two constitute what Helmholtz termed the "**axis-ligament**" of the malleus.

The posterior end of the crus breve of the incus is tipped with cartilage and fixed by means of a ligament to the fossa incudis (Fig. 677). Some observers describe this as a diarthrodial joint.

The vestibular surface, and the circumference, of the base of the stapes are covered with hyaline cartilage; that encircling the base of the stapes is joined to the circumference of the fenestra vestibuli by a ring of elastic fibres, named the **ligamentum annulare baseos stapedis.** The posterior part of this ligament is thicker and shorter than the anterior, and acts as a hinge on which the base of the stapes moves when the stapedius muscle contracts.

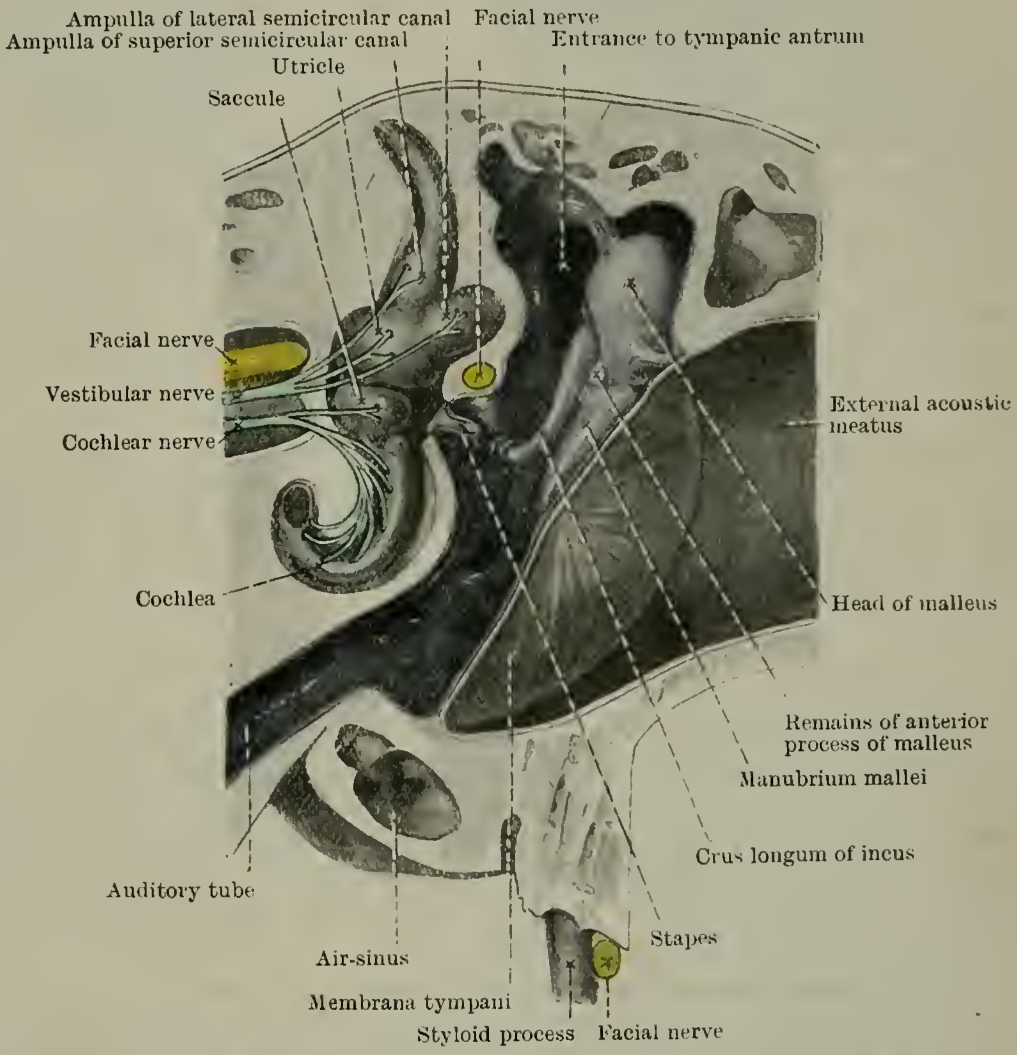

Fig. 683.—The Tympanic Cavity and Adjacent Parts (semi-diagrammatic).

Development of the Auditory Ossicles.—The malleus and incus are developed from the upper end of Meckel's cartilage; the stapes arises from the mesoderm in the region of the fenestra vestibuli, where it is developed around a small artery, the stapedial artery, which atrophies in man, but persists in many mammals. Ossification commences in all three bones about the third month of fœtal life. The malleus is ossified from two centres, one for the head and manubrium, and one for the processus anterior; the incus from one centre which appears in the upper part of its crus longum, and ultimately extends into the processus lenticularis; the stapes from one centre which appears in the base of the bone.

Muscles of the Tympanic Cavity.—These are the m. tensor tympani and m. stapedius.

The **m. tensor tympani**, the larger, takes origin from the roof of the cartilaginous part of the auditory tube, from the adjacent part of the great wing of the sphenoidal bone, and from the bony canal in which the muscle lies. The muscle ends in a tendon which bends lateralwards round the pulley-like posterior end of the septum canalis musculotubarii, and passes across the tympanic cavity to be inserted into the medial edge and anterior surface of the manubrium mallei, near its upper end. When the muscle contracts it draws the manubrium mallei towards the tympanic cavity, and so renders tense the membrana tympani. It receives its nerve from the motor division of the trigeminal nerve, through the otic ganglion.

The **m. stapedius** arises within the eminentia pyramidalis, and from the canal which prolongs the hollow of this eminence downwards. Its tendon emerges from the apex of the eminence and is inserted into the posterior surface of the neck of the stapes. On contraction it draws back the head of the stapes, and so tilts the anterior part of the base towards the tympanic cavity. It is supplied by the facial nerve.

Movements of the Auditory Ossicles.—The manubrium mallei follows all the movements of the membrana tympani, while the malleus and incus move together around an axis extending forwards through the crus breve of the incus and the anterior ligament of the malleus. When the membrana tympani moves medialwards it carries with it the manubrium mallei, while the incus, moving medialwards at the same time, forces the base of the stapes towards the labyrinth. This movement is communicated to the fluid (perilymph) in the labyrinth, and causes a lateral bulging of the secondary tympanic membrane which closes the fenestra cochleæ. These movements are reversed when the membrana tympani is relaxed, unless the lateral movement of the membrane is excessive. In such a condition the incus does not follow the full movement of the malleus, but merely glides on this bone at the incudo-malleolar joint, and thus the forcible dragging of the base of the stapes out of the fenestra vestibuli is prevented. The cog-tooth arrangement, already described, on the head of the malleus and body of the incus, causes the incudo-malleolar joint to become locked during the medial movement of manubrium mallei, the joint becoming unlocked during its lateral movement.

Tunica Mucosa Tympanica.—The **mucous lining of the tympanic cavity** is continuous, through the auditory tube, with that of the nasal part of the pharynx; it extends backwards also and lines the tympanic antrum and the mastoid air-cells. Thin, transparent, and closely united with the subjacent periosteum, it covers the medial surface of the membrana tympani and is reflected over the auditory ossicles and their ligaments. It also supplies sheaths for the tendons of the tensor tympani and stapedius muscles, and forms the following **folds**: (*a*) one from the roof of the recessus epitympanicus to the head of the malleus and body of the incus; (*b*) one enveloping the chorda tympani nerve and crus longum of the incus; (*c*) two extending from the processus lateralis mallei—one to the anterior, the other to the posterior margin of the notch of Rivinus. A recess, the **pouch of Prussak**, is situated between the membrana flaccida and the neck of the malleus. This pouch communicates behind with the tympanic cavity, and may serve as a reservoir for pus or other fluid, since its opening into the tympanic cavity is above the level of its floor, a condition analogous to the opening from the maxillary air-sinus into the nasal cavity. The fold of mucous membrane which envelops the chorda tympani nerve gives rise to two pouches, one in front of, and the other behind, the manubrium mallei; these are named the **anterior** and **posterior recesses of Tröltsch**. The epithelium which lines the mucous membrane is flattened over the membrana tympani, promontory, and auditory ossicles, but ciliated and columnar over the greater portion of the rest of the cavity.

Vessels and Nerves of the Tympanic Cavity.—The **arteries** supplying the tympanic cavity are: (1) The anterior tympanic artery, a branch of the internal maxillary artery, which reaches the cavity by way of the petro-tympanic fissure. (2) The stylo-mastoid branch of the posterior auricular artery, which passes through the stylo-mastoid foramen and the facial canal; it supplies branches to the tympanic antrum and mastoid air-cells, to the stapedius muscle, to the floor and medial wall of the tympanic cavity, and forms an anastomotic circle, around the membrana tympani, with the anterior tympanic artery. (3) The middle meningeal artery sends a branch to the tensor tympani muscle, and gives off its superficial petrosal artery, which passes to the tympanic cavity through the hiatus canalis facialis; some twigs from the posterior division of the middle meningeal artery reach the tympanic antrum and epitympanic recess through the petro-squamous fissure. (4) The internal carotid artery, in its passage through the canal in the temporal bone, gives off one or two tympanic twigs. (5) A branch from the ascending pharyngeal accompanies the tympanic nerve. The **veins** drain into the pterygoid plexus, and the superior petrosal sinus. The **lymph-vessels** form a network in the mucous membrane and end mainly in the retro-pharyngeal and parotid lymph-glands. The **nerves** supplying the muscles of the tympanic cavity have already been referred to (pp. 828, 691). The mucous membrane receives its nerves from the tympanic plexus, which is described on p. 697. The chorda tympani branch of the facial nerve passes from behind, upwards, and forwards through the tympanic cavity; its course is described on p. 694.

Early Condition of Tympanic Cavity.—During the greater part of fœtal life the tympanic cavity is almost completely filled by a soft, reddish, jelly-like embryonic tissue in which there is a slit-like space lined with epithelium. Towards the end of fœtal life this tissue disappears, and at birth the cavity is filled with fluid which becomes absorbed, after the entrance of air from the nasal part of the pharynx through the auditory tube.

AURIS INTERNA.

The **internal ear** is situated in the petrous part of the temporal bone, and consists of two sets of structures, (1) a series of passages hollowed out of the bone and constituting the **osseous labyrinth**; these are continuous with each other, and are named from before backwards the **cochlea**, **vestibule**, and **semicircular canals** (Figs. 684, 685); (2) a complex arrangement of membranous channels (Fig. 688), situated within, but not nearly filling, the osseous labyrinth and forming the **membranous labyrinth**. These channels are named the **ductus cochlearis**, the **utricle**, the **saccule**, and the **semicircular ducts**; the utricle and saccule are lodged within the vestibule.

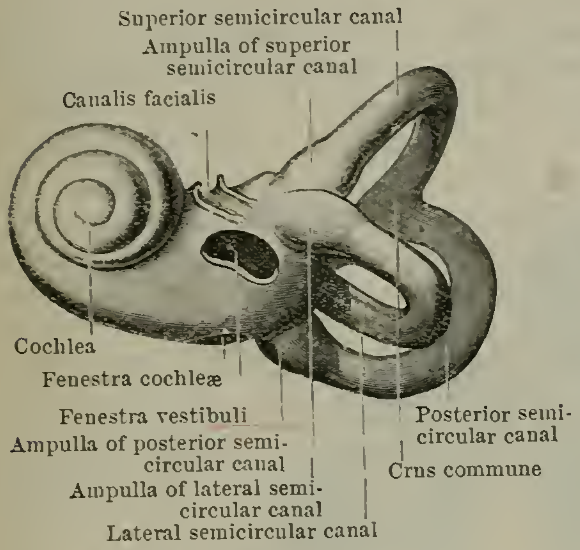
Superior semicircular canal
Ampulla of superior semicircular canal
Canalis facialis
Cochlea
Fenestra cochleæ
Fenestra vestibuli
Ampulla of posterior semicircular canal
Ampulla of lateral semicircular canal
Lateral semicircular canal
Posterior semicircular canal
Crus commune

Fig. 684.—Left Bony Labyrinth (viewed from the lateral aspect).

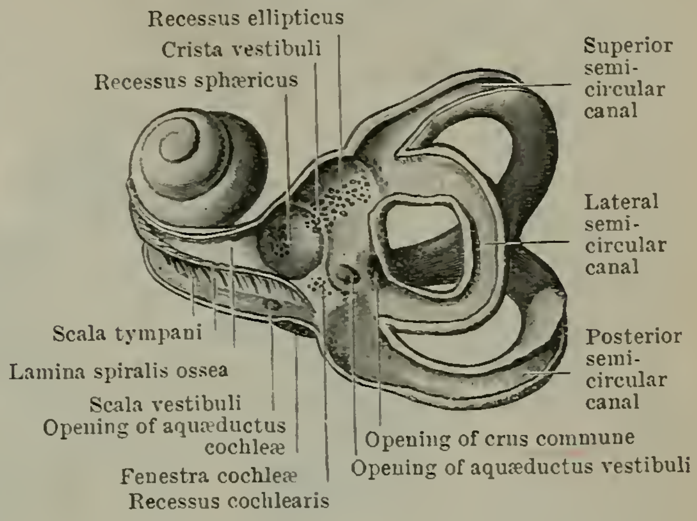

Fig. 685.—Interior of Left Bony Labyrinth (viewed from lateral aspect).

LABYRINTHUS OSSEUS.

Vestibulum.—The **vestibule** is the central portion of the osseous labyrinth, and communicates behind with the semicircular canals and in front with the cochlea. It is somewhat ovoid in shape, its long axis being directed forwards and lateralwards. It measures about 6 mm. antero-posteriorly, 4-5 mm. vertically, and about 3 mm. transversely. Its lateral wall is directed towards the tympanic cavity, and in it is the fenestra vestibuli, which is closed by the base of the stapes. Its medial wall corresponds with the bottom of the internal acoustic meatus, and presents, at its antero-inferior part, a circular depression, the **recessus sphæricus**, which lodges the saccule. This recess is perforated by twelve or fifteen small foramina (**macula cribrosa media**), which transmit the filaments of the acoustic nerve to the saccule. The recessus sphæricus is limited above and behind by an oblique ridge, the **crista vestibuli**, the anterior end of which is triangular in shape and named the **pyramis vestibuli**. Posteriorly this crista divides into two limbs, between which is a small depression, the **recessus cochlearis**. This recess is perforated by several small foramina, for the passage of the nervous filaments supplying the vestibular end of the ductus cochlearis. Above and behind the crista vestibuli, in the roof and medial wall of the vestibule, is an oval depression, the **recessus ellipticus**, which lodges the utricle. The pyramis vestibuli and adjacent part of the recessus ellipticus are perforated by twenty-five or thirty small foramina (**macula cribrosa superior**). The foramina in the pyramis vestibuli transmit the nerves to the utricle; those in the recessus ellipticus, the nerves to the ampullæ of the superior and lateral semicircular ducts. Behind and below the recessus ellipticus is a furrow, gradually deepening to form a canal, the **aquæductus vestibuli**, which passes backwards through the petrous part of the temporal bone, and opens, as a slit-like fissure, about midway between the internal acoustic meatus and the groove for the transverse sinus. This aqueduct is from 8 to 10 mm. long, and gives passage to the ductus endolymphaticus and a small vein. At the posterior part of the vestibule are five circular openings leading into the semicircular canals; at its anterior part is an elliptical opening, leading into the scala vestibuli of the cochlea. This opening is bounded below by a thin osseous plate, the **lamina spiralis ossea**, which springs from the floor of the vestibule immediately lateral to the recessus sphæricus, and forms, in the cochlea, the bony part of the septum between the scala tympani and the scala vestibuli.

Canales Semicirculares Ossei.—The **osseous semicircular canals** (Figs. 684, 685), three in number, are situated above and behind the vestibule. They are distinguished from each other by their position, and are named superior, posterior, and lateral. Each forms about two-thirds of a circle, one end of which is dilated and termed the osseous ampulla. They are somewhat compressed from side to side, and their diameter is from 1 to 1·5 mm., whilst that of the ampullæ is about 2 mm. They open into the vestibule by five apertures, since the medial end of the superior, and the upper end of the posterior, join to form a common canal or crus commune.

The **superior semicircular canal**, 15 to 20 mm. long, is vertical and placed transversely to the long axis of the petrous part of the temporal bone. Its convexity is directed upwards, and its position is indicated by the arcuate eminence. Its ampullated end is the anterior and lateral, and opens into the vestibule immediately above that of the lateral canal. Its opposite end joins the non-ampullated end of the posterior canal to form the **crus commune**, which is about 4 mm. long, and opens into the upper and medial part of the vestibule. The **posterior semicircular canal**, from 18 to 22 mm. long, is also vertical. Its ampulla is placed inferiorly, and opens into the lower and posterior part of the vestibule, where there are six or eight small apertures (**macula cribrosa inferior**), for the transmission of the nerves to this ampulla. Its upper end terminates in the crus commune. The **lateral canal**, from 12 to 15 mm. long, arches nearly horizontally. Its lateral end is ampullated, and opens into the vestibule immediately above the fenestra vestibuli, close to the ampullary end of the superior canal.

Crum Brown (*Journ. Anat. and Physiol.*, London, vol. viii.) pointed out that the lateral canal of one ear is very nearly in the same plane as that of the other; while the superior canal of one ear is nearly parallel to the posterior canal of the other.

Cochlea.[1]—When freed from its surroundings the **cochlea** assumes the form of a short cone (Fig. 684); the central part of its **base** corresponds with the bottom of the internal acoustic meatus, whilst its apex or **cupula**, directed forwards and lateralwards, is in close relation with the semicanal for the tensor tympani muscle. It measures about 9 mm. across the base and about 5 mm. from base to apex, and consists of a spirally arranged tube, which forms from 2½ to 2¾ coils around a central pillar, termed the **modiolus**. The length of the tube is from 28 to 30 mm., and its diameter, near the base of the cochlea, 2 mm. Its coils are distinguished by the terms basal, central, and apical; the basal coil gives rise to the promontory on the labyrinthic wall of the tympanic cavity.

The modiolus is about 3 mm. in height, and its diameter diminishes rapidly from the base to the apex; the latter ends about 1 mm. from the cupula. Its **base** corresponds with the **area cochleæ** on the fundus of the internal acoustic meatus, and exhibits the **tractus spiralis foraminosus**, which transmits the nerves for the basal and central coils of the cochlea and the **foramen centrale**, which gives passage to the nerves for the apical coil. The foramina of the tractus spiralis foraminosus traverse the modiolus, running at first parallel to its long axis, and then bending outwards to reach the attached edge of the lamina spiralis ossea, where they expand and form by their apposition a spiral canal, the **canalis spiralis cochleæ**, which lodges the **ganglion spirale cochleæ**. From this spiral canal numerous small canals, for the transmission of vessels and nerves, pass outwards to the free edge of the lamina spiralis ossea.

The **lamina spiralis ossea**, a thin, flat shelf of bone, winds round the modiolus like the thread of a screw, and, projecting about half-way into the cochlear tube, incompletely divides it into two passages, an upper, the **scala vestibuli**, and a lower, the **scala tympani**. The lamina spiralis ossea begins at the floor of the vestibule, near the fenestra cochleæ, and ends near the cupula of the cochlea in a sickle-shaped process, the **hamulus laminæ spiralis**, which assists to bound an aperture named the **helicotrema**. In the basal coil the upper surface of the lamina spiralis ossea forms almost a right angle with the modiolus, but the angle becomes more and more acute on ascending the tube. In the lower half of the basal coil a second smaller bony plate, the **lamina spiralis secundaria**, projects from the outer wall of the cochlea towards the lamina spiralis ossea, without, however, reaching it. If viewed from the vestibule a slit-like fissure, the **fissura vestibuli**, is seen between the two laminæ, which are continuous with one another round the posterior end of the fissure. A membrane, the **membrana basilaris**, stretches from the free edge of the lamina spiralis ossea to the outer wall of the cochlea, and completes the septum between the scala vestibuli and scala tympani, but the two scalæ communicate with each other through the opening of the helicotrema at the cupula of the cochlea. The scala tympani begins at the fenestra cochleæ, which is closed by the secondary tympanic membrane (p. 827). At the commencement of the scala tympani a crest, termed the **crista semilunaris**, stretches from the attached margin of the lamina spiralis ossea towards the orifice of the fenestra cochleæ. Close to this crest is seen the inner orifice of the **aquæductus cochleæ**, a canal measuring from 10 to 12 mm. in length, and opening on the under surface of the petrous part of the temporal bone in front of the fossa jugularis. This aqueduct establishes a communication between the scala tympani and the subarachnoid cavity, and transmits a small vein to join the inferior petrosal sinus. The scala vestibuli, the higher of the two passages, begins in the vestibule; in the basal coil its diameter is less than that of the scala tympani, but in the upper coils it exceeds it.

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[1] In the following description the cochlea is supposed to be placed on its base.

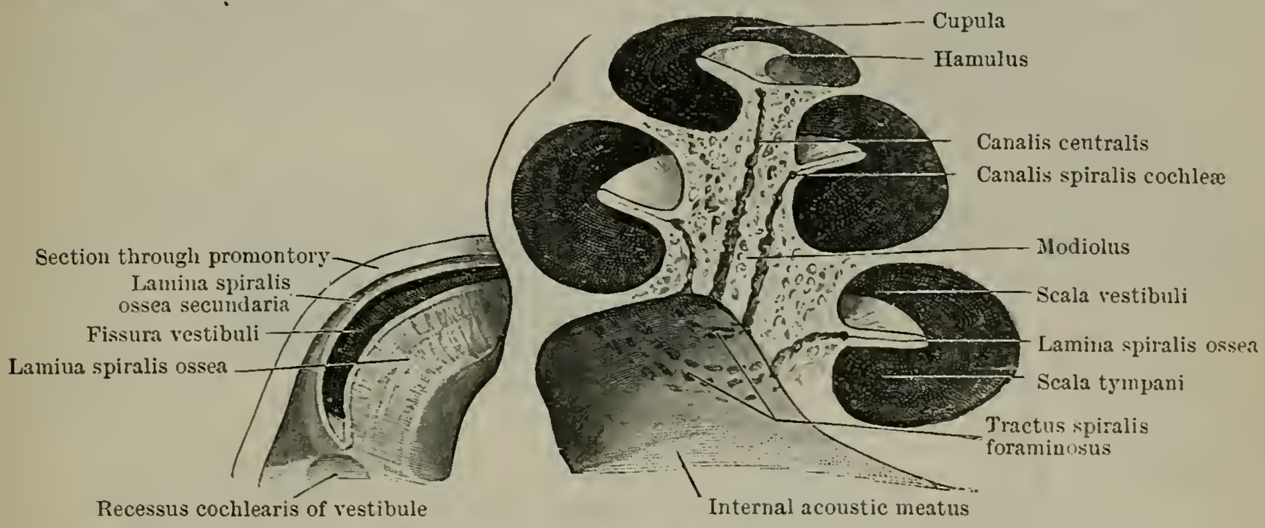

FIG. 686.—SECTION OF BONY COCHLEA.

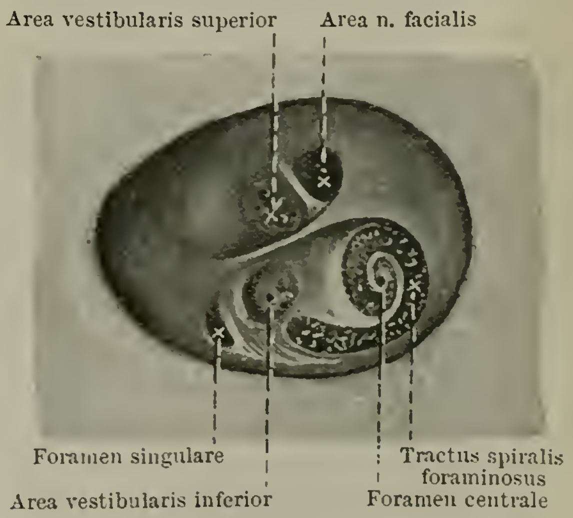
Area vestibularis superior
Area n. facialis
Foramen singulare
Area vestibularis inferior
Tractus spiralis foraminosus
Foramen centrale

FIG. 687.—BOTTOM OF INTERNAL ACOUSTIC MEATUS DIVIDED INTO UPPER AND LOWER AREAS BY THE CRISTA TRANSVERSA.

The **fundus of the internal acoustic meatus** has been referred to as forming the medial wall of the vestibule and the base of the modiolus. It is divided by a transverse ridge, the **crista transversa**, into a **fossula superior** and a **fossula inferior**. In the anterior part of the fossula superior is a single large opening for the transmission of the facial nerve; the posterior part of this fossula is named the **area vestibularis superior**, and is perforated by the nerves of the utricle and the ampullæ of the superior and lateral semicircular ducts. The anterior part of the fossula inferior is termed the **area cochleæ**: in it are the **canalis centralis** of the modiolus and the surrounding **tractus spiralis**

foraminosus, for the passage of the nerves to the cochlea. Behind the area cochleæ, and separated from it by a ridge, is the **area vestibularis inferior**, which is pierced by the nerves to the saccule; behind this area is the **foramen singulare**, which gives passage to the nerves of the ampulla of the posterior semicircular duct.

LABYRINTHUS MEMBRANACEUS.

The **membranous labyrinth** (Fig. 688) is contained within the bony labyrinth, but does not nearly fill it. It contains a fluid termed **endolymph**, while the interval between it and the bony labyrinth is named the **perilymphatic space**, and is occupied by a fluid termed **perilymph**. The perilymphatic space in the vestibule is continuous behind with that of the semicircular canals, and opens in front into the scala vestibuli; at the apex of the cochlea it is continuous, through the helicotrema, with the scala tympani, which is shut off from the tympanic cavity by the secondary tympanic membrane. Through the aquæductus cochleæ the perilymphatic space communicates with the subarachnoid cavity. The ductus semicirculares and the ductus cochlearis follow the course and lie along the inner surfaces of the outer walls of the corresponding bony tubes. The bony vestibule, on the other hand, contains two membranous sacs, the **utricle** and **saccule**. The former receives the ends of the semicircular ducts, whilst the latter communicates with the ductus cochlearis. Moreover, the cavities of the utricle and saccule are indirectly connected, and thus all parts of the membranous labyrinth communicate with each other.

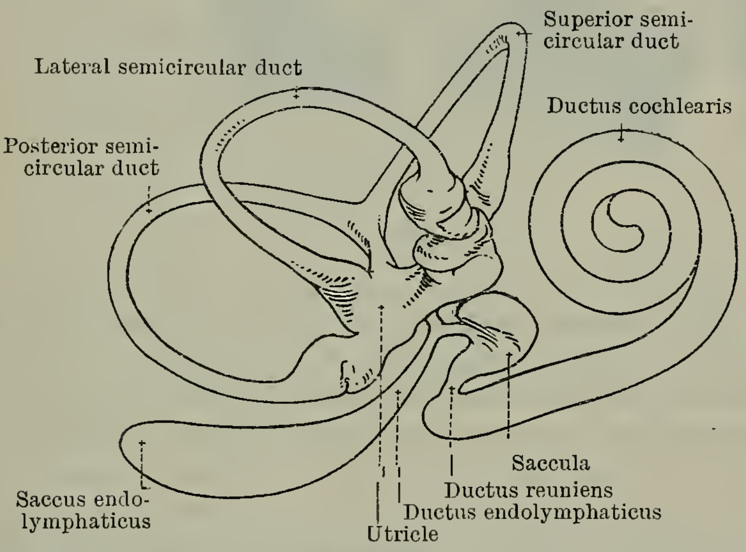

Fig. 688.—Diagrammatic Representation of the Different Parts of the Membranous Labyrinth. (Milne-Dickie.)

(From a model made by Dr. J. H. M. Dickie, and sections made by Dr. J. S. Fraser.)

Utriculus.—The **utricle** is larger than the saccule, and (Fig. 683) occupies the postero-superior portion of the vestibule. Its highest part, or **recessus utriculi**, lies in the recessus ellipticus, and the ampullæ of the superior and lateral semicircular ducts open into it. The non-ampullated end of the lateral semicircular duct opens into the central part of the utricle, and this part is prolonged upwards and backwards as the **sinus superior**, into which the crus commune of the superior and posterior semicircular ducts open. The ampulla of the posterior semicircular duct opens into the lower and medial part, or **sinus inferior**. The floor and anterior wall of the recessus utriculi are thickened to form the **macula acustica utriculi**, to which the utricular fibres of the acoustic nerve are transmitted through the foramina in the pyramis vestibuli. Whitish in colour, and of an oval or nearly rhombic shape, this macula measures 3 mm. in length and 2·3 mm. in its greatest breadth.

Sacculus.—The **saccule** occupies the recessus sphæricus, in the lower and anterior part of the vestibule (Fig. 683). It is of an oval shape and measures 3 mm. in its longest, and about 2 mm. in its shortest diameter. It presents anteriorly an oval, whitish thickening, the **macula acustica sacculi**. This has a breadth of about 1·5 mm., and to it the saccular fibres of the acoustic nerve are distributed. The upper end of the saccule is directed upwards and backwards, and forms the **sinus utricularis sacculi**, which comes into contact with the utricle, and here the utricle and saccule are separated by a common wall (Milne Dickie[1]). From the lower part of the saccule a short canal, the **ductus reuniens (Henseni)**, descends and gradually widens into the vestibular end of the ductus cochlearis. A second small channel, the **ductus endolymphaticus**, is continued from the posterior part of the saccule, and is joined by a small canal, the **ductus utriculosaccularis**, which arises from the medial side of the utricle. The ductus endolymphaticus then enters and traverses the aquæductus vestibuli and ends, under the dura mater on the posterior surface of the petrous part of the temporal bone, in a dilated blind pouch, termed the **saccus endolymphaticus**; this, according to Rüdinger, is perforated by minute foramina, through which the endolymph may pass into the meningeal lymphatics.

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[1] *Journal of Laryngology, Rhinology, and Otology*, vol. xxxv.

The vestibule also contains the vestibular extremity of the ductus cochlearis, which lies immediately below the saccule in the recessus cochlearis.

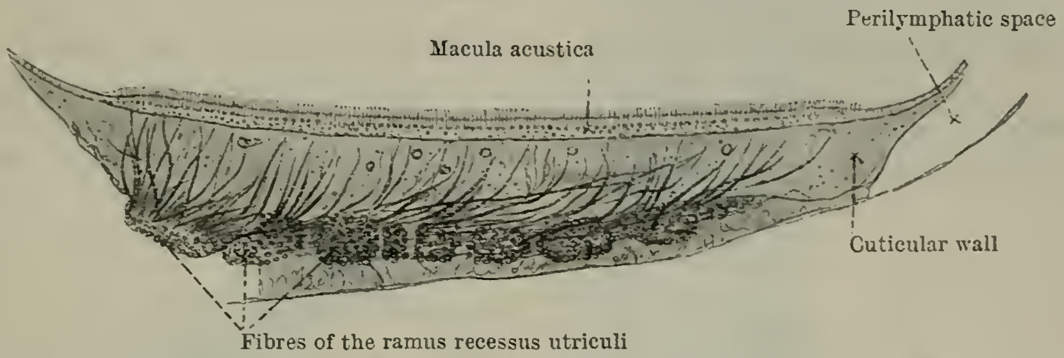

FIG. 689.—VERTICAL SECTION OF THE WALL OF THE RECESSUS UTRICULI WITH THE MACULA ACUSTICA AND THE BUNDLES OF NERVE FIBRES.

Structure.—The walls of the utricle and saccule are composed of (*a*) an external layer of connective tissue which blends with the periosteal lining of the vestibule, (*b*) an intermediate transparent layer or tunica propria, and (*c*) an internal layer of pavement epithelium. The walls are thickened at the maculæ acusticæ; towards the periphery of the maculæ the epithelium is cubical, while on them it is columnar.

In the maculæ of the utricle and saccule two kinds of cells are found, (*a*) supporting cells, and (*b*) hair-cells. The **supporting cells** are somewhat fusiform, each containing, near its middle, a nucleus. Their branched, deep ends are attached to the membrana propria; their free ends lie between the hair-cells and form a thin inner limiting cuticle. The **hair-cells** are flask-shaped and do not reach the membrana propria, their rounded ends lying between the supporting cells. Each hair-cell contains, in its deepest part, a large nucleus, the rest of the cell being granular and pigmented. From the free end of each there projects a stiff, hair-like process, which, on the application of reagents, splits into several finer filaments. The nerve-fibres pierce the membrana propria, and ramify around the deep ends of the hair-cells (Fig. 691). A collection of small crystals of carbonate of lime, termed **otoconia**, adheres to each of the maculæ.

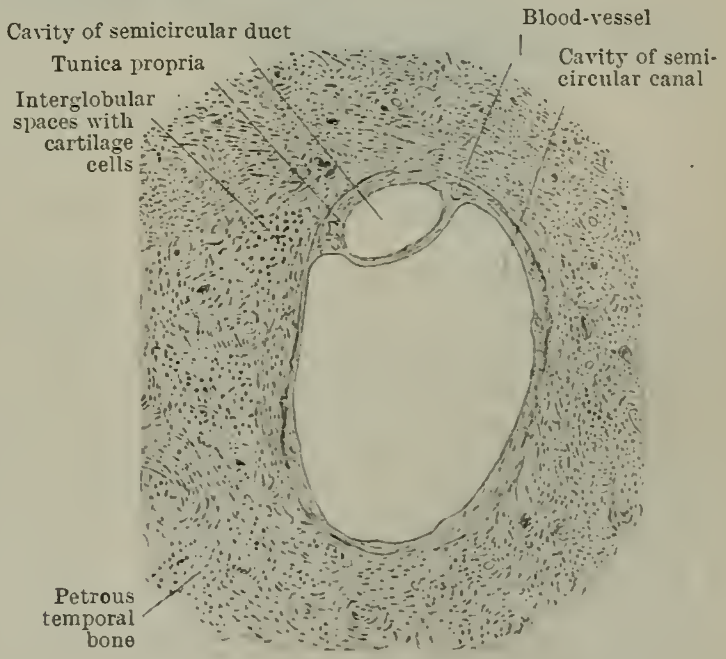
Cavity of semicircular duct
Tunica propria
Interglobular spaces with cartilage cells
Blood-vessel
Cavity of semi-circular canal
Petrous temporal bone

FIG. 690.—SECTION OF A SEMICIRCULAR CANAL AND DUCT.

(From a section made by Dr. J. S. Fraser.)

Ductus Semicirculares.—The **semicircular ducts** are elliptical on transverse section (Fig. 690), and are attached to the walls of the bony canals. The convex wall of each duct is fixed to the periosteal lining of the canal, whilst the opposite part is connected by delicate fibrous bands to the bony wall. Like the bony canals, each of the semicircular ducts is dilated at one end into an ampulla; these ampullæ nearly fill the corresponding portions of the bony tubes, but the diameter of the semicircular ducts is only about one-fourth of that of the osseous canals.

Structure.—Each semicircular duct consists of three layers, (*a*) an outer vascular and partly pigmented fibrous stratum which fixes the duct to the bony wall; (*b*) an intermediate, transparent

tunica propria, presenting a number of papilliform elevations which project towards the lumen. The fibrous layer and tunica propria are thinnest along the attached surface of the duct, and in this region also the papilliform elevations are absent; (*c*) an internal **epithelial layer**, composed of pavement cells. In each ampulla the tunica propria is thickened, and projects into the cavity as a transverse elevation, termed the **septum transversum**, which, when seen from above, is somewhat fiddle-shaped; the most prominent part of this septum is named the **crista ampullaris**. The cells covering the crista ampullaris consist of **supporting cells** and **hair-cells**, and are similar in their arrangement to those in the maculæ of the utricle and saccule; the hairs of the hair-cells are, however, considerably longer, and project as far as the middle of the ampullary lumen. In fresh specimens they appear to end free, but in hardened preparations are seen to terminate in a soft, clear, dome-like structure, the **cupula terminalis**, which is radially striated. The nerves form arborisations around the bases of the hair-cells.

In most mammals a ridge (*crista quarta*) projects into the posterior end of the lateral semicircular duct, and to this crista nerve-filaments have been traced.

Ductus Cochlearis.—The **ductus cochlearis** (O.T. **membranous cochlea** or **scala media**) is a spirally arranged canal inside the bony cochlea. Its lower end occupies the recessus cochlearis of the vestibule and communicates with the saccule through the ductus reuniens; its upper end is closed, and is named the **lagena**, or **cæcum cupulare**; it is fixed to the cupula of the cochlea, and partly bounds the helicotrema. As already stated (p. 839) the membrana basilaris stretches from the free edge of the lamina spiralis ossea to the outer wall of the cochlea. A second, more delicate membrane, the **membrana vestibularis** (O.T. **membrane of Reissner**), stretches from the thickened periosteum covering the upper surface of the lamina spiralis ossea to the outer wall of the cochlea, some distance above the external attachment of the membrana basilaris. A canal is thus enclosed between the underlying scala tympani and membrana basilaris, and the overlying scala vestibuli, and constitutes the **ductus cochlearis**. Triangular on transverse section, the ductus cochlearis possesses a roof, an outer wall, and a floor; it is lined throughout with epithelium and filled with endolymph. On its floor the epithelium is greatly modified, and there the endings of the cochlear nerve are found.

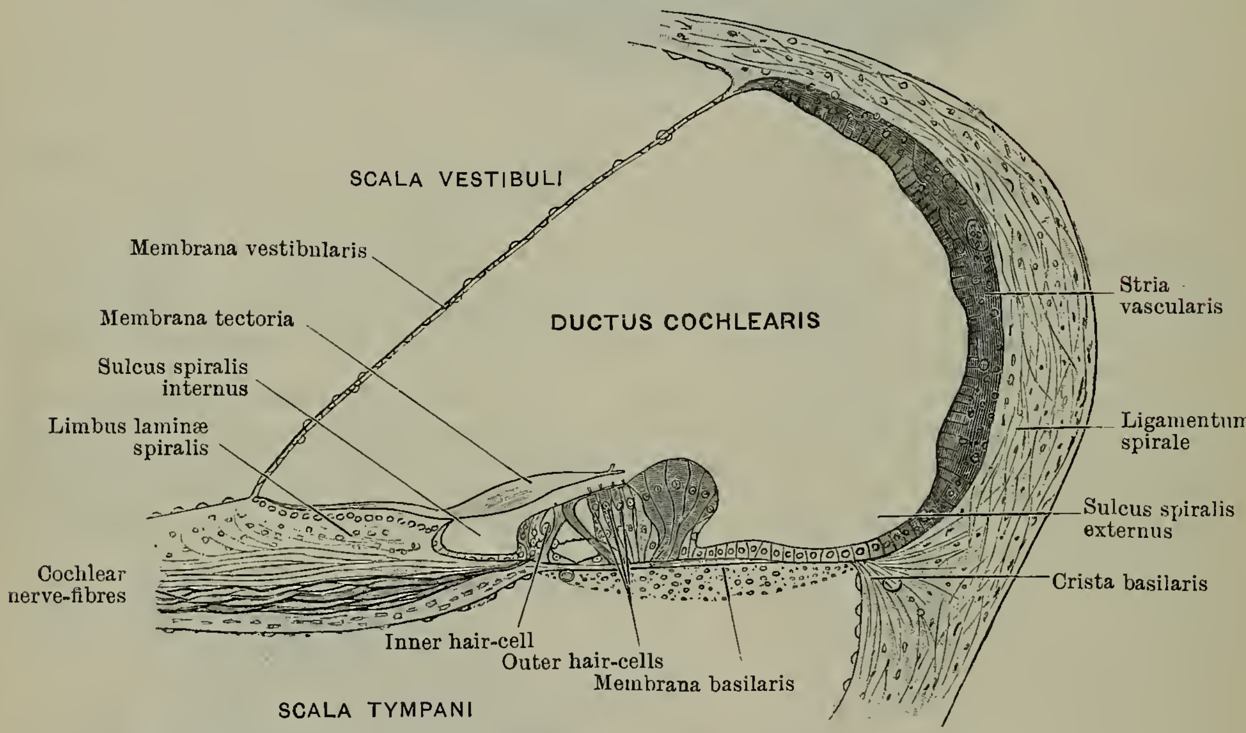

FIG. 691.—SECTION ACROSS THE DUCTUS COCHLEARIS. (Retzius.)

The **roof** or **vestibular wall** of the ductus cochlearis is formed by the membrana vestibularis, a delicate, nearly homogeneous membrane, covered on both surfaces by a layer of epithelium. Its entire thickness is about 3 μ.

The **outer wall** of the ductus cochlearis (Fig. 691) consists of the periosteal lining of the bony cochlea, which, however, is thickened and greatly modified to form the **ligamentum spirale cochleæ**. This ligament projects inwards inferiorly as a triangular crest, the **crista basilaris**, to which the outer edge of the membrana basilaris is attached. In the upper part of the ligamentum spirale the periosteum is of a reddish-yellow colour, and contains, immediately under its epithelial lining, numerous small blood-vessels and capillary loops, forming the **stria vascularis.** The lower limit of this stria is bounded by a prominence, the **prominentia spiralis,** in which is seen a vessel, the **vas prominens,** and between this prominence and the crista basilaris is a concavity, the **sulcus spiralis externus.** The height of the outer wall of the ductus cochlearis diminishes towards the apex of the cochlea.

The **floor** or **tympanal wall** of the ductus cochlearis is formed by the periosteum covering that portion of the lamina spiralis ossea which is situated on the outer side of the membrana vestibularis, and by the **membrana basilaris,** which stretches from the free edge of the lamina spiralis ossea to the crista basilaris. On the inner part of the membrana basilaris the complicated structure termed the **organon spirale** (O.T. **organ of Corti**) is situated. The lamina spiralis ossea consists of two plates of bone, between which are placed the canals for the branches of the cochlear nerve. On the upper plate the periosteum is thickened and modified to form the **limbus laminæ spiralis,** the outer border of which is concave, and appears, in radial sections, as a C-shaped indentation, the **sulcus spiralis internus** (Fig. 691). The portions of the limbus which project above and below this concavity are termed respectively the **labium vestibulare** and **labium tympanicum.** The latter is perforated by about 4000 small apertures, the **foramina nervosa,** for the transmission of the cochlear nerves, and is continuous with the membrana basilaris. The upper surface of the labium vestibulare presents a number of furrows crossing each other nearly at right angles, and intersecting a series of elevations which, at the free margin of the labium, form a row of tooth-like structures, about 7000 in number, the **auditory teeth of Huschke.** Covering the limbus is a layer of apparently squamous epithelium; the deeper protoplasmic portions of the cells, however, with their contained nuclei, lie in the intervals between the elevations and auditory teeth. This layer of epithelium is continuous above with that covering the under surface of the membrana vestibularis and below with that which lines the sulcus spiralis internus.

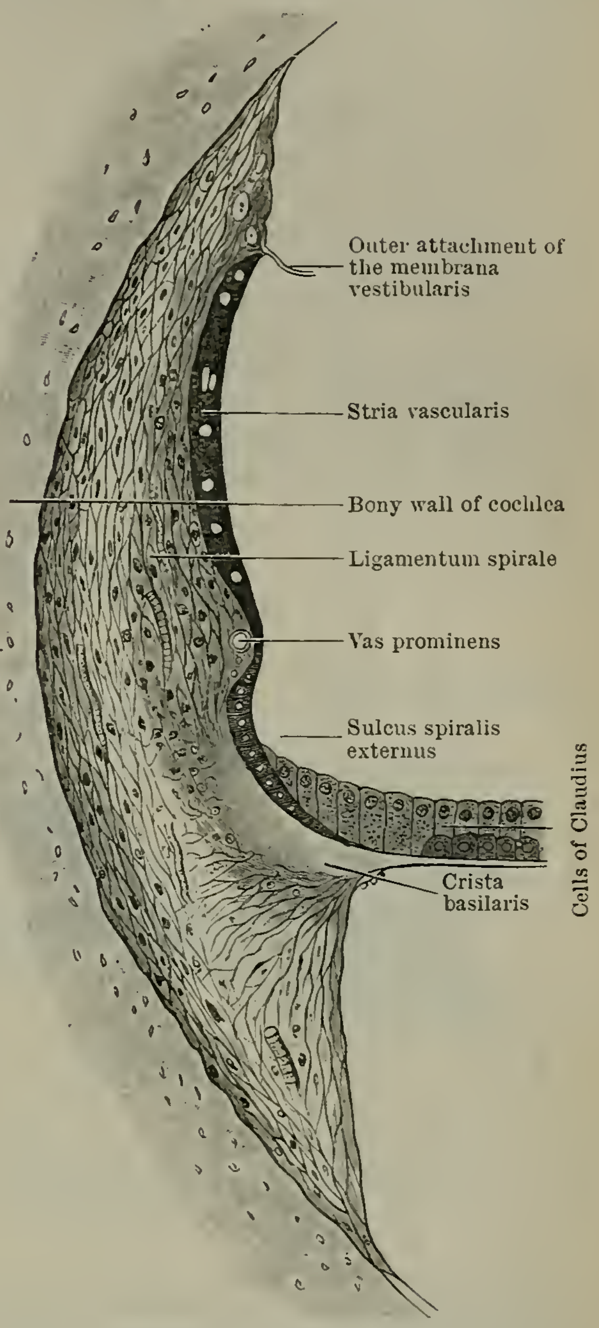

Fig. 692.—Transverse Section through Outer Wall of Ductus Cochlearis. (Schwalbe.)

Membrana Basilaris.—The basilar membrane stretches from the tympanic lip of the lamina spiralis ossea to the crista basilaris. Its inner part is thin, and supports the organon spirale; it is named the **zona arcuata,** and reaches as far as the foot-plate of the outer rod of Corti. Its outer part is thicker and distinctly striated, and is termed the **zona pectinata.** The substantia propria of the membrane is almost homogeneous, but exhibits, in its deeper part, numerous fibres. These fibres are most distinct in the zona pectinata, and number, according to Retzius, about 24,000. Covering the under surface of the membrana basilaris is a layer of connective tissue, containing, in its inner part, small blood-vessels; one of these is larger than the others and lies below the tunnel of Corti, and is named the vas spirale. The width of the membrana basilaris increases from 0·21 mm. in the basal coil to 0·36 mm. in the apical coil.

Organon Spirale (O.T. **Organ of Corti**) (Fig. 693).—Placed upon the zona arcuata or inner portion of the membrana basilaris, the organon spirale consists of an epithelial eminence which extends along the entire length of the ductus cochlearis, and comprises the following structures: (1) Corti's rods or pillars, (2) hair-cells (inner and outer), (3) supporting cells of Deiters, (4) the cells of Hensen and Claudius, (5) the lamina reticularis, and (6) the membrana tectoria.

The **rods of Corti** form two rows, **inner** and **outer**, of stiff, pillar-like structures, and each rod presents a base or foot-plate, an intermediate elongated portion, and an upper end or head. The bases of the rods are planted on the membrana basilaris, those of the inner row at some little distance from those of the outer. The intermediate portions of the rods incline towards each other and the heads come into contact, so that, between the two rows and the membrana basilaris, a triangular tunnel, the **tunnel of Corti**, is enclosed; this tunnel increases both in height and width on passing towards the apex of the cochlea. The **inner rods** number nearly 6000, and the head of each resembles somewhat the proximal end of the ulna, presenting externally a deep concavity for the reception of a corresponding convexity on the head of the outer rod. The part of the head which overhangs this concavity is prolonged outwards, under the name of the **head-plate**, and overlaps the head of the outer rod. The expanded bases of the inner rods are placed immediately on the outer side of the foramina nervosa of the labium tympanicum; the intermediate parts of these rods are sinuously curved, and form with the membrana basilaris an angle of about 60°. The **outer rods** number about 4000, and are longer than the inner, especially in the upper turns of the cochlea. They are more inclined towards the membrana basilaris, and form with it an angle of about 40°. The head of each is convex internally, to fit the concavity on the head of the inner rod, and is prolonged outwards as a plate, the **phalangeal process**, which becomes connected with the lamina reticularis; in the head is an oval body which has an affinity for certain reagents. The main part of each rod consists of a nearly homogeneous material, which is finely striated. At the base of each rod, on the surface next Corti's tunnel, is a nucleated mass of protoplasm which reaches as far as the head of the rod, and covers also a part of the tunnel floor; this protoplasm may be regarded as the undifferentiated part of the cell from which the rod was developed. Slit-like intervals, for the transmission of nerves, exist between the intermediate portions of adjacent rods.

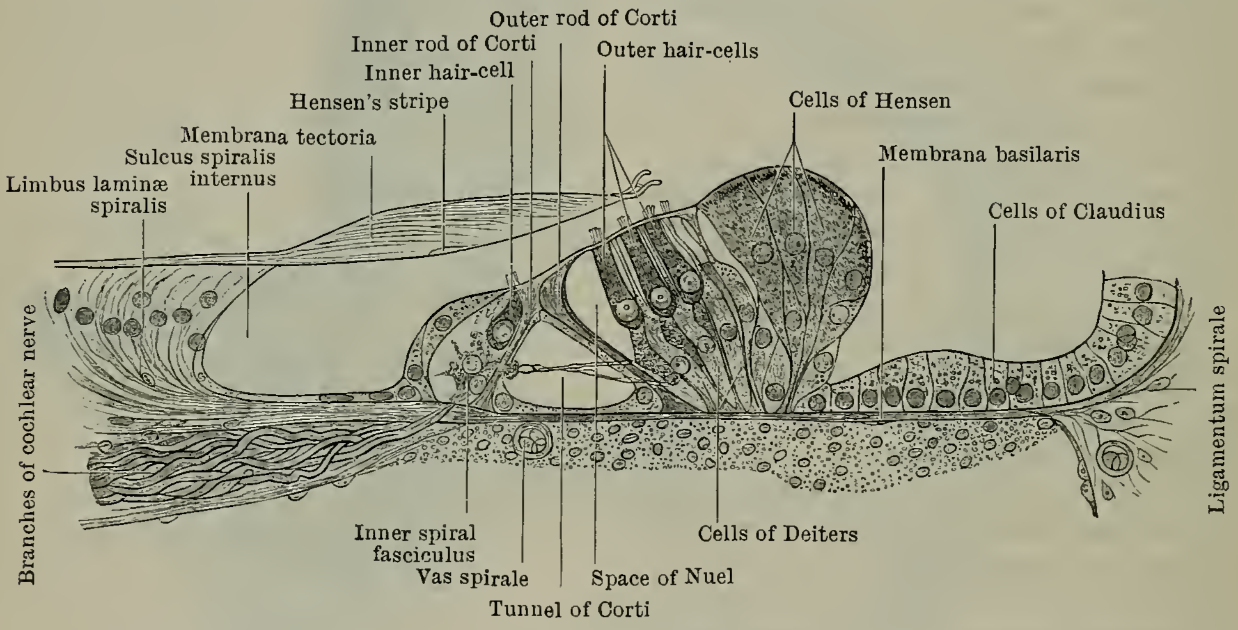

FIG. 693.—TRANSVERSE SECTION OF THE ORGANON SPIRALE FROM THE CENTRAL COIL OF THE DUCTUS COCHLEARIS. (Retzius.)

Hair-cells.—These, like Corti's rods, form two sets, **inner** and **outer**; the former consists of a single row lying immediately internal to the inner rods—the latter of three, or, it may be, four rows placed to the outer side of the external rods. The **inner hair-cells** are about 3500 in number; the diameter of each is greater than that of an inner rod, and so each inner hair-cell is supported by more than one rod. The free end of each hair-cell is surmounted by about twenty fine hair-like processes, arranged in the form of a crescent, with its concavity directed inwards. The deep end of the cell contains a large nucleus and is rounded; it reaches only about half-way down the rod, and is in contact with the arborisations of the nerve terminations. To the inner side of this row of hair-cells are two or three rows of elongated columnar cells, which act as supporting cells, and are continuous with the low columnar cells lining the sulcus spiralis internus. The **outer hair-cells** number about 12,000, and form three rows in the basal coil and four rows in the upper two coils, although in the higher coils the rows are not so regularly arranged. The rounded free end of each hair-cell supports about twenty hairlets arranged in the form of a crescent, opening inwards; the deep end reaches about half-way to the membrana basilaris, and is in contact with the nerve arborisations.

Alternating with the rows of the outer hair-cells are the rows of **Deiters' supporting cells**, the lower ends of which are expanded on the membrana basilaris, whilst their upper ends are tapered; the nucleus is placed near the middle of each cell, and, in addition, each cell contains a bright, thread-like structure called the **supporting fibre**. This fibre is attached by a club-shaped base to the membrana basilaris, and expands, at the free end of the cell, to form one of the phalanges of the membrana reticularis.

The **cells of Hensen**, or outer supporting cells, consist of about half a dozen rows, immediately outside Deiters' cells, and form a well-marked elevation on the floor of the ductus cochlearis. Their deep extremities are narrow and attached to the membrana basilaris, whilst their free ends are expanded; each cell contains a nucleus and some pigment granules. The columnar cells, situated externally to the cells of Hensen, and covering the outer part of the zona pectinata, are named the **cells of Claudius**. A space, the **space of Nuel**, exists between the outer rods of Corti and the neighbouring row of hair-cells; it communicates with Corti's tunnel, and extends outwards between the outer hair-cells as far as Hensen's cells.

The **lamina reticularis** is a thin cuticular structure which lies over the organon spirale, and extends from the heads of the outer rods as far as Hensen's cells. It consists of two or three rows of structures, named **phalanges**, which are elongated cuticular plates resembling in shape the digital phalanges. The innermost row is formed by the phalangeal processes of the heads of the outer row of Corti's rods; the succeeding row, or rows, represent the expanded upper ends of Deiters' supporting cells. The number of rows of phalanges, therefore, varies with the number of rows of outer hair-cells and the alternating cells of Deiters. The free ends of the hair-cells occupy the circular apertures between the constricted middle portions of the phalanges.

The **membrana tectoria** (Fig. 693) is an elastic membrane overlying the sulcus spiralis internus and the organon spirale. Attached, by its inner border, to the limbus laminæ spiralis, near the lower edge of the membrana vestibularis, it reaches outwards as far as the outer row of hair-cells. Its inner portion is thin and overlies the auditory teeth of Huschke. Its outer part is thickened, but becomes attenuated near its external border, which, according to Retzius, is attached to the outer row of Deiters' cells. The hairs of the hair-cells project into the under surface of the membrane, and on this surface, opposite the interval between the inner and outer rows of hair-cells, is a clear, spirally arranged band, named **Hensen's stripe**.

Hardesty[1] is of opinion that the lateral border of the membrana tectoria is free, and is finely and irregularly scalloped. He describes the membrane as consisting of multitudes of delicate fibrils embedded in a transparent matrix of a soft, collagenous, semi-solid character with marked adhesiveness. The fibres run in curves from the vestibular lip and from the upper surface of the membrane to its under surface where, by their interlacement, they produce the appearance known as Hensen's stripe. Hardesty also describes a thin *accessory tectorial membrane*, lying along the under surface of the outer zone of the principal membrane, and attached to the latter by its outer border.

Nervus Acusticus (Fig. 694).—The **acoustic nerve** divides within the internal acoustic meatus into an anterior or cochlear and a posterior or vestibular nerve.

Nervus Cochleæ.—The **cochlear nerve** is distributed to the hair-cells of the organon spirale, the branches for the basal and middle coils entering the foramina in the tractus spiralis foraminosus, those for the apical coil running in the canalis centralis of the modiolus. The nerve-fibres traverse the bony canals of the modiolus, and then radiate outwards between the lamellæ of the lamina spiralis ossea. Contained in the spiral canal of the modiolus, near the attached margin of the lamina, is a ganglion of bipolar nerve-cells, named the **ganglion spirale** (O.T. **ganglion of Corti**) (Fig. 695); the fibres of the nerve arise from the cells of this ganglion. Beyond the ganglion spirale the nerve-fibres extend outwards, at first in bundles, and then in a more or less continuous sheet, from the outer edge of which they are again collected into bundles, which pass through the foramina nervosa of the labium tympanicum. Beyond this they appear as naked axis-cylinders, and, turning in a spiral manner (**inner** or **first spiral fasciculus**), send fibrillæ towards the inner row of hair-cells. Other fibrils run between the inner rods and form a **second spiral fasciculus** in Corti's tunnel, from which fibrils extend outwards across the tunnel, and, passing between the outer rods, enter Nuel's space. They form a spiral fasciculus on the inner aspect of each row of Deiters' cells, and fibrillæ pass from these fasciculi towards the bases of the outer hair-cells. The hair-cells in the basal and middle coils of the cochlea are more richly supplied with nerves than those in the apical coil.

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[1] Irving Hardesty, *American Journal of Anatomy*, vol. viii.

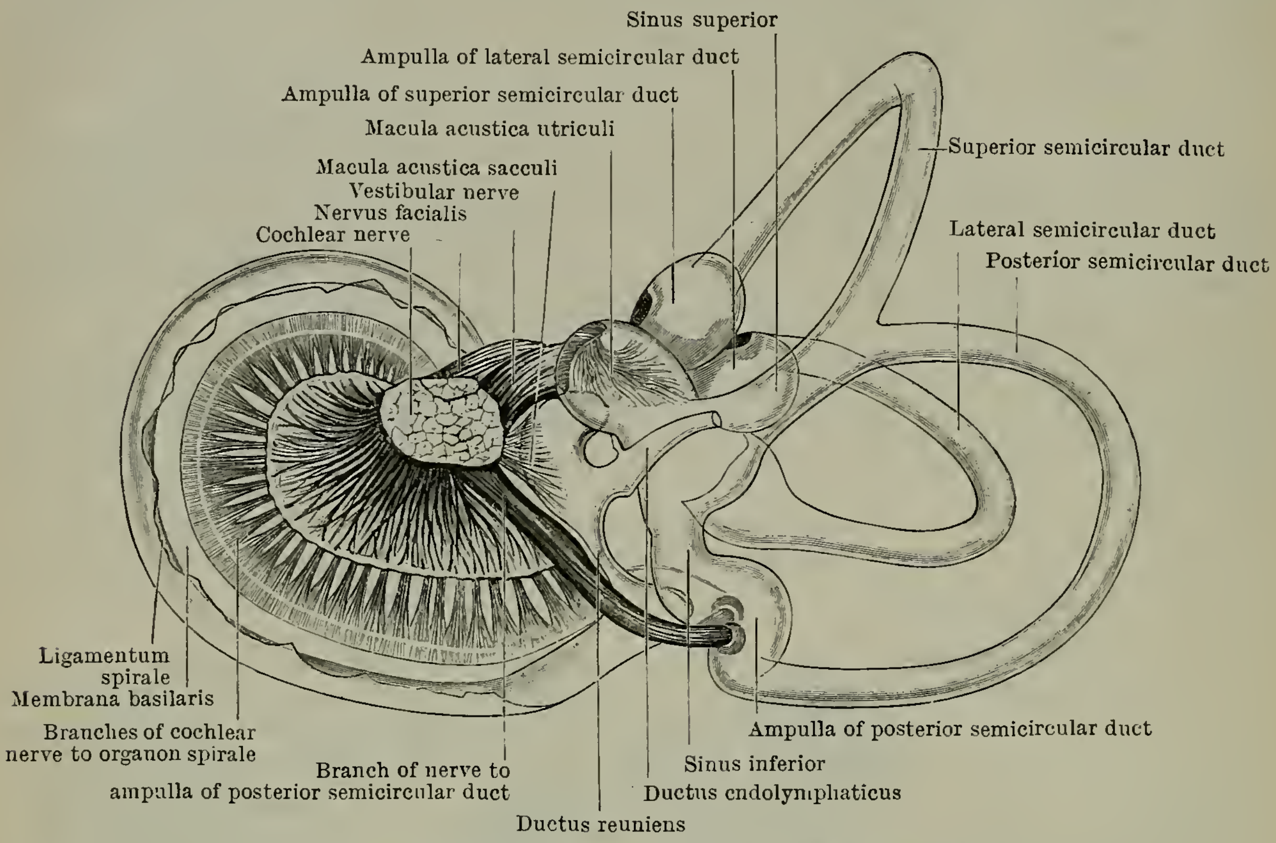
Sinus superior
Ampulla of lateral semicircular duct
Ampulla of superior semicircular duct
Macula acustica utriculi
Macula acustica sacculi
Vestibular nerve
Nervus facialis
Cochlear nerve
Superior semicircular duct
Lateral semicircular duct
Posterior semicircular duct
Ligamentum spirale
Membrana basilaris
Branches of cochlear nerve to organon spirale
Branch of nerve to ampulla of posterior semicircular duct
Ductus reuniens
Sinus inferior
Ductus endolymphaticus
Ampulla of posterior semicircular duct

FIG. 694.—MEMBRANOUS LABYRINTH OF A FIVE MONTHS' FŒTUS, viewed from its postero-medial aspect. (Retzius.)

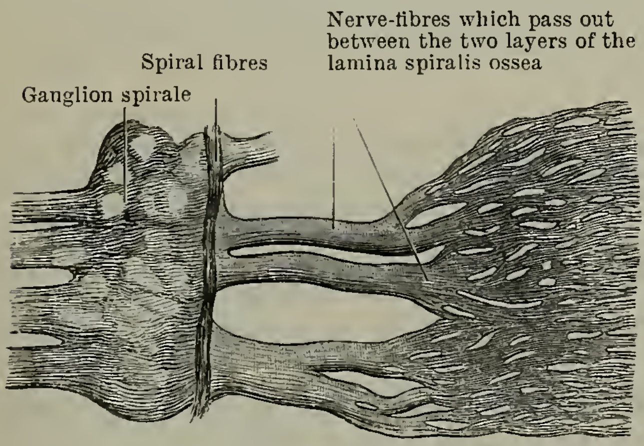
Nerve-fibres which pass out between the two layers of the lamina spiralis ossea
Spiral fibres
Ganglion spirale

FIG. 695.—PART OF COCHLEAR NERVE, highly magnified. (Henle.)

The cochlear nerve gives off a vestibular branch, the terminal filaments of which go through the foramina in the recessus cochlearis and are distributed to the hair-cells of the vestibular end of the ductus cochlearis. On this vestibular branch there is a minute ganglion (Bœttcher).

Nervus Vestibuli.—The **vestibular nerve** is distributed to the utricle, the saccule, and the ampullæ of the semicircular ducts. It divides into three branches, superior, inferior, and posterior, and each of these splits into filaments which pass through foramina in the fundus of the internal acoustic meatus. The filaments from the superior branch go through the foramina in the area vestibularis superior and supply the macula of the utricle and the cristæ ampullares of the superior and lateral semicircular ducts; those from the inferior branch run through the foramina in the area vestibularis inferior to the macula of the saccule. The posterior branch passes through the foramen singulare, and its filaments, six to eight in number, are distributed to the crista ampullaris of the posterior semicircular duct. On the trunk of the vestibular nerve, within the internal acoustic meatus, is a ganglion, the **vestibular ganglion,** of bipolar nerve cells, from which the fibres of the nerve take origin. Sometimes the vestibular nerve divides on the proximal side of the ganglion and the latter is then split into three parts, one on each of the three branches of the nerve.

Vessels of the Internal Ear.—The arteries of the internal ear are the internal auditory artery, a branch of the basilar artery, and the stylo-mastoid artery, a branch of the posterior auricular artery. The internal auditory artery enters the internal acoustic meatus and divides into vestibular and cochlear branches. The vestibular branch supplies the soft tissues in the vestibule and semicircular canals, each canal receiving two arteries, which, starting from the ends of the canal, anastomose on the summit of the arch. The cochlear branch divides into numerous twigs, which enter the foramina in the tractus spiralis foraminosus, and run outwards in the lamina spiralis ossea to reach the soft structures; the largest of these arteries runs in the canalis centralis. The stylo-mastoid artery also supplies some minute branches to the cochlea. The **veins** from the cochlea and vestibule unite, at the bottom of the internal acoustic meatus, with the veins from the semicircular canals to form the **internal auditory vein,** which may open either into the posterior part of the inferior petrosal sinus or into the transverse sinus. A small vein passes through the aquæductus cochleæ and opens into the inferior petrosal sinus or into the internal jugular vein. Another small vein traverses the aquæductus vestibuli and ends in the superior petrosal sinus.

DEVELOPMENT OF LABYRINTH (Figs. 696, 697).

The epithelial lining of the labyrinth is derived from an invagination of the cephalic ectoderm, termed the **auditory pit,** which appears opposite the hind brain immediately above the first visceral cleft. The mouth of the pit is closed by the growing together of its margins, and the pit then assumes the form of a hollow vesicle, the **otic vesicle,** which severs its connexion with the ectoderm and sinks into the subjacent mesoderm. The vesicle soon becomes pear-shaped; and from its middle part a diverticulum is given off which later forms the ductus and saccus endolymphaticus.[1] About the fifth week the anterior part of the vesicle is prolonged forwards as a diverticulum, the future ductus cochlearis. This is at first short and straight, but it elongates and curves on itself, so that at the twelfth week all three coils of the ductus cochlearis are differentiated. From the upper part of the vesicle the three semicircular ducts are developed, and appear as hollow, disc-like evaginations; the central parts of the walls of each disc coalesce and disappear, leaving only the peripheral ring or canal. The three ducts are free about the beginning of the second month, and are developed in the following order, viz.: superior, posterior, and lateral. The intermediate part of the otic vesicle is divided by a constriction into an anterior

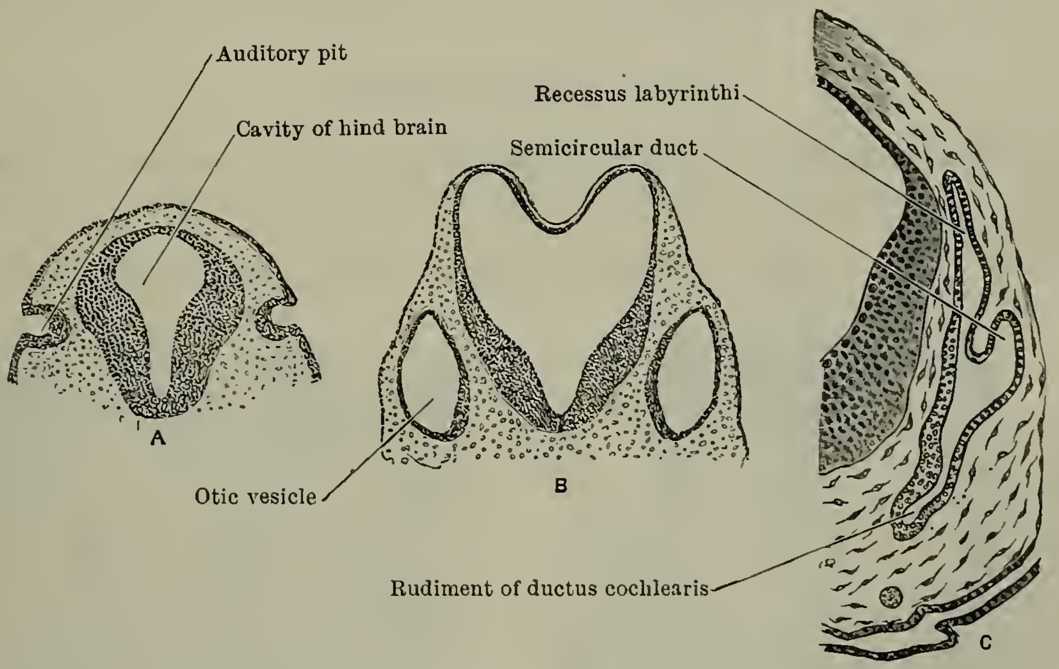

FIG. 696.—SECTIONS THROUGH THE REGION OF THE HIND BRAIN OF FŒTAL RABBITS (to illustrate the development of the labyrinthine epithelium).

In A the ectoderm is invaginated to form the auditory pit; in B the auditory pit is closed to form the otic vesicle which is detached from the ectoderm; in C a further stage in the development of the vesicle is shown.

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[1] See p. 55.

part, the saccule, communicating with the ductus cochlearis, and a posterior part, the utricle, communicating with the semicircular ducts. The constriction extends for some distance into the ductus endolymphaticus, and thus the utricle and saccule are connected by a Y-shaped tube. Another constriction makes its appearance between the saccule and the vestibular end of the ductus cochlearis and forms the **canalis reuniens.** The epithelial lining is at first columnar, but becomes cubical throughout the whole labyrinth, except opposite the terminations of the acoustic nerve, where it forms the columnar epithelium of the maculæ of the utricle and saccule, of the cristæ ampullares, and of the organon spirale. On the floor of the ductus cochlearis two ridges appear, of which the inner forms the limbus laminæ spiralis, whilst the cells of the outer become modified to form the rods of Corti, the hair-cells, and the supporting cells of Deiters and Hensen.

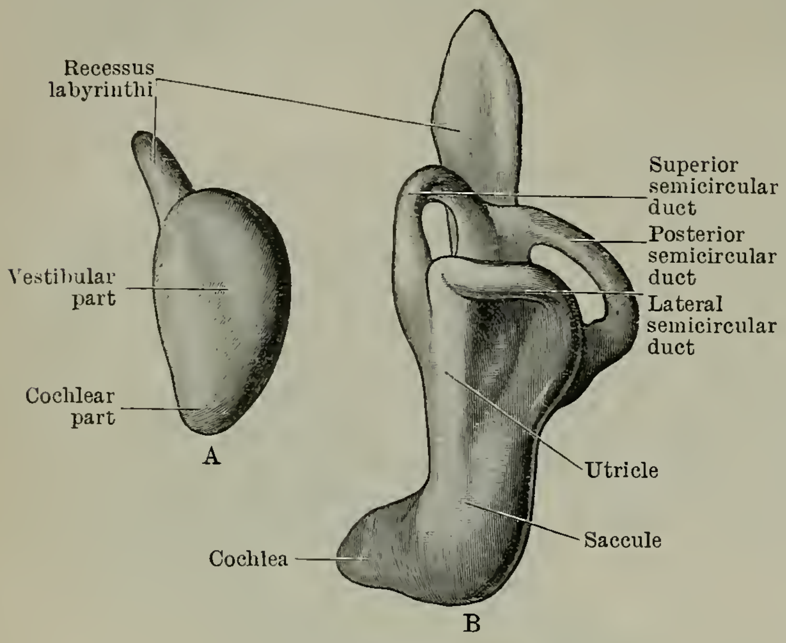
Recessus labyrinthi
Vestibular part
Cochlear part
A
Superior semicircular duct
Posterior semicircular duct
Lateral semicircular duct
Utricle
Saccule
Cochlea
B

Fig. 697.

A, Left labyrinth of a human embryo of about four weeks ; B, Left labyrinth of a human embryo of about five weeks. (From W. His, jun.)

The mesoderm surrounding the otic vesicle is differentiated into : (1) a fibrous layer, the wall of the membranous labyrinth ; (2) a cartilaginous capsule, the future bony labyrinth ; and (3) an intervening layer of gelatinous tissue, which is ultimately absorbed, leaving the perilymphatic space between the bony and membranous labyrinths.

The development of the external and middle parts of the ear are described on pp. 57, 58.

ORGANON GUSTUS.

The peripheral **gustatory organ** consists of groups of modified epithelial cells, termed **calyculi gustatorii** or **taste-buds,** found on the tongue and in its immediate neighbourhood.

Taste-buds are present in large numbers around the circumference of the papillæ vallatæ, while some are found also on their opposing walls (Fig. 698). They are very numerous over the folia linguæ, which correspond with the papillæ foliatæ of the tongue of the rabbit, and are found also over the posterior part and sides of the tongue, either on the papillæ fungiformes or throughout the stratified epithelium. They exist, also, on the oral surface of the velum palatinum and on the posterior surface of the epiglottis.

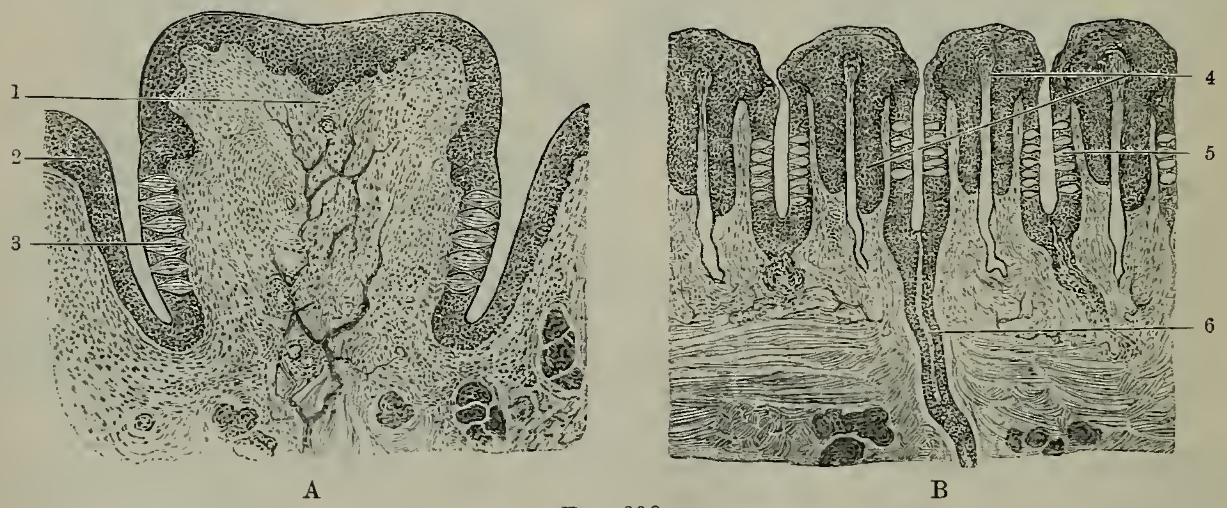

Fig. 698.

A, Section through a papilla vallata of human tongue.

B, Section through a part of the papilla foliata of a rabbit.

1. Papilla. 2. Vallum. 3. Taste-buds. 4. Papillæ. 5. Taste-buds. 6. Duct of a serous gland.

Structure of Taste-buds (Fig. 699).—The taste-buds are oval or flask-shaped, and occupy nests in the stratified epithelium of the regions mentioned. The deep extremity of each is expanded and rests upon the corium; the free end is perforated by a minute pore, termed the **gustatory pore.** They consist of two kinds of epithelial cells—(*a*) supporting cells, and (*b*) gustatory cells (Fig. 700). The **supporting cells** are elongated, nucleated spindles, and are mostly arranged like the staves of a cask to form the outer envelope of the taste-bud; but some are found in the interior amongst the gustatory cells. The **gustatory cells** occupy the centre of the taste-bud, and each consists of a nucleated cell-body, prolonged into a peripheral and a central process. The peripheral process is rod-like and almost hyaline, and terminates at the gustatory pore in a slender filament, the **gustatory hair.** The central process passes towards the deep extremity of the taste-bud, where it ends in a single or branched varicose filament.

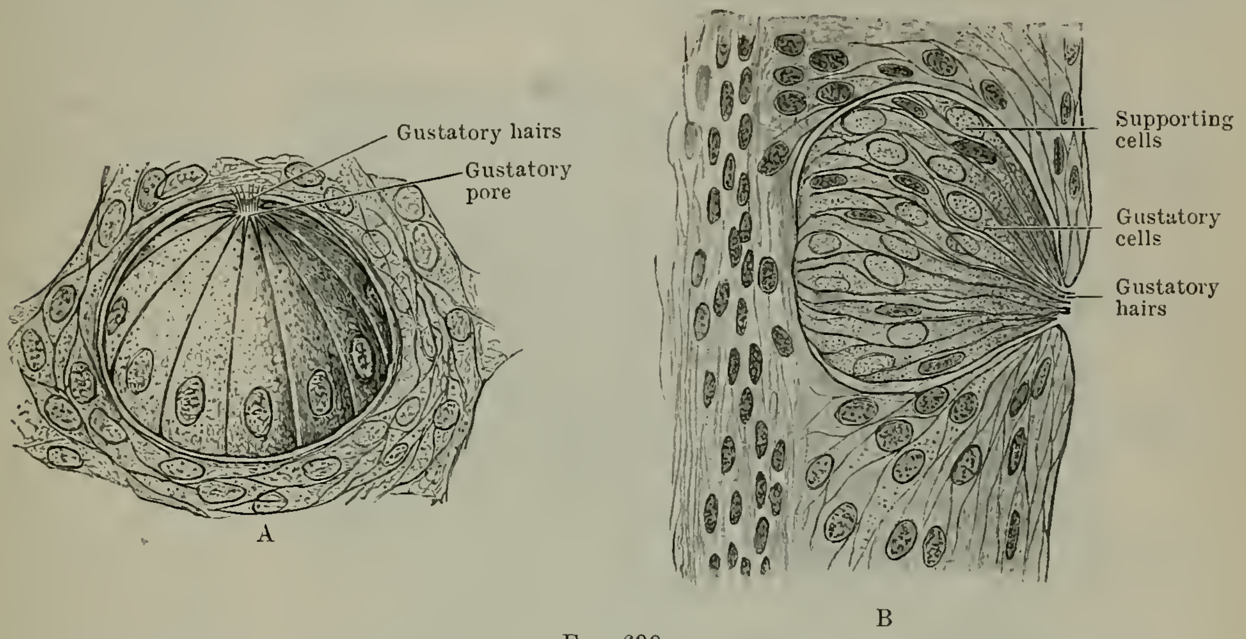

Fig. 699.

A, Three-quarter surface view of a taste-bud from the papilla foliata of a rabbit (highly magnified).

B, Vertical section of a taste-bud from the papill foliata of a rabbit (highly magnified).

Nerves of Taste.—The nerve supplying the taste-buds over the anterior part of the tongue is the chorda tympani, which is derived from the sensory root of the facial nerve; that for the posterior part is the glossopharyngeal. The nerve-fibrils, having lost their medullary sheaths, ramify partly between the gustatory cells and partly amongst the supporting cells of the taste-buds.

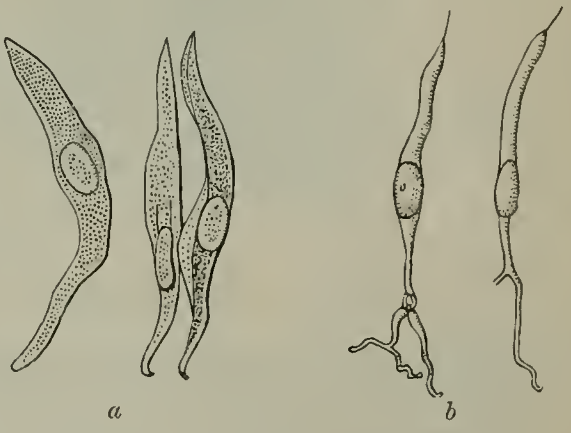

Fig. 700.—Isolated Cells from the Taste-bud of a Rabbit. (Engelmann.)
a, Supporting cells. *b*, Gustatory cells.

The ducts of Ebner's glands open into the bottom of the valleys surrounding the papillæ vallatæ, and the serous-like secretion of these glands probably washes the free hair-like extremities of the gustatory cells, and so renders them ready to be stimulated by successive substances.

The development of the tongue is described on pp. 50-51.

INTEGUMENTUM COMMUNE.

The **integument** or **skin** covers the body, and is continuous, at the orifices on its surface, with the mucous lining of the alimentary and other canals. It contains the peripheral terminations of many of the sensory nerves, and serves as an organ of protection to the deeper tissues. It plays an important part in regulating the body temperature, and, by means of its sudoriferous and sebaceous glands, acts as an excretory structure. Its superficial layers are modified in certain situations to form appendages in the shape of hairs and nails.

The skin is very elastic, and its colour, determined partly by its own pigment and partly by that of the blood, is deeper on exposed parts and in the regions of the genitals, axillæ, and mammary areolæ, than elsewhere. The colour varies also with race and age, and the different races of the world are roughly classified, according to the colour of their skin, into the three groups of white, yellow, and black. The skin is pinkish in colour in childhood, but it assumes a yellowish tinge in old age. In certain diseases (*e.g.* icterus and melasma Addisonii) the colour undergoes marked alteration.

The surface of the skin is perforated by the hair-follicles and by the ducts of the sudoriferous and sebaceous glands, and on the palms, soles, and flexor surfaces of the digits it presents numerous permanent ridges, the **cristæ cutis**, which correspond with rows of underlying papillæ. Over the terminal phalanges these ridges form distinctive patterns, which are retained from youth to old age, and may be utilised for purposes of identification. Retinacula of the skin are seen in the neighbourhood of the joints, and it can be thrown into wrinkles by the contraction of the subcutaneous muscles, where those exist. Over the greater part of the body it is freely movable; but on the scalp and lateral surfaces of the auriculæ, as well as on the palms and soles, it is bound down to the subjacent tissues.

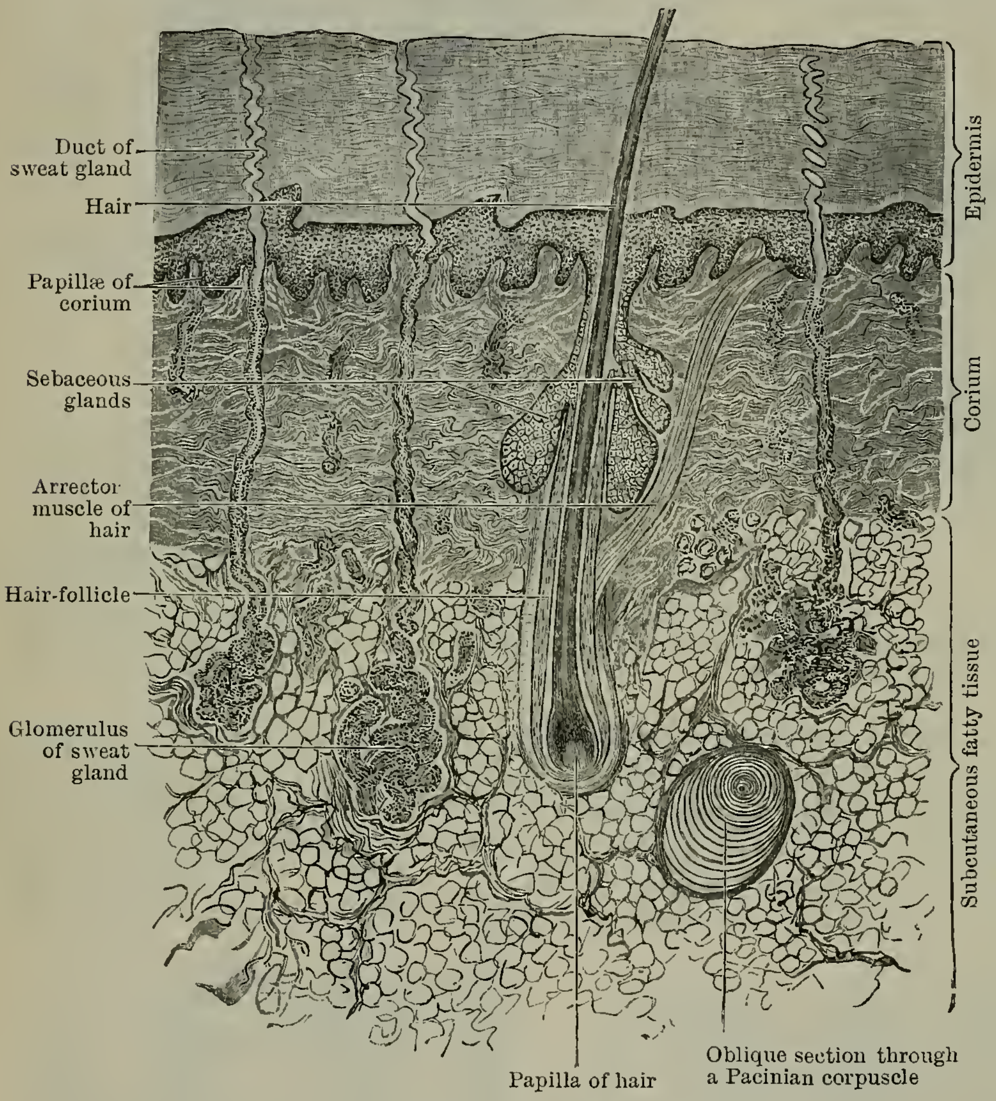

Fig. 701.—Vertical Section of the Skin (schematic).

Structure.—The skin consists of a deep stratum, the corium, and a superficial, the epidermis (Fig. 701).

The **corium** or **cutis vera** is derived from the embryonic mesoderm, and consists essentially of a felted interlacement of connective tissue and elastic fibres. In the deeper layer, or **stratum reticulare** of the corium, the fibrous bundles are coarse and form an open network, in the meshes of which are vessels, nerves, pellets of fat, hair-follicles, and glands. This reticular stratum passes, as a rule, without any line of demarcation, into the panniculus adiposus or subcutaneous fatty tissue, but in some parts it rests upon a layer of striped or unstriped muscular fibres—the latter in the case of the scrotum. In the superficial layer, or **stratum papillare**, of the corium, the connective tissue-bundles are finer and form a close network. Projecting from the superficial surface of this stratum are numerous finger-like, single, or branched elevations, termed **papillæ** (Fig. 702), which are received into corresponding depressions on the deep surface of the epidermis. These papillæ vary in size, being small on the eyelids, but large on the palms and soles, where they may attain a length of 225 μ, and produce the permanent ridges already referred to. Each ridge usually contains two rows of papillæ, between which the ducts of the sudoriferous glands pass to open on the surface. The papillæ consist of fine connective tissue and elastic fibres, mostly arranged parallel to the long axis of the papillæ; the majority contain capillary loops, but some contain the terminations of nerves. The superficial surface of the corium is covered with a thin, homogeneous basement-membrane.

The **epidermis** or **cuticle** is derived from the embryonic ectoderm and covers the corium. Its thickness varies in different parts of the body and ranges from 0·3 mm. to 1 mm. or more; it is thickest on the palms of the hands and soles of the feet, and thinnest on the eyelids and penis. It is non-vascular and consists of stratified epithelium; its superficial layers are modified to form the **stratum corneum**, which may be separated by maceration or blistering from the deeper, softer portion, or **stratum mucosum** (**Malpighi**). The epidermis consists from within outwards of the following five strata (Fig. 702):—

1. The **stratum germinativum** is a single stratum of nucleated columnar cells planted by denticulated ends on the basement-membrane of the corium.

2. The **stratum mucosum** consists of six or eight layers of polygonal, nucleated "prickle-cells," the finger-like processes of which join those of adjacent cells. Between the cells of this layer are minute channels, in which leucocytes or pigment granules may be seen. The cells of the stratum mucosum are characterised by the presence of numerous epidermic fibrils, which are coloured violet by hæmatoxylin and red by carmine. These fibrils are unaffected by boiling, but swell up under the action of acids and alkalies, and form the filaments of union between adjacent cells. On account of their presence, L. Ranvier has named this layer the **stratum filamentosum**. The dark colour of the negro's skin is caused by the presence of numerous pigment granules in the deeper layers of the stratum mucosum; the pigment—of which *melanin* forms an important constituent—is absent from the more superficial layers of the epidermis.

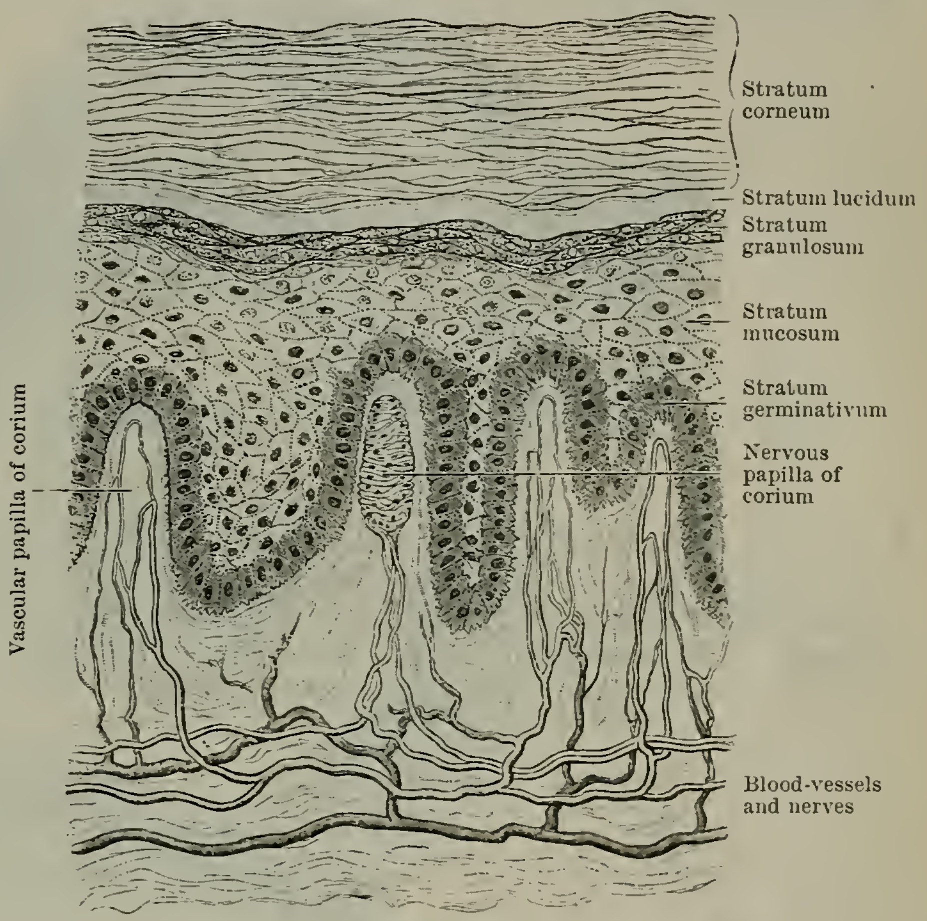

Fig. 702.—Vertical Section of Epidermis and Papillæ of Corium (highly magnified).

3. The **stratum granulosum** comprises two or three layers of horizontally arranged, flattened cells. Scattered around the nuclei of these cells are elliptical or spherical granules of *eleidin*, a substance staining deeply with carmine and hæmatoxylin, and probably representing an intermediate stage between the protoplasm of the cells of the deeper strata and the keratin of the cells of the superficial layers.

4. The **stratum lucidum** consists of several strata of squamous cells, which contain granules or droplets of *keratohyalin*, a hyaline substance, staining less deeply than eleidin.

5. The **stratum corneum** is made up of several layers of flattened non-nucleated squames, the more superficial of which assume the form of horny scales, and are from time to time removed by friction. The deeper cells contain granules of a fatty material having the consistency and plasticity of beeswax, and staining with osmic acid. The peripheral parts of the cells consist of **keratin**, a highly resistant substance which is unaffected by mineral acids, and is indigestible in pepsin-hydrochloric acid.

L. Ranvier has pointed out that the **stratum lucidum** is really double, and has named the deeper of its two layers the **stratum intermedium**; this he describes as consisting of two or three layers of clear cells with atrophied nuclei, while in the cell-walls the epidermic fibrils "are rolled up like the threads of a cocoon."

Regeneration of the epidermis is generally regarded as taking place by cell proliferation in the stratum germinativum, the young cells gradually passing through the polyhedral and granular stages, and ultimately becoming the flattened squames of the stratum corneum, while the eleidin granules of the stratum granulosum are converted into the keratin of the stratum corneum.

Vessels and Nerves of the Skin.—In the subcutaneous tissue the **arteries** form a plexus from which branches extend into the corium, where they supply the hair-follicles and glands, and form a second plexus under the papillæ, to which small loops are given. The **veins** and the **lymph-vessels** commence in the papillæ, and, after forming subpapillary plexuses, open into their respective subcutaneous vessels.

The **nerves** of the skin vary in number in different parts of the body; they are extremely numerous where the sense of touch is acute, *e.g.* on the palmar surfaces of the terminal phalanges, whilst in the skin of the back, where the sensibility is less, they are fewer in number. Their different modes of ending are described on pp. 856-859.

APPENDAGES OF THE SKIN.

The appendages of the skin are the nails, the hairs, the sebaceous glands, and the sudoriferous or sweat glands.

Ungues.—The **nails** (Figs. 703, 704) are epidermal structures, and represent the hoofs and claws of the lower animals. The **root** of the nail is hidden from view and embedded in a fold of skin; the **body**, or uncovered part, rests on the corium and ends in a **free margin**. The greater part of the lateral margin of the nail is overlapped by a duplicature of skin, termed the **vallum unguis** or **nail-wall**. The nails are pink in colour, with the exception of small semilunar areas near their roots, which are more opaque than the rest, and are named the **lunulæ**. The lunulæ diminish in size from the thumb towards the little finger, whilst the thickness of the nail diminishes towards its root and lateral margins. The corium under the nail is highly vascular and sensitive, and presents, especially under the anterior part of the body, numerous longitudinally arranged ridges. The part of the corium under the body is termed the **nail-bed**; that under the root, the **nail-matrix**. The deep part of the nail consists of the stratum germinativum and stratum mucosum, while its superficial horny portion is constituted by a greatly thickened stratum lucidum, and consists of nucleated, keratinised squames. The stratum corneum is represented by the thin cuticular fold overlapping the lunula, and termed the **eponychium**, while the stratum granulosum can be traced only as far forwards as the nail-root.

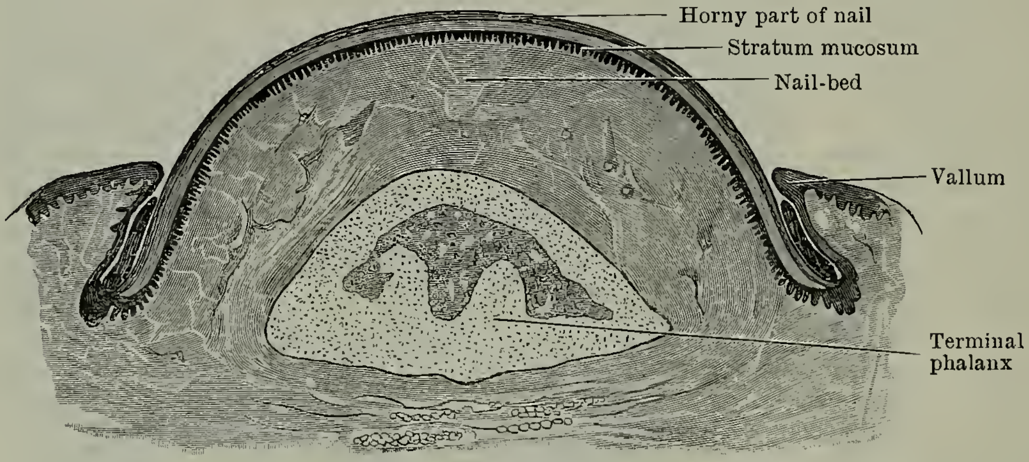

FIG. 703.—TRANSVERSE SECTION OF A NAIL.

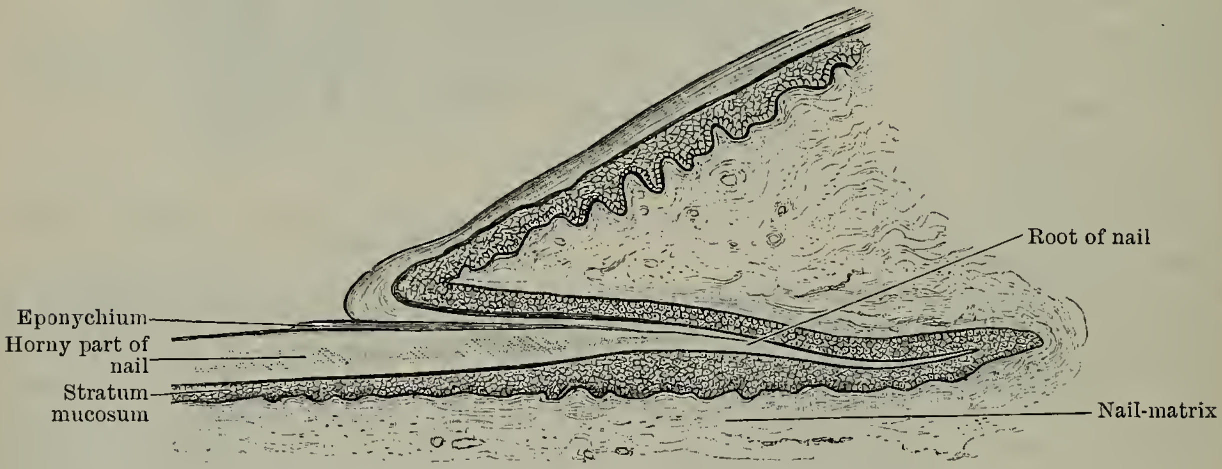

FIG. 704.—LONGITUDINAL SECTION THROUGH ROOT OF NAIL.

Pili.—**Hairs** are well developed on the external genitals, scalp, and margins of the eyelids, in the axilla, the vestibule of the nose, and at the entrance to the concha, and also on the face of the male. Those on the genitals and face appear about puberty. Rudimentary over the greater part of the body, hairs are absent from the flexor surfaces of the hands and feet, the dorsal surfaces of the terminal phalanges, the glans penis, the inner surface of the prepuce, and medial surfaces of the labia. Marked variations, individual and racial, exist as to the colour of the hair, and also as to the manner of its growth; hence the terms straight, curly, woolly, etc., are used to designate it. Straight hairs are coarser than curly ones, and have, moreover, a circular or oval outline on transverse section, curly hairs being flat and riband-like.

The **root of the hair** is embedded in a depression of the skin, termed the **hair-follicle** (Fig. 705); the free portion of the hair is named the **scapus** or **shaft**, and consists from without inwards of cuticle, cortex, and medulla. The *cuticle* is formed by a layer of imbricated scales which overlap one another from below upwards. The *cortex* consists of longitudinally arranged fibres made up of elongated, closely applied, fusiform cells, which contain pigment and sometimes air-spaces, the latter especially in white hairs. The *medulla*, absent from the fine hairs of the body generally and from the hairs of young children, forms a central core, which appears black by transmitted, and white by reflected, light, and is composed of polyhedral nucleated cells containing pigment, fat-granules, and air-spaces.

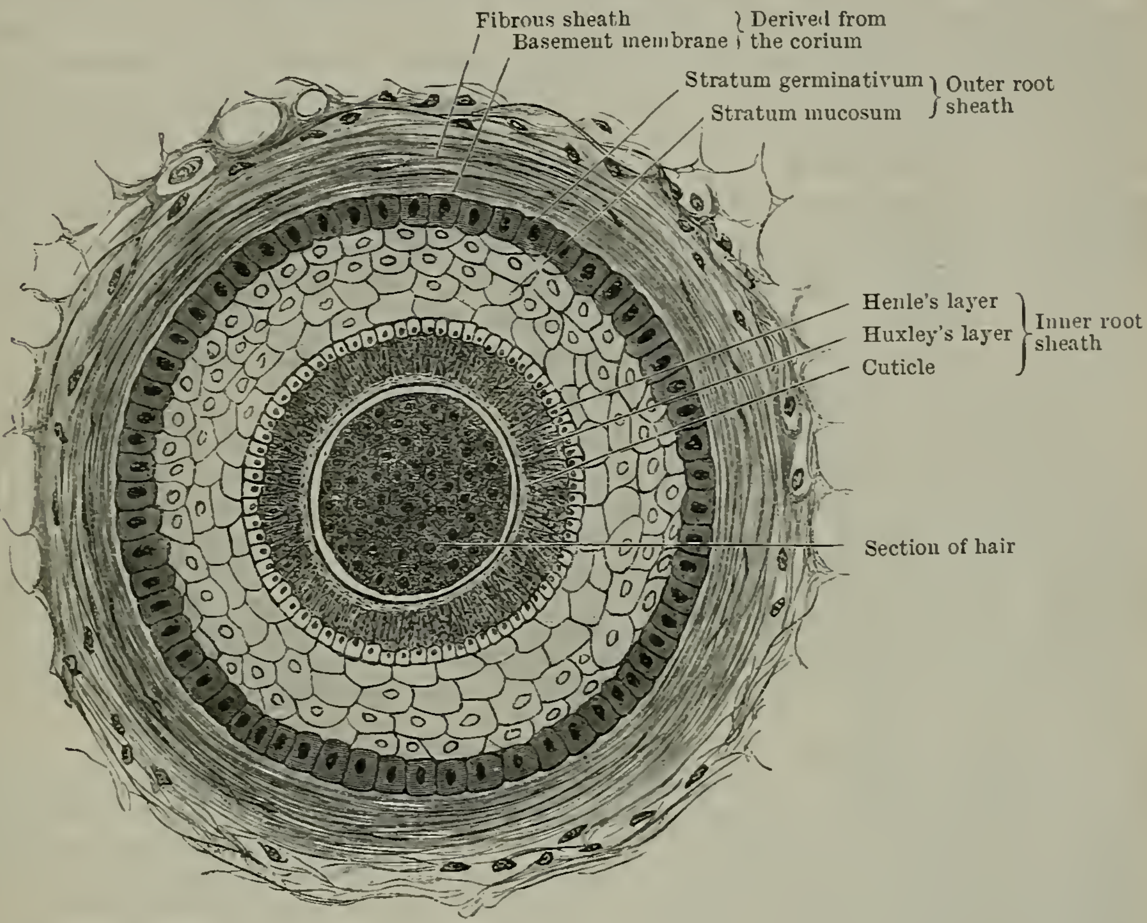

Fig. 705.—Transverse Section of a Hair-Follicle with a contained Hair (highly magnified).

The **hair-follicle** is an oblique or curved—the latter in curly hairs—invagination of the epidermis and corium, and in the case of large hairs extends into the subcutaneous tissue (Fig. 701); the ducts of the sebaceous glands open into the hair-follicles a short distance below their orifices. The dermic coat or portion of the follicle derived from the corium consists of a fibrous sheath of external longitudinal and internal circular connective tissue fibres, the latter being lined by a hyaline layer directly continuous with the basement-membrane of the corium. The parts of the follicle derived from the epidermis are named the **inner** and **outer root-sheaths**. Below the orifices of the sebaceous gland-ducts the outer root-sheath is formed by the stratum germinativum and stratum mucosum, while above these orifices all the epidermal strata contribute to it. The inner root-sheath surrounds the cuticle of the hair, and comprises from without inwards—(*a*) *Henle's layer,* a layer of nucleated cubical cells; (*b*) *Huxley's layer,* one or two layers of polyhedral nucleated cells; and (*c*) *a delicate cuticle,* composed of a layer of flattened imbricated cells, with atrophied nuclei. The bottom of the hair-follicle is moulded on a vascular **papilla**, derived from the corium and capped by the **bulb of the hair** or expanded part of the hair-root. The cells of the bulb are continuous with those of the outer root-sheath, and form the different parts of the hair, as well as its inner root-sheath. The vessels form capillary loops in the papilla of the hair, and send twigs into the outer layer of its fibrous sheath; the inner and outer root-sheaths and the hair are non-vascular. The nerves end in longitudinal and annular fibrils below the level of the sebaceous glands and outside the hyaline layer of the follicle.

Glandulæ Sebaceæ.—Sebaceous glands exist wherever there are hairs, and their ducts open into the superficial parts of the hair-follicles (Fig. 701); the number of glands associated with each follicle varies from one to four. On the labia minora and mammary areolæ they open on the surface of the skin independently of hair-follicles, and in the latter situations undergo great enlargement during pregnancy. The deep end of each gland expands into a cluster of oval or flask-shaped **alveoli**, which are surrounded by a basement-membrane, and filled with polyhedral cells containing oil droplets. By the breaking down of the superficial cells, their oily contents are liberated as the *sebum cutaneum* and discharged into the hair-follicle, whilst the deeper cells undergo proliferation. The size of the glands bears no proportion to that of the hairs, the glands being very large in the minute hair-follicles of the fœtus and new-born child, and also in the follicles of the rudimentary hairs of the nose and certain parts of the face.

Bundles of non-striped muscular fibres are associated with the hair-follicles, and are named the **mm. arrectores pilorum**. Attached to the deep part of the hair-follicle, and forming with it an acute angle, they pass outwards close to the sebaceous glands, and end in the papillary layer of the corium. They are situated on the side towards which the hair slopes, so that, on contraction, they diminish the obliquity of the hair-follicle and render the hair more erect, and, at the same time, compress the sebaceous glands and expel their contents. The condition of "goose-skin" is caused by the contraction of these slender muscles.

Arthur Thomson suggests that the condition of curly hair is produced by the contraction of the mm. arrectores pilorum. Straight hair is thick and cylindrical; curly hair is flat and ribbon-like. When the arrector muscle contracts, the thick rounded hair resists the tendency of the muscle to bend it, while the flat hair, not sufficiently strong to resist the strain of the muscle, becomes bent, and this is probably the explanation why the follicle assumes the curved form characteristic of the scalp of a bushman. The sebaceous gland lies in the concavity of the bend between the follicle and the muscle, and forms a mass of greater resistance, around which the follicle may be curved by the contraction of the muscle. The cells at the root of the hair accommodate themselves to the curved follicle, and, becoming more horny as they advance to the surface, retain the form of the follicle in which they are moulded.

Glandulæ Sudoriferæ.—Sudoriferous or **sweat glands** are found in the skin of nearly every part of the body; they are relatively few in number on the back of the trunk, but are very plentiful on the palms and soles, where they open on the summits of the curved ridges. Each consists of an elongated tube; the deeper portion of the tube forms its secretory part, and is coiled in the subcutaneous tissue or deep part of the corium in the form of an ovoid or spherical ball, termed the **corpus glandulæ sudoriferæ** (O.T. **glomerulus**) (Fig. 701). The superficial part of the tube, or **ductus sudoriferus**, extends through the corium and epidermis, and opens on the surface by a funnel-shaped orifice, the **porus sudoriferus**; where the epidermis is thick the duct is spirally coiled. The corpora glandulæ, as a rule, vary in diameter from 0·1 to 0·5 mm., but in the axillæ they measure from 1 to 4 mm. Each is surrounded by a capillary network and by a capsule of connective tissue, inside which is a homogeneous basement-membrane. The lumen of the tube is lined by a layer of nucleated, granular, and striated, columnar, epithelial cells, between the deep ends of which and the basement-membrane is a layer of non-striped muscular fibres, the long axis of the fibres being more or less parallel with that of the tube. The excretory ducts are devoid of muscular fibres, and consist of a basement-membrane lined by two or three layers of polyhedral cells, which are covered, next the lumen of the duct, with a thin cuticle.

The **glandulæ ciliares**, at the margins of the eyelids, and the **glandulæ ceruminosæ** of the external acoustic meatus, are modified sudoriferous glands; the former are, however, not coiled, while the cell-protoplasm of the latter contains yellowish pigment, and their gland-ducts, in the fœtus, open into hair-follicles.

Development of the Skin and its Appendages.

Skin.—The vascular and sensitive corium is developed from the mesoderm, the cells of which, immediately underlying the ectoderm, have, by the second month of fœtal life, become aggregated together and flattened parallel to the surface of the embryo. By the third month they form two layers, the superficial of which becomes the corium, and the deeper the subcutaneous tissue; the papillæ of the corium make their appearance in the fourth month. The epidermis, nails, hairs, sudoriferous and sebaceous glands are of ectodermal origin.

The epidermis at first consists of a single layer of cells, but by the end of the second month two layers are present, a superficial, of irregular cells, and a deeper, of more or less cubical cells. By the third month three strata are seen; the deep layer consists of a layer of cubical cells—the future stratum germinativum; the middle comprises two or three layers of irregular cells—the future stratum mucosum; and the superficial, a double stratum of large cells. This superficial layer appears to be homologous with a thin membrane, termed the *epitrichium*, first described as covering the embryo of the sloth and overlying its hairs, but since shown to be present also in birds and mammals. Over the hairy parts of the body the epitrichium disappears about the sixth month; but over the free edges and the roots of the nails, and on the palms and soles, it develops into several layers of cells, which, in these parts, probably persist to form the thick stratum corneum. The part which persists over the roots of the nails is termed the *eponychium*, and covers the proximal parts of the lunulæ (p. 852, Fig. 704).

Nails.—The rudiments of the nails are seen about the beginning of the third month of fœtal life, and consists of thickenings of the epitrichium over the ends of the digits. Owing to the greater growth of the volar surfaces of the digits, the nail rudiments come to be placed dorsally, and, at the proximal edge of each, an ingrowth of the stratum mucosum occurs to form its root, while the future nail is limited behind and at the sides by a groove. The superficial cells of the stratum mucosum are keratinised to form a thick stratum lucidum, the future nail proper, over the greater part of which the epitrichium disappears. The latter persists in the adult as the eponychium across the root of the nail, and, until the fifth month, also forms a thick mass over the distal edge of the nail, and is continued into the stratum corneum over the end of the digit. The future distal edge of the nail, at this stage, is continuous with the stratum lucidum in front of it; but this continuity is lost, and by the seventh month the nail presents a free border. The nails grow in length, and are renewed, in case of removal, by a proliferation of the cells of the stratum mucosum at the roots of the nails, while an increase in their thickness takes place from the stratum mucosum underlying the lunulæ.

Hairs.—The hair-rudiments appear about the third month of fœtal life as solid downgrowths of the stratum mucosum, which pass obliquely into the subjacent corium. The deep end of each downgrowth of cells expands to form the hair-bulb, and is moulded on a papilla derived from the corium; the epidermis immediately overlying the papilla is differentiated into the hair and its inner root-sheath, while the peripheral cells form its outer root-sheath. The surrounding corium is condensed to form the fibrous sheath of the hair-follicle, the hyaline layer of which is continuous with the basement-membrane covering the corium. The hair gradually elongates, and, reaching the neck of the follicle, its extremity lies at first under the epitrichium, but becomes free on the disappearance of the latter about the fifth month of fœtal life. The first crop of hairs constitutes the *lanugo*, and is well developed by the seventh month; it consists of very delicate hairs, some of which are shed before, the remainder shortly after birth—the last to drop out being those of the eyelashes and scalp—and are replaced by stronger hairs. Shedding and renewal of the hairs take place during life; prior to the shedding of a hair active growth and proliferation of the cells of the hair-bulb cease, and the papilla becomes atrophied, while the hair-root, gradually approaching the surface, at last drops out. New hairs arise from epidermic buds, which extend downwards from the follicle, and their development is identical with that of the original hairs.

Sebaceous Glands.—These appear about the fifth month of fœtal life as solid outgrowths from the sides of the hair-follicles, and consist of epidermal offshoots continued from the cells of the outer root-sheath. Their deep ends become enlarged and lobulated, to form the secreting part of the gland, while the narrow neck connecting this with the follicle forms its duct. The sebaceous secretion, together with the cast-off epidermal cells, is collected on the surface of the body during the last months of intra-uterine life, and forms a layer of varying thickness, termed the *vernix caseosa* or *smegma embryonum*.

Sudoriferous Glands.—These, like the hairs, arise as solid downgrowths of the stratum mucosum. They descend, however, perpendicularly, instead of obliquely, and are of a yellowish colour; they appear on the palms and soles early in the fifth month of fœtal life, but much later over the hairy parts of the body. The downgrowths extend through the corium, and, on reaching the subcutaneous tissue, become coiled up to form the body or secreting part of the gland. The ducts of the glands do not open on the surface until the seventh month.

ENDINGS OF NERVES OF GENERAL SENSATIONS.

Under this heading will be described the terminations of those sensory nerves which are widely distributed throughout the body and are associated with the muscular sense and the senses of pressure, heat, cold, and pain. These nerves may end (*a*) as fine ramifications of the naked axis-cylinders lying *free* amongst the tissues, or (*b*) in *special end-organs* where the terminations of the axis-cylinders are surrounded by connective tissue capsules.

FREE NERVE-ENDINGS.

Free nerve-endings are found chiefly in the epithelium covering the skin or the mucous membranes, and constitute the peripheral pain end-organs. The nerve-fibres, after subdividing in the sub-epithelial connective tissue, lose successively their medullary and primitive sheaths and are continued as naked axis-cylinders, which, if stained with gold chloride, are seen to consist of fine varicose filaments. The axis-cylinders subdivide and form primary and secondary plexuses, and from the latter numerous fibrillæ pierce the sub-epithelial basement-membrane and ramify between the overlying epithelial cells where they end in minute knobs or flattened discs. In the epidermis the nerve-fibrillæ are limited to the stratum mucosum, but in the cornea they reach the surface layers of epithelium (Fig. 706). Free nerve-endings also occur around the sudoriferous glands, in the papillæ and root-sheaths of the hair-follicles, in the sub-epithelial and intermuscular connective tissues, and in serous membranes.

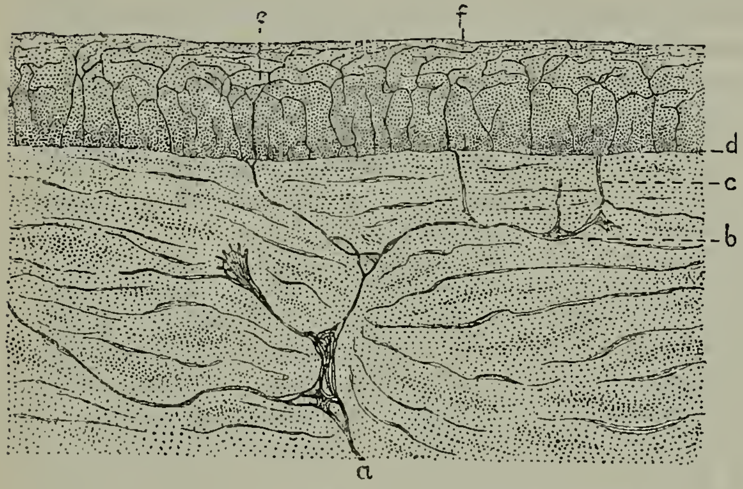

Fig. 706.—Vertical Section of Cornea stained with Chloride of Gold. (Ranvier.)

a, *b*, primary plexus in connective tissue of cornea; *c*, branch passing to sub-epithelial plexus *d*; *e*, intra-epithelial plexus; *f*, terminations of fibrils.

Modifications of free nerve-endings are seen in the *tactile discs* or *cells of Merkel*; here the neuro-fibrillæ end in the deeper layers of the epidermis in crescentic or cup-shaped expansions, in contact with large, modified epithelial cells. These tactile discs are well marked in the pig's snout (Fig. 707).

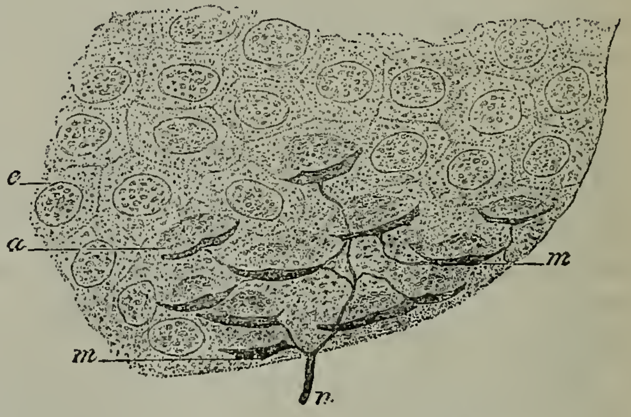

Fig. 707.—Ending of Nerve in Tactile Discs of the Pig's Snout (Ranvier). (From Quain's *Anatomy*.)

n, medullated fibre; *m*, terminal discs in muscle; *e*, cells from the stratum mucosum of the epidermis; *a*, somewhat modified cell to which a tactile disc is applied.

SPECIAL END-ORGANS.

The **special end-organs** vary greatly in size and form, but in all of them the termination of the axis-cylinder is enclosed within a connective tissue capsule or sheath of varying thickness. The following are the more important special end-organs.

(1) **End-bulbs of Krause** (Fig. 709).—These are minute cylindrical or oval bodies which are found in the conjunctiva, in

the mucous membrane of the lips, and in the skin of the glans penis and glans clitoridis. Each consists of a thin connective tissue capsule enclosing a core of homogeneous or nucleated semifluid substance. As the nerve-fibre pierces the capsule, it loses its medullary sheath, and the axis-cylinder is continued into the core of the bulb where it may pursue a somewhat tortuous course, but more frequently divides into minute varicose fibrils which form an intricate plexus. The end-bulbs of the glans penis and glans clitoridis are named *genital corpuscles* and differ from those just described in that they are larger and possess thicker capsules. Similar endings, termed *articular bulbs*, are found in the synovial membranes of certain joints, *e.g.* those of the fingers.

(2) **Corpuscles of Grandry** (Fig. 708).—These are seen in the skin covering the beaks of aquatic animals, and in the mucous membrane of the duck's palate. Each consists of two or more flattened epithelial cells enclosed within a capsule, and the axis-cylinder ends in flattened "tactile discs" which lie between the cells.

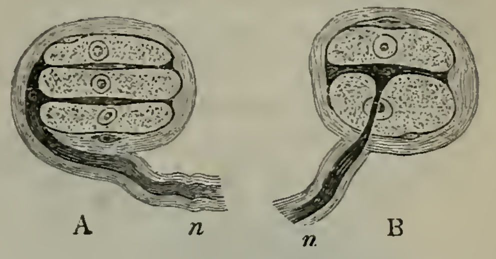

Fig. 708.—Grandry's Corpuscles from the Duck's Tongue (Izquiardo). (From Quain's *Anatomy.*)

A, composed of three cells with two interposed discs, into which the axis-cylinder of the nerve-cell is observed to pass. In B there is but one tactile disc enclosed between two tactile cells.

(3) **Corpuscles of Pacini** (Fig. 709).—These are widely distributed and consist of small oval bodies which measure from 2 to 3 mm. in length and about 1 mm. in width. They are found on the cutaneous nerves of the hand and foot, on the infra-orbital and intercostal nerves, on the cutaneous nerves of the neck, nipple, and mamma, and on the nerves of the solar plexus. They are present in the parietal peritoneum and on the nerves of the joints, and are very plentiful in the mesentery of the cat. The capsule of the corpuscle consists of a number of connective tissue tunics arranged concentrically around a central core of more or less clear protoplasm; the deeper tunics are closely applied to each other, but those towards the circumference of the corpuscle are here and there separated by narrow lymph-spaces. Each corpuscle is attached to a nerve trunk by a narrow pedicle composed of a single medullated nerve-fibre which pierces the capsule and on reaching the

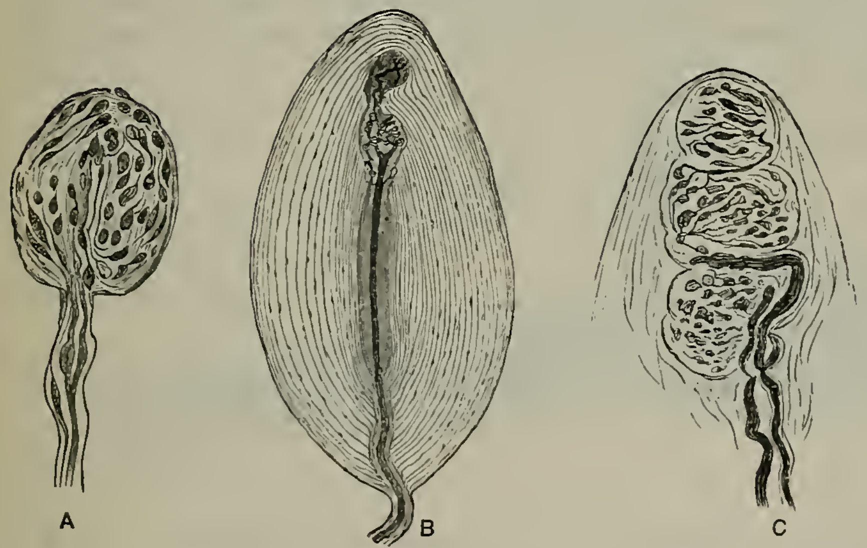

Fig. 709.

A, End-bulb (Krause).
B, Corpuscle of Pacini × 12 } (After Ranvier.)
C, Corpuscle of Wagner and Meissner } (After Ranvier.)

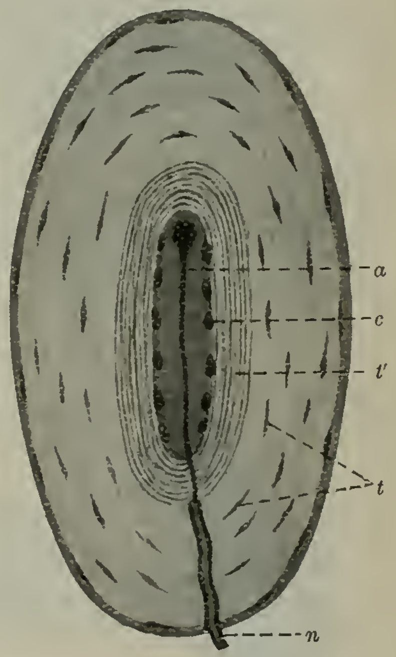

Fig. 710.—Corpuscle of Herbst (Sobotta).

n, medullated nerve-fibre; *a*, its axis-cylinder ending in an enlargement; *c*, nuclei of cells of core; *t*, nuclei of cells of outer tunics; *t'*, inner tunics.

core, loses its medullary sheath. The axis-cylinder is continued into the core as far as its distal end and there terminates in one or more enlargements in which the neuro-fibrillæ form a dense plexus. The **corpuscles of Herbst** (Fig. 710), which are found in the skin of birds, differ from the Pacinian corpuscles in that their cores consist of nucleated cells, between which the axis-cylinder extends as a single or branched process.

(4) **Corpuscles of Golgi and Mazzoni.**—These are present in the subcutaneous tissue of the pulp of the fingers and also in other parts of the skin. Their capsules are thinner and their cores thicker than those of the Pacinian corpuscles, while their axis-cylinders undergo a greater degree of ramification and their terminal filaments end in somewhat flattened expansions.

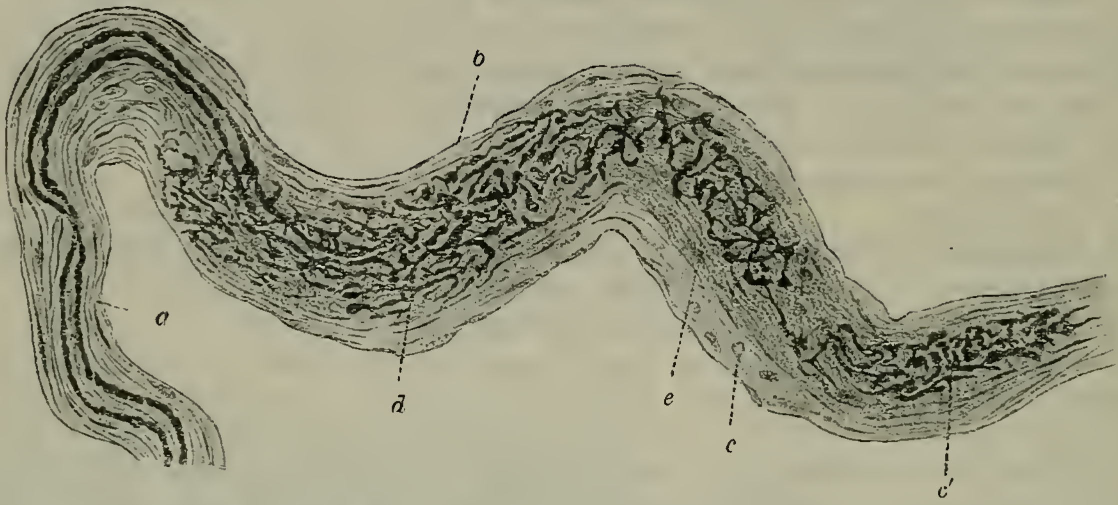

Fig. 711.—An Organ of Ruffini from the Subcutaneous Tissue. (From Quain's *Anatomy.*)

a, Entering nerve-fibres ; *b*, *d*, endings of their axis-cylinders ; *e*, *c*, capsule of organ ; *c′*, core.

(5) **Tactile Corpuscles of Wagner and Meissner** (Fig. 709).—These are plentifully distributed in the papillæ of the corium of the hand, foot, and front of the forearm. They are found also in the skin of the lips, in the mucous membrane of the tip of the tongue, in the palpebral conjunctiva and the skin of the nipple. They are oval in shape, and their length varies from ·04 mm. to ·15 mm., and their thickness from ·03 mm. to ·06 mm. One or more nerve-fibres pierce the capsule of the corpuscle, losing, at the same time, their medullary sheaths. The axis-cylinders, which are frequently varicose, assume a spiral or convoluted course and end in terminal enlargements. From the deep surface of the capsule imperfect membranous septa are continued inwards between the nerve ramifications.

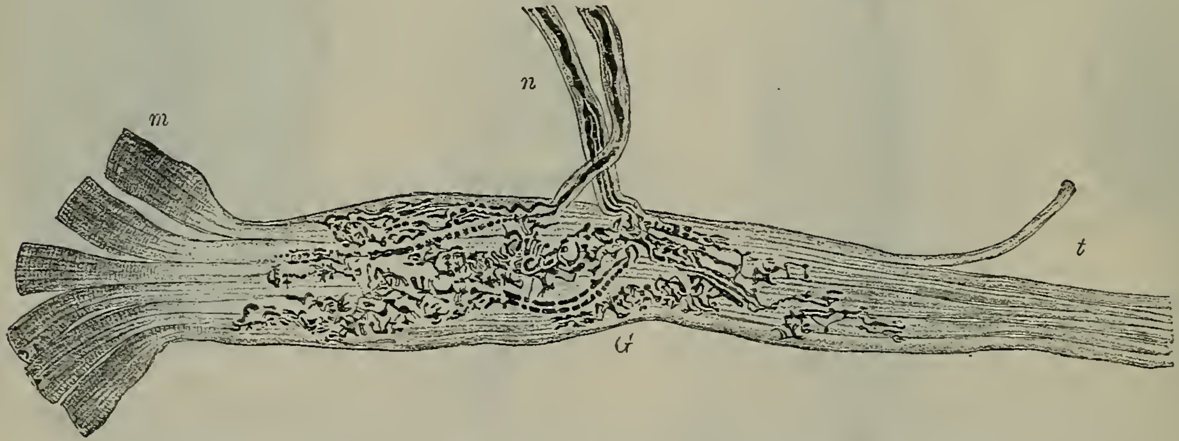

Fig. 712.—Organ of Golgi from the Human Tendo Calcaneus, Chloride of Gold Preparation (Ciaccio). (From Quain's *Anatomy.*)

m, Muscular fibres ; *t*, tendon bundles ; G, Golgi's organ ; *n*, two nerve-fibres passing into it.

(6) **Organs of Ruffini** (Fig. 713).—These were found by Ruffini in the subcutaneous connective tissue of the fingers. They are of considerable size, and their shape is oval or fusiform. One or more nerve-fibres penetrate the side of the capsule, within which they pursue a curved course and then lose their medullary sheaths.

The axis-cylinders break up into a close-meshed network which lies between, or partly encircles, the smaller fasciculi of connective tissue.

(7) **Neuro-tendinous Spindles** (Fig. 712).—These were first described by Golgi in 1878. They consist of long spindle-shaped bodies, and are usually found near the junctions of the tendons with their muscles. Each is surrounded by a capsule which encloses a number of *intrafusal* tendon fasciculi. The nerve-fibres pierce the side of the capsule and then lose their medullary sheaths; the axis-cylinders subdivide, and their terminal branches ramify between, or partly encircle, the smaller tendon bundles and end in plate-like expansions.

(8) **Neuro-muscular Spindles.**—These are widely distributed throughout the voluntary muscles but are more numerous in the muscles of the limbs than in those of the trunk, and are plentifully found in the muscles of the hand and foot. They have not yet been seen in the intrinsic muscles of the tongue, and only a few are present in the ocular muscles. They lie in the connective tissue between the muscular bundles, and each consists of a lamellated capsule enclosing a fasciculus of striped muscular fibres (*intrafusal fibres*), together with minute blood-vessels and three or four medullated nerve-fibres. These intrafusal muscular fibres display many of the characteristics of embryonic muscle; they are smaller both in length and diameter than ordinary muscular fibres; they contain numerous nuclei near the centre of the spindle where their cross striation is less distinct; they also possess more protoplasm than ordinary muscular fibres. The nerve-fibres pierce the side of the capsule, inside which they lose their medullary sheaths and undergo subdivision; they are then prolonged in a spiral or annular manner around the individual muscular fibres and end in flat or oval enlargements.

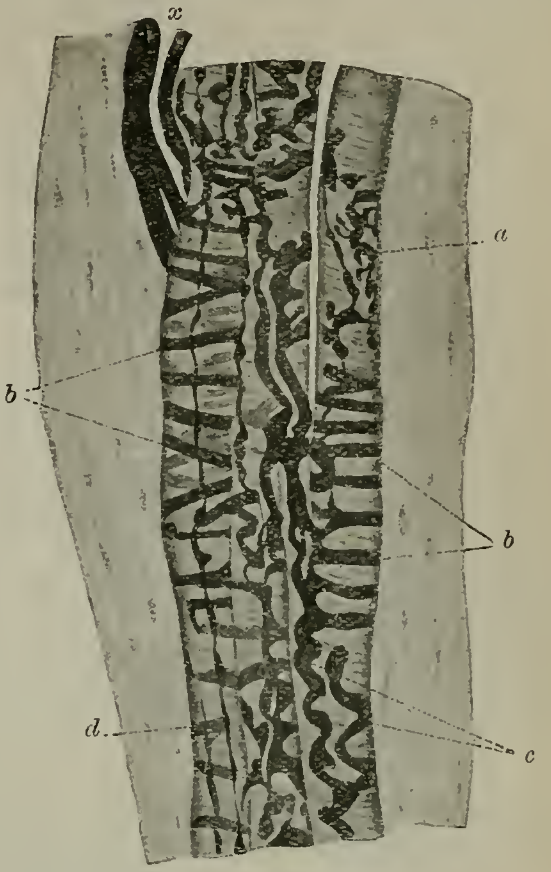

Fig. 713.—Ending of Nerve-fibres in Muscle Spindle (Ruffini). (From Quain's *Anatomy.*)

Three intrafusal muscular fibres are shown: *x*, nerve-fibres entering spindle; *a*, axis-cylinders terminating around and between the intrafusal fibres in *b*, ring-like; *c*, spiral; and *d*, irregularly ramified endings.

THE VASCULAR SYSTEM.

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ALL the tissues of the body require that food and other materials necessary for their growth, maintenance, and work shall be carried to them in a fluid form, and that the products of their work shall be removed, also in a fluid form, either to the tissues by which they can be used or, if they are residual or effete and would be dangerous if they accumulated in the body, to places where they can be eliminated.

It is to meet these necessities that the tubular vascular system is provided. It is filled with the media used for the transport of materials to and from the tissues which are corpuscle-laden fluids called **blood** and **lymph**.

It consists of the **heart, arteries, veins,** and **lymph vessels.**

The heart is a rhythmically contractile muscular pump, and it is divided into receiving and ejecting chambers. During the intervals between its rhythmical contractions blood flows into its receiving chambers, which are termed **atria,** from vessels called **veins.** As soon as the receiving chambers are full they contract and force their contents into ejecting chambers called **ventricles,** then the ventricles contract and project the blood into efferent vessels known as **arteries.**

The two stem arteries into which the blood is projected are necessarily large, but they break up into branches, which again branch, and so, by repeated branchings, the arteries rapidly become smaller as they approach the tissue areas they supply. Ultimately the smallest branches, which are called **arterioles,** end in plexuses of vessels of extremely small calibre which are known as **capillaries.**

Capillary networks, whose meshes vary in size and form in different regions, are found in all tissues except cartilage. They are drained by vessels called **veins,** which gradually unite with one another to form larger and larger trunks, and through the terminal and largest trunks the blood is returned to the atria of the heart.

As the blood passes through the parts of the capillary plexuses into which the arterioles open, some of its fluid portion, which is termed **blood plasma,** passes through the thin walls of the capillaries and permeates the tissues, from which part re-enters the capillaries towards their venous ends, and so is returned to the heart.

The remaining part is passed from the tissues into a set of capillary vessels called **lymph capillaries.** The lymph capillaries join larger vessels, **lymph vessels,** which unite together, like the smaller veins, to form still larger vessels, and ultimately all the lymph is passed into two terminal lymph vessels, one on the right and one on the left side, which end in the great veins at the root of the neck; thus the fluid which irrigates the tissues is eventually passed on to the heart.

It is, however, a well-known fact that much fluid containing effete products is removed from the body by the action of the kidneys as urine. The fluid exudes from the renal blood capillaries and is transmitted through the walls of the renal tubules into their cavities, and so by way of the ureter and urinary bladder to the exterior. A large quantity of fluid is also given off from the skin and in the breath from the lungs as watery vapour. The fluid thus passed out of the body is replenished by fluid taken in by the mouth and passed, after it becomes food-laden, through the walls of the abdominal part of the alimentary canal, into the blood and lymph capillaries which lie in the tissues of those walls.

An indispensable necessity for the proper performance of tissue work, other than food in the ordinary sense, is **oxygen**, and one of the effete products which must be discharged is **carbonic acid.**

The lowest vertebrates obtain their oxygen from water, by means of capillary plexuses in their gills through which the blood passes on its way from the heart to the tissues. In fishes, therefore, the heart is essentially a single tube, divided mainly into a single receiving and a single rejecting chamber.

Gills are not, however, well adapted for obtaining oxygen from air; therefore as land animals were evolved from fish other means for obtaining oxygen had to be adopted, and special organs called lungs were developed.

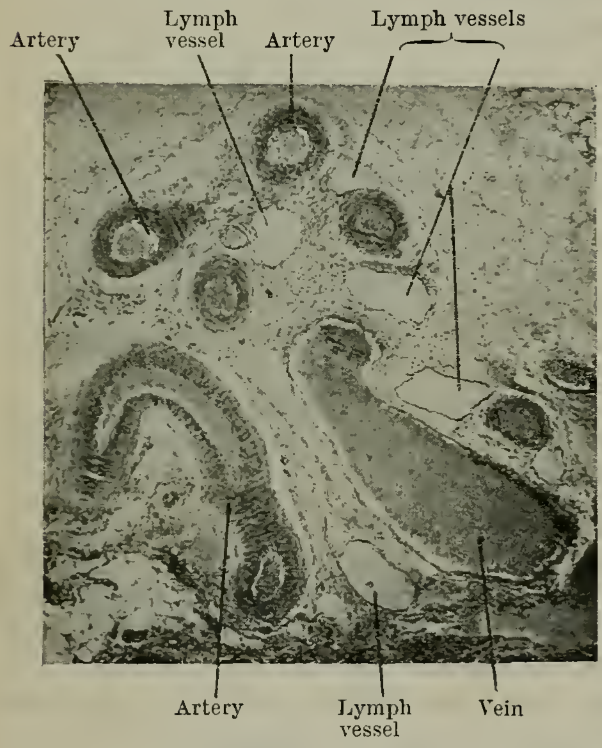

Fig. 714.—Photograph of a Section of Arteries, a Vein, and Lymph Vessels.

Since a certain amount of moisture is necessary for all active tissues, obviously the gills were ill adapted for transformation into lungs. They were placed too superficially and their surface epithelium, which would have had to play an active part, could not have been easily and regularly kept in a sufficiently moist and warm condition.

Another organ, the swim-bladder of certain fishes, was available. It was deeply situated and therefore could be kept warm and moist; further, it developed as a diverticulum from the alimentary canal and consequently could be kept in communication with the external air through the mouth and nose. It was supplied, however, by branches of the aorta which contained oxygenated blood; consequently, its adoption for transformation into lungs necessitated an alteration of the circulation, whereby it should be possible for the venous blood, returned to the heart by the veins, to be sent first through the lungs, where it could lose its carbonic acid and obtain oxygen, and then through the body generally.

The process of evolution whereby this object was attained was gradual during the period of transition from fish to mammal. It was fully achieved by the complete division of the single longitudinal tube of the primitive heart into right and left halves, by the formation of septa, and by the connexion of the right ventricle with arteries passing to the lungs and the left atrium with the veins returning blood from the lungs, whilst the left ventricle was connected with the arteries supplying the body generally and the right atrium with the veins returning blood from the body. In this way two circulations were established, the pulmonary and the systemic; the arteries and veins of the lung circulation constituting the **pulmonary system of blood-vessels**, and those of the body generally the **systemic system of blood-vessels**, which are subdivisions of the blood vascular system.

There is in addition the system of vessels called lymph vessels which return some of the fluid from the tissues to the systemic veins. They constitute the **lymph vascular system.**

THE TISSUES OF THE VASCULAR SYSTEM.

The tissues of which the various parts of the vascular system are composed are, endothelium, areolar tissues, white fibrous tissue, elastic tissue, unstriped muscle, and cardiac muscle, and of these endothelium alone is found in all parts of the system. It lines the cavities of the heart, the arteries, the arterioles, the veins, and the lymph vessels, and it is the only constituent of the walls of the majority of the capillaries.

The Tissues of the Heart.—The heart consists mainly of cardiac muscle with a certain amount of areolar tissue, white fibrous tissue and elastic tissue, and its cavities are lined with a single layer of endothelial cells.

The cardiac muscle is peculiar, inasmuch as its cells are striated like voluntary muscle, but they are devoid of a cell membrane. They branch and anastomose with one another, their nuclei are central, and they are not under the control of the will; that is, they are involuntary.

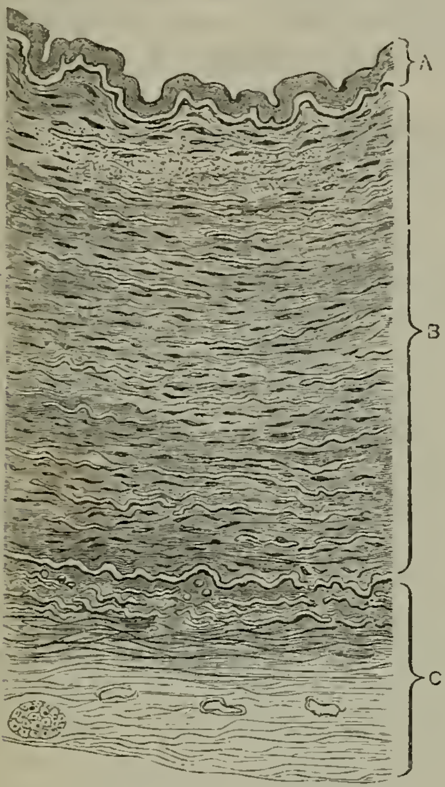

Fig. 715.—Transverse Section through the Wall of a Large Artery.

A, Tunica intima. B, Tunica media. C, Tunica externa.

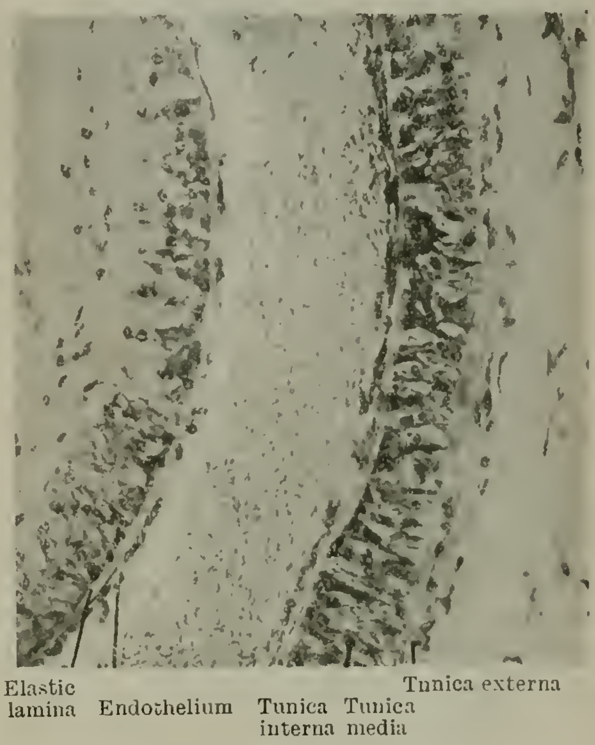

Fig. 716.—Photograph of a Longitudinal Section of a Small Artery.

The contractions of the muscle provide the main propulsive force which drives the blood through the blood-vessels.

The tissues of the arteries are unstriped muscle, areolar tissue, white fibrous tissue, elastic tissue, and endothelium. All the arteries are lined by a single layer of endothelial cells, but the other tissues are present in different amounts in different vessels.

In vessels of the largest size elastic tissue predominates, so that by their distension, as blood is suddenly forced into them by the contractions of the heart, the smaller vessels may be preserved from sudden great strain, whilst the elastic reaction of the distended walls keeps up a steady onflow of blood in the arteries, in the intervals between the contractions of the heart.

All parts of the body are not equally active at the same time, and it is obvious that an active part will require, during its activity, more blood than it does when it is quiescent. Therefore it is necessary that the flow of blood to any particular tissue or organ shall be capable of regulation. The regulation is obtained by means of unstriped muscle, which predominates in the arteries of medium and small size.

The muscle consists of spindle-shaped cells which, for the main part, are arranged in spiral bundles in the middle parts of the walls of the arteries, where they form, with a little intermingled areolar, elastic and white fibrous tissue, the **tunica media** or middle coat of the artery.

The muscle fibres are not under control of the will, that is they are involuntary, but they are under control of the nervous system. Therefore when there is a call from any area for more blood they are relaxed, the calibres of the arteries are enlarged and more blood is permitted to flow through them, whilst when less blood is required they are contracted and the lumina of the arteries are diminished.

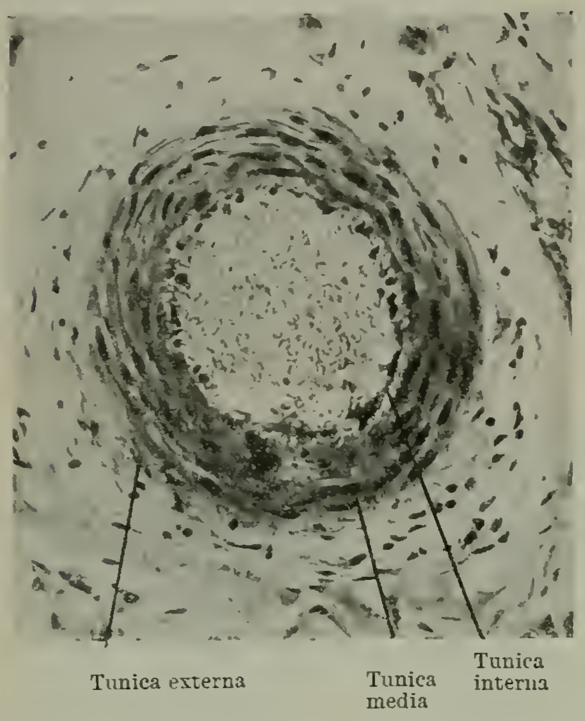

Fig. 717.—Photograph of a Transverse Section of a Small Artery.

The tunica media, above spoken of, intervenes between the two other coats of the arteries, which are termed respectively the **tunica intima** and the **tunica externa**.

The Tunica Intima.—The constituent parts of the tunica intima, as it exists in arteries of medium size, are the endothelial lining, a thin layer of fine connective tissue fibres and cells called *subendothelial connective tissue*, and a layer of elastic fibrils, running more or less longitudinally, or an elastic fenestrated membrane called the *elastic lamina*.

In the smaller arteries the subendothelial tissue disappears. The smallest arteries are devoid of the elastic lamina also.

In the larger arteries, on the other hand, the subendothelial tissue increases in amount and is intermingled with elastic fibrils which merge into the elastic lamina so that the boundary between the two is lost, whilst in the largest arteries the combined subendothelial tissue and elastic lamina are blended with the tunica media, which itself consists mainly of layers of elastic fibrils.

The Tunica Media.—In typical arteries, that is, arteries of medium size, the middle coat consists mainly of unstriped muscle fibres bound together and into more or less spiral strata, by fine connective tissue intermingled with the elastic fibrils.

As the arteries become smaller, and the tunica media is reduced, the muscular strata become fewer and fewer until only a single layer of scattered fibrils remains (Fig. 718). In the largest arteries the muscle fibres disappear and are replaced by increase of the elastic fibrils.

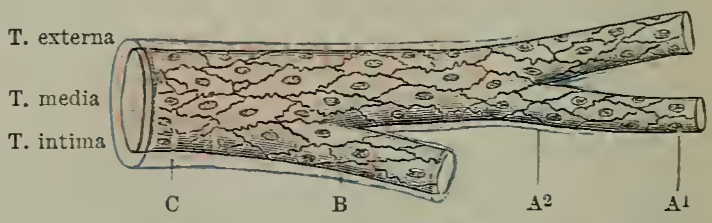

Fig. 718.—Structure of Blood-vessels (diagrammatic).

A^1, Capillary—with simple endothelial walls. A^2, Larger capillary—with connective tissue sheath, "adventitia capillaris." B, Capillary arteriole—showing muscle cells of middle coat, few and scattered. C, Artery—muscular elements of the tunica media forming a continuous layer.

Tunica Externa.—The outer tunic of an artery consists almost entirely of fibrillated connective tissue, in which lie many connective tissue corpuscles. In all but the smallest arteries numerous elastic fibres are also present. The elastic element is specially strong near the middle coat in small and medium-sized vessels, and is sometimes described as an external elastic membrane. In some arteries longitudinally arranged unstriped muscular fibres are also found in the external coat.

The external coat is the strongest and least friable coat of the artery. It disappears on the smallest arteries as the muscle fibres disappear, but is very strong around small, medium, and large arteries.

Vagina Vasis.—In addition to the three tunics above described, arteries are enclosed in a **sheath** of the surrounding connective tissue, and are more or less connected with it by fine strands of fibrillated connective tissue.

The Tissues of Capillaries.—Capillaries measure from 8 μ to 12·5 μ in diameter, and about ·75 mm. in length. Their walls are simple, and, in the smallest capillaries, consist of elongated elastic endothelial cells, with sinuous edges, pointed extremities, and oval nuclei. The cells are cemented to one another, along their margins, by intercellular cement, which readily stains with nitrate of silver. Here and there the cement substance appears to accumulate, forming minute spots indicative of the less perfect apposition of the edges of the cells. Such spots, when small, form the so-called **stigmata**; when larger they are known as **stomata.**

The larger capillaries are invested by a connective tissue sheath consisting of branched cells which are united together and to the endothelial cells of the capillary wall. This sheath is termed the **tunica externa capillaris.**

Capillaries are arranged in networks, the nature and character of which differ in different tissues. The small arteries which end in them are known as **capillary arterioles**, and the venous radicles which commence from them are appropriately termed **capillary veins.**

Exchanges between the blood and lymph and the tissues take place through the walls of the capillaries, but only where they consist of endothelium alone.

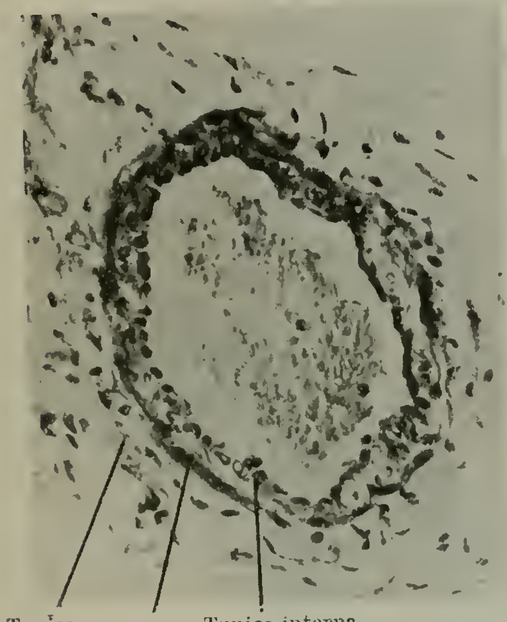

FIG. 719.—PHOTOGRAPH OF A TRANSVERSE SECTION OF A SMALL VEIN.

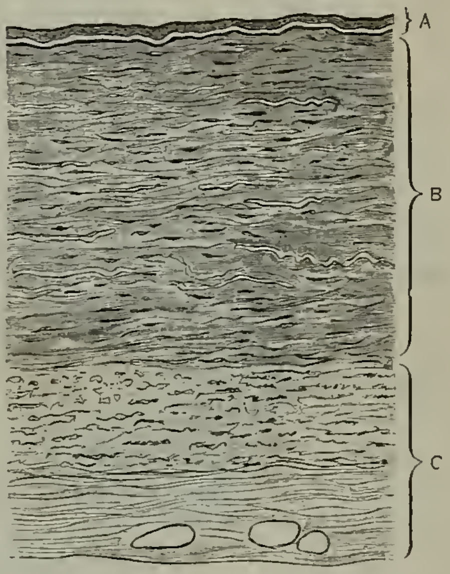

FIG. 720.—TRANSVERSE SECTION OF THE WALL OF A VEIN.

A, Tunica intima. B, Tunica media. C, Tunica externa.

The Tissues of Veins.—The walls of veins are similar in structure to those of arteries; they are, however, thinner, so much so, that, although veins are cylindrical tubes when full of blood, they collapse when empty and their lumina almost disappear. The structural details of the three tunics vary somewhat in different veins; in most the innermost tunic is marked by folds which constitute valves. Like the arteries, the veins are enclosed in connective tissue sheaths.

Tunica Intima.—In the majority of the veins the tunica intima includes an internal endothelial layer, a middle layer of subendothelial connective tissue, and an outer layer of elastic tissue. The innermost tunic of a vein is less brittle than the inner coat of an artery, and is more easily peeled off from the middle coat. The subendothelial tissue is a fine fibrillated connective tissue, less abundant than in the arteries, and in many cases it is absent. The elastic layer consists of lamellæ of elastic fibres which are arranged longitudinally; it rarely has the appearance of a fenestrated membrane.

One of the chief peculiarities of the tunica intima is the presence of folds of its substance which constitute **valves.** The cusps of the valves are of semilunar shape, and they are usually arranged in pairs. Their convex borders are continuous with the vessel wall, and their free borders are turned towards the heart; whilst, therefore, they do not interfere with the free flow of blood from the periphery, they prevent any backward flow towards it, and they help to sustain the column of blood in all vessels in which there is an upward flow. Each valve cusp consists of a fold of the endothelial layer, strengthened by a little connective tissue. As a general rule, the wall of the vein is dilated on the cardiac side of each valve into a shallow pouch or sinus; consequently, when the veins are distended they assume a nodulated appearance. The valves are more numerous in the deep than in the superficial veins, and in the veins of children than in the veins of adults.

Tunica Media.—The middle tunic is much thinner than the corresponding tunic of an artery, and it contains a smaller amount of muscular and a larger amount of ordinary connective tissue; indeed, so much does the latter preponderate that it separates the muscular fibres into a number of bands, which are isolated from one another by strands of connective tissue; therefore the muscle fibres do not form a continuous layer. In some of the veins the more internal muscular fibres do not retain the transverse direction which is usually met with both in arteries and veins; on the contrary, they run longitudinally. This condition is met with in the branches of the mesenteric veins, in the femoral and iliac veins, and in the umbilical veins. The middle tunic is absent in the thoracic part of the inferior vena cava; it is but slightly developed in many of the larger veins, whilst in the jugular veins its muscular tissue is very small in amount.

Tunica Externa.—This tunic consists of white fibrous and elastic tissue. In many of the larger veins a considerable amount of muscular tissue is also present; this is the case in the iliac and axillary veins, the abdominal part of the inferior vena cava, the azygos and hemiazygos veins, and in the renal, spermatic, splenic, superior mesenteric, portal, and hepatic veins. The striped muscle fibres of the heart are prolonged into it at the terminations of the venæ cavæ. The external tunic is frequently thicker than the middle tunic, and the two are not easily separable from one another.

Vascular and Nervous Supply of Arteries and Veins.—**Blood-vessels.**—The walls of the blood-vessels are supplied by numerous small arteries, called *vasa vasorum,* which are distributed to the outer and middle tunics. They arise either from the vessels they supply or from adjacent arteries, and after a short course enter the walls of the vessels in which they end. The blood is returned by small venæ vasorum.

Lymphatics.—Although the cell spaces in the middle and inner tunics may be regarded as the commencement of lymphatics, definite lymphatic vessels are limited to the outer tunic.

Nerves.—Arteries and veins are well supplied with nerves, which form a coarse network in the outer tunic. Branches from this network enter the tunica media, where they form a finer network which supplies twigs to the muscle fibres and sends fine filaments into the inner coat.

COR.

The **heart** is a hollow muscular organ. It receives blood from the veins, and propels it into and along the arteries. The cavity of the fully developed heart is completely separated into right and left halves by an obliquely placed longitudinal septum, and each half is divided into a posterior receiving chamber, the **atrium**, and an anterior ejecting chamber, the **ventricle**. The separation of the atria from the ventricles, however, is not complete. Externally a comparatively shallow constriction, running transversely to the long axis of the organ, indicates the distinction between the atria and ventricles; internally a wide aperture is left between the atrium and ventricle of each side. Each **atrio-ventricular aperture** is provided with a valve which allows the free passage of blood from the atrium to the ventricle, but effectually prevents its return.

The **shape** of the heart is that of an irregular and somewhat flattened cone; and a base, an apex, two surfaces (inferior or diaphragmatic and antero-superior or sterno-costal), and three borders (right, left, and inferior) are distinguishable.

An oblique groove, the **sulcus coronarius**, runs transversely to the long axis of the organ; it separates the postero-superior or atrial portion from the antero-inferior or ventricular part. The separation of the atrial portion into right and left chambers is marked, externally, at the base of the heart only, where an indistinct interatrial groove exists. The division of the ventricular part into right and left ventricles is more definitely marked on the surface by anterior and an inferior longitudinal sulcus which meet at the inferior border to the right of the apex.

The heart lies in the middle mediastinum. It rests below on the diaphragm, and is enclosed in a fibro-serous sac, called the pericardium, which intervenes between it and the neighbouring structures. Its long axis, from base to apex, runs obliquely from behind forwards, downwards, and to the left.

Basis Cordis.—The base, which is formed by the atria, and almost entirely by the left atrium, is directed upwards, posteriorly, and to the right. It lies anterior to the descending thoracic aorta, the œsophagus, and the lower right pulmonary vein, which separate it from the bodies of the sixth, seventh, and eighth thoracic vertebræ.

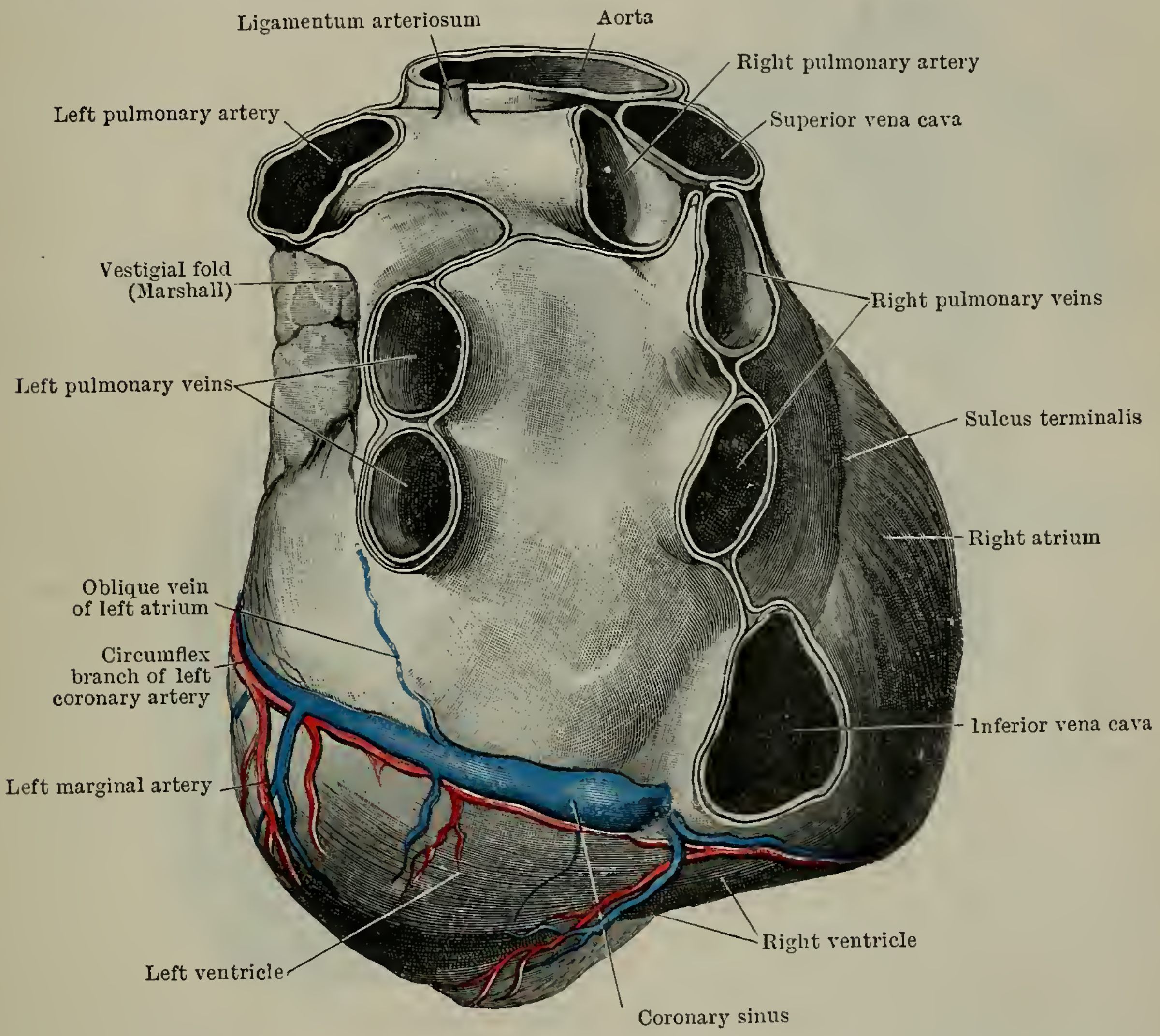

FIG. 721.—THE BASE AND DIAPHRAGMATIC SURFACE OF THE HEART, showing the openings of the great vessels and the line of reflexion of the serous pericardium in a formalin-hardened preparation.

On the whole the base is somewhat flattened. It is irregularly quadrilateral in outline, and the terminations of the superior and inferior venæ cavæ and the four pulmonary veins pass through it. The opening of the superior vena cava is situated at the upper right angle, that of the inferior cava occupies the lower angle on the right side; between and a little to the left of those openings are the orifices of the two right pulmonary veins, and immediately to the right of the latter is the indistinct posterior interatrial sulcus, which descends to the left of the orifice of the inferior vena cava. The openings of the two left pulmonary veins are situated near the left border of the base. The portion of the surface which lies between the right and left pulmonary veins forms the anterior boundary of a section of the pericardial cavity called the great oblique sinus.

The base is limited below by the inferior part of the coronary sulcus, in which the coronary sinus lies; its upper border is in relation with the pulmonary arteries. A fold of pericardium, the *vestigial fold*, descends, near the left border of the base, from the left branch of the pulmonary artery, above, to the left superior pulmonary vein below. It contains the ligamentum v. cavæ sinistræ, and from its lower end a small vein, *the oblique vein of the left atrium*, passes below the orifice of the lower left pulmonary vein, and descends to the coronary sinus. Further, it is from the base that the visceral layer of the pericardium, which elsewhere completely invests the heart, is reflected to the fibrous layer, the lines of reflexion corresponding with the orifices of the great vessels.[1]

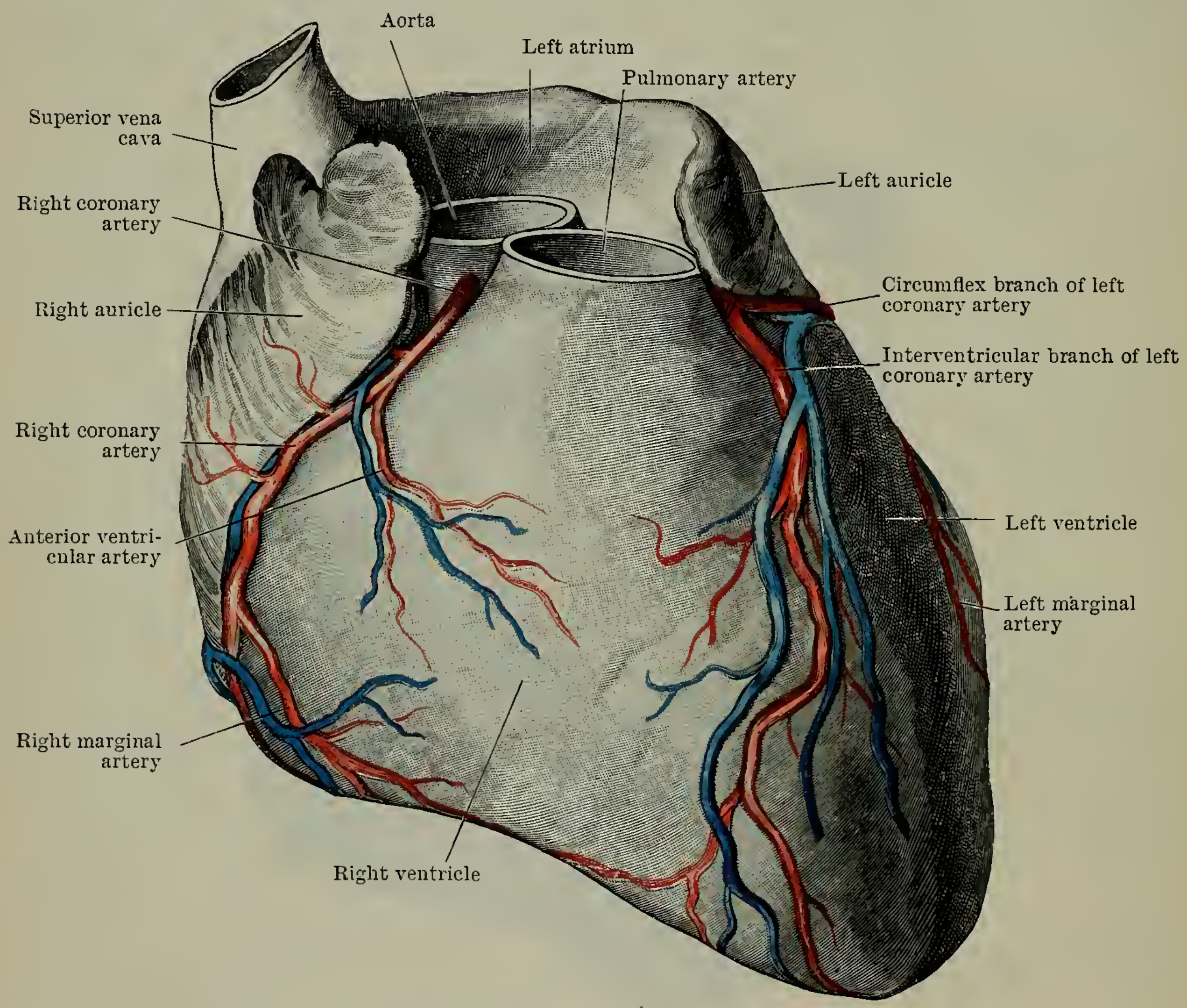

FIG. 722.—THE STERNO-COSTAL SURFACE OF FORMALIN-FIXED HEART.

The *apex*, bluntly rounded, is formed entirely by the left ventricle. It is directed downwards, anteriorly, and to the left, and is situated, under cover of the anterior borders of the left lung and pleura, behind the fifth left intercostal space, or behind the sixth rib, three and a half inches from the anterior median line.

The *diaphragmatic surface* is formed by the ventricular part of the heart. It rests upon the diaphragm, chiefly on the central tendon, but, upon the left side, on a small portion of the muscular substance also, and it is divided into two areas —a smaller to the right side and a larger to the left side—by an oblique antero-posterior groove, the **inferior interventricular sulcus.** It is separated from the base by the posterior or inferior portion of the coronary sulcus.

The *sterno-costal surface* is directed upwards, anteriorly, and to the left. It lies posterior to the body of the sternum and the medial extremities of the cartilages of the third, fourth, fifth, and sixth ribs of the right side, and a greater extent of the corresponding cartilages of the left side. This surface is separated into upper and lower sections by the anterior portion of the coronary sulcus, which runs obliquely from above downwards, and from left to right, from the level of the third left to that of the sixth right costal cartilage. The upper section of the surface, which is concave anteriorly, is formed by the atria; it is separated from the sternum by the ascending aorta and the pulmonary artery, and is continuous laterally with the auricles of the atria which, projecting forwards, embrace the great vessels. The lower section of the sterno-costal surface is convex; it is formed by the ventricular part of the heart, and is divided, by an anterior interventricular sulcus, into a smaller left and a larger right part. At the junction of the atrial and ventricular parts of this surface are the orifices of the pulmonary artery and the aorta, the former lying anterior to the latter.

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[1] In the fœtus and young child the atrial portion of the heart forms not only the base, but also the posterior part of the inferior or diaphragmatic surface.

The *right margin* of the heart is formed by the right atrium. It lies posterior to the cartilages of the third, fourth, fifth, and sixth ribs on the right side, about half an inch from the margin of the sternum; it is in relation with the right pleura and lung, the phrenic nerve with its accompanying vessels intervening, and it is marked by a shallow groove—the *sulcus terminalis*—which passes from the front of the superior vena cava to the front of the inferior vena cava. The *inferior margin* of the sterno-costal surface is sharp, thin, and usually concave corresponding with the curvature of the anterior part of the diaphragm; it is formed mainly by the right ventricle and only near the apex by the left ventricle. It lies, almost horizontally, in the angle between the diaphragm and the anterior wall of the thorax, passing from the sixth right costal cartilage, posterior to the lower part of the body of the sternum, or the xiphoid process, and the cartilages of the sixth and seventh ribs on the left side, to the apex of the heart.

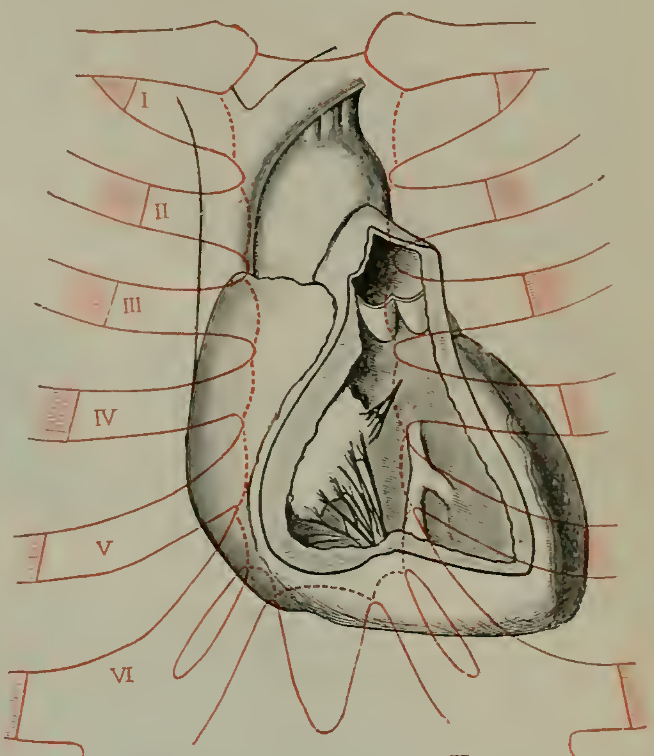

Fig. 723.—The Relation of the Heart to the Anterior Wall of the Thorax.

I, II, III, IV, V, VI, the upper six costal cartilages.

The *left margin* is formed mainly by the left ventricle, and only to a small extent by the left atrium; it is thick and rounded. It lies in relation with the left pleura and lung, the phrenic nerve and its accompanying vessels intervening, and it passes from just above the third left costal cartilage, about an inch from the sternum, to the apex of the heart, descending obliquely and with a convexity to the left.

THE CHAMBERS OF THE HEART.

Atria.—The **atrial** or basal portion of the heart is cuboidal in form. Its long axis, which lies transversely, is curved, with the concavity of the curve forwards. Its cavity is divided into two chambers—the right and left atria—by a septum which runs from the anterior wall backwards and to the right, so obliquely that the right atrium lies anterior and to the right, and the left atrium posterior and to the left.

Each atrium is also somewhat cuboidal in form, the long axes of both being vertical, and each possesses a well-marked, ear-shaped, forward prolongation, known as the **auricle**, which projects from its anterior and upper angle.

Atrium Dextrum.—The **right atrium** receives, posteriorly, the superior vena cava above and the inferior vena cava below. Between them, and a little above its middle, it is crossed posteriorly by the lower right pulmonary vein. It is separated by the pericardium from the posterior part of the right lung and pleura. It is continuous below and anteriorly with the right ventricle, at the atrio-ventricular aperture. Above and anteriorly it is in relation with the ascending aorta, and from the junction of this aspect with the right lateral boundary the right auricle is prolonged anteriorly and to the left. Its right side forms the right margin of the heart, and is in relation with the right phrenic nerve and its accompanying vessels, and with the right pleura and lung, the pericardium intervening. On the left the right atrium is limited by the oblique septum which separates it from the left atrium. The sulcus terminalis is a shallow groove on the surface of the right atrium, which passes from the front of the superior vena cava to the front of the inferior vena cava. It indicates the junction of the primitive sinus venosus (see p. 72) with the atrium proper.

The interior of the right atrium is lined with a glistening membrane, the **endocardium**; its walls are smooth, except anteriorly and in the auricle where muscular bundles, the **musculi pectinati**, form a series of small vertical columns. The musculi pectinati terminate, posteriorly, in a crest, the **crista terminalis**, which corresponds in position with the sulcus terminalis on the external surface.

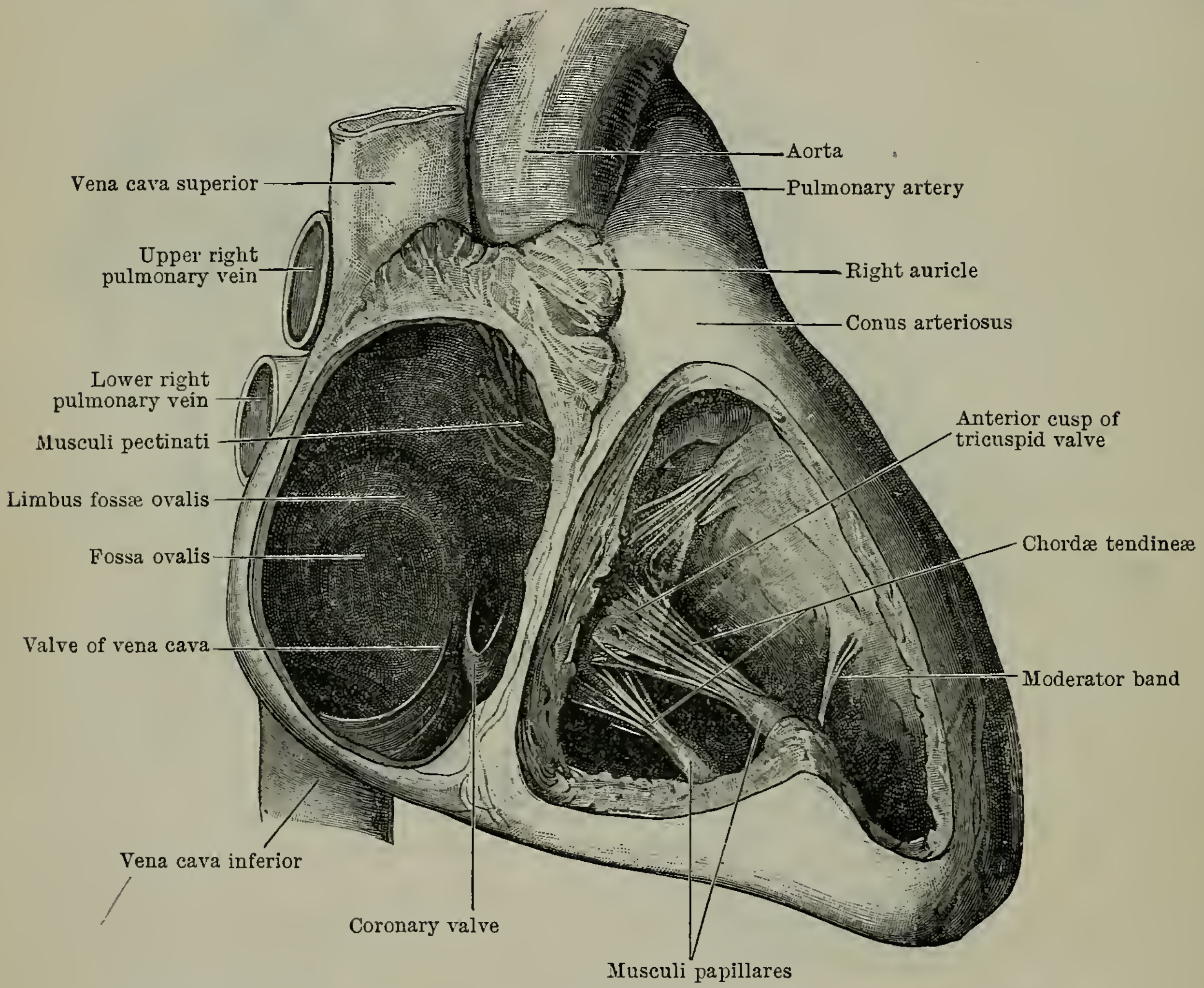

FIG. 724.—THE CAVITIES OF THE RIGHT ATRIUM AND RIGHT VENTRICLE OF THE HEART.
From a formalin-fixed heart.

At the upper and posterior part of the cavity is the opening of the superior vena cava, devoid of a valve. At the lower and posterior part is the orifice of the inferior vena cava, bounded, anteriorly, by the rudimentary **valve of the vena cava** (O.T. Eustachian); and immediately anterior and to the left of this valve, between it and the atrio-ventricular orifice, is the opening of the coronary sinus, guarded by the unicuspid **coronary valve**. The atrio-ventricular aperture, guarded by a tricuspid valve, is known as the **tricuspid orifice**. It is situated in the inferior part of the anterior boundary, and admits three fingers. A number of small fossæ, foramina venarum minimarum, are scattered over the walls, and into some of them the **venæ cordis minimæ** open. In the septal wall is an oval depression, the **fossa ovalis**, bounded, above and anteriorly, by a raised margin, the **limbus fossæ ovalis**, which is continuous, inferiorly, with the valve of the vena cava; the fossa is the remains of an aperture, the **foramen ovale**, through which the two atria communicated with one another before birth. Even in the adult a portion of the aperture persists at the upper part of the fossa in about one in five cases. Between the apertures of the superior and inferior venæ cavæ, and posterior to the upper part of the fossa ovalis, a small eminence may be distinguished, which is called the **tuberculum intervenosum**; it probably directs the blood from the superior vena cava to the tricuspid orifice, during fœtal life.

The **valvula venæ cavæ inferioris** is a thin and sometimes fenestrated fold of endocardium and subendocardial tissue, which extends from the anterior and lower margin of the orifice of the inferior vena cava to the anterior part of the limbus ovalis. It varies very much in size, and is usually of falciform shape; its apex is attached to the limbus fossæ ovalis and its base to the margin of the inferior caval orifice. It is an important structure in the fœtus, directing the blood from the inferior vena cava through the foramen ovale into the left atrium.

The **valvula sinus coronarii** is usually a single fold of endocardium which is placed at the right margin of the orifice of the coronary sinus. It is almost invariably incompetent.

Atrium Sinistrum.—The left atrium is in relation posteriorly with the descending thoracic aorta and the œsophagus, but is separated from them by the pericardium and the oblique sinus of the pericardium. Below and anteriorly it is continuous with the left ventricle. Its sterno-costal surface is concave, and lies in close relation to the ascending aorta, the pulmonary artery, and the left coronary artery. Its right side, formed by the interatrial septum, is directed anteriorly and to the right. Its left side forms a very small portion of the left margin of the heart, and from it, at its junction with the antero-superior surface, the long and narrow left auricle is prolonged, forwards, round the left side of the ascending portion of the aorta and the trunk of the pulmonary artery.

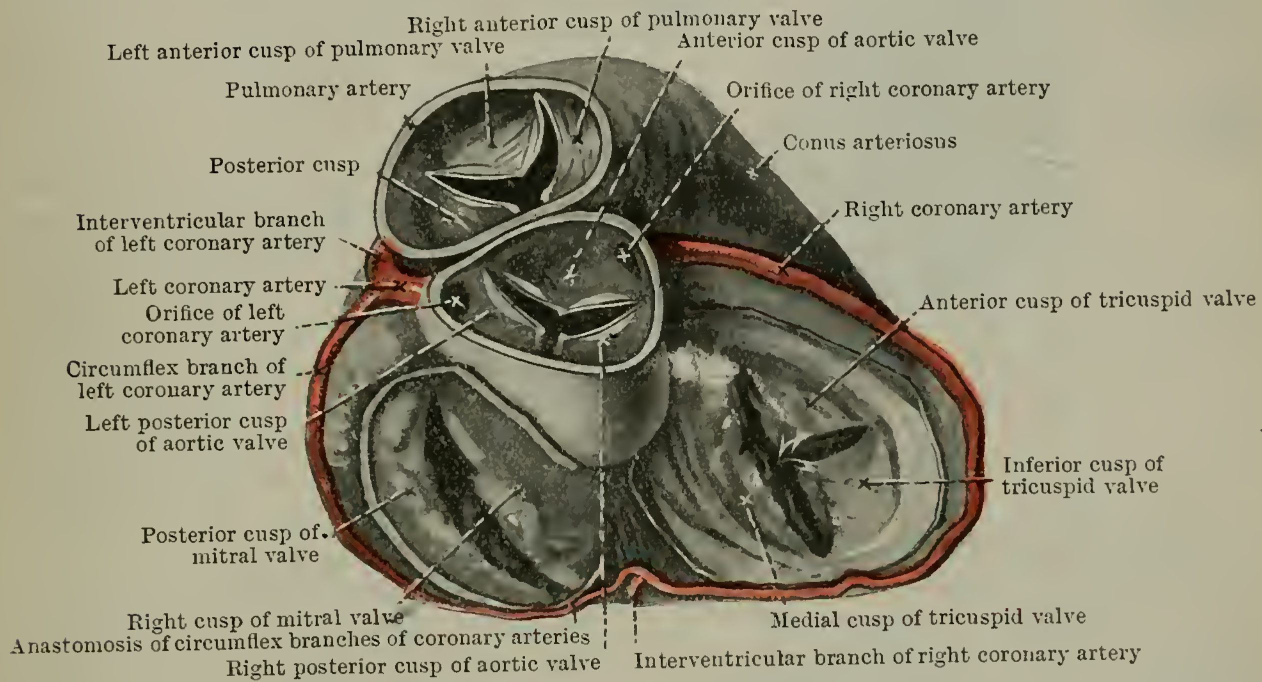
Right anterior cusp of pulmonary valve
Left anterior cusp of pulmonary valve
Anterior cusp of aortic valve
Pulmonary artery
Orifice of right coronary artery
Conus arteriosus
Posterior cusp
Right coronary artery
Interventricular branch of left coronary artery
Left coronary artery
Orifice of left coronary artery
Anterior cusp of tricuspid valve
Circumflex branch of left coronary artery
Left posterior cusp of aortic valve
Inferior cusp of tricuspid valve
Posterior cusp of mitral valve
Right cusp of mitral valve
Anastomosis of circumflex branches of coronary arteries
Right posterior cusp of aortic valve
Medial cusp of tricuspid valve
Interventricular branch of right coronary artery

Fig. 725.—The Bases of the Ventricles of the Heart, showing the atrio-ventricular, aortic, and pulmonary orifices and their valves.

The four pulmonary veins enter the upper part of the posterior surface, two on each side.

The **interior of the left atrium** is lined with endocardium, and its walls are smooth, except in the auricle, where musculi pectinati are present, and on the septum, in a position corresponding with the upper part of the fossa ovalis on the right side, where there are several musculo-fibrous bundles radiating anteriorly and upwards. These septal bundles are separated at their bases by small semilunar depressions, in the largest of which remains of the foramen ovale may be found. Foramina venarum minimarum, and the apertures of venæ cordis minimæ, are scattered irregularly over the inner aspect, whilst in the inferior part of the anterior boundary is the atrio-ventricular aperture or mitral orifice. The orifice is oval in form; its long axis is placed obliquely antero-posteriorly, and from left to right, and is capable of admitting two fingers. It is guarded by a valve formed of two large cusps, known as the **mitral valve**.

Ventriculi.—The **ventricular portion** of the heart is conical and somewhat flattened. The base, directed upwards and posteriorly, is partly continuous with the atrial portion and partly free. It is perforated by four orifices, the two atrio-ventricular, the aortic, and the pulmonary. The atrio-ventricular orifices are placed, one on each side, inferiorly and posteriorly; anteriorly and between them is the aortic orifice, whilst the orifice of the pulmonary artery is still more anterior, and slightly to the left of the aortic orifice.

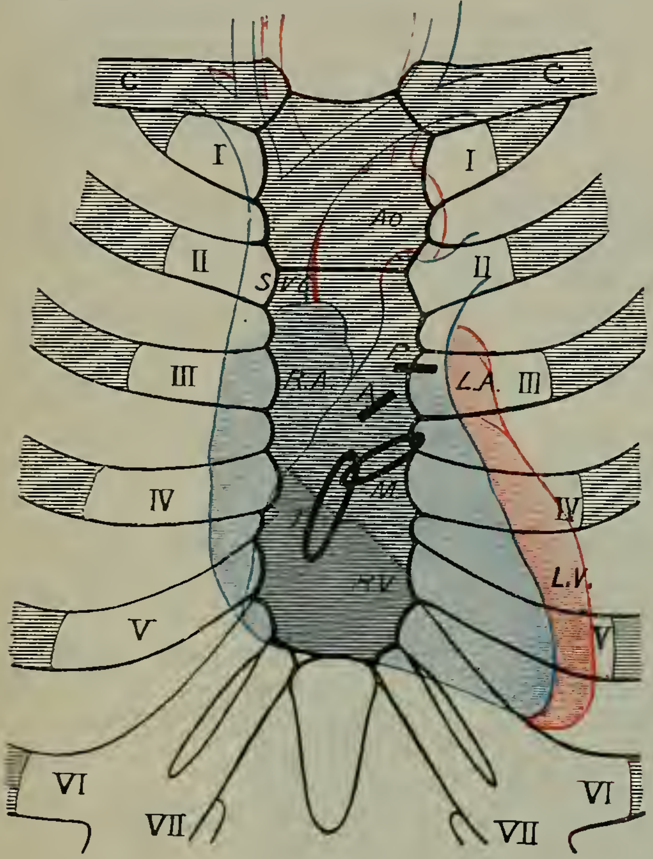

Fig. 726.—The Relations of the Heart and the Atrio-Ventricular, Aortic, and Pulmonary Orifices to the Anterior Thoracic Wall.

I to VII, Costal cartilages.
A, Aortic orifice.
Ao, Aorta.
C, Clavicle.
LA, Left atrium.
LV, Left ventricle.
M, Mitral orifice.
P, Pulmonary orifice.
RA, Right atrium.
RV, Right ventricle.
SVc, Superior vena cava.
T, Tricuspid orifice.

In the triangle between the atrio-ventricular and the aortic orifices is embedded a mass of dense fibrous tissue which is the representative of the os cordis of the ox. It is continuous with the upper part of the interventricular septum, and with fibrous rings which surround the apertures at the bases of the ventricles.

The diaphragmatic surfaces and the sterno-costal surfaces of the two ventricles constitute respectively the greater portions of the corresponding surfaces of the heart; the former rest upon the diaphragm, whilst the latter are directed upwards and anteriorly towards the sternum and the costal cartilages of the left side. The apex of the left ventricle forms the **apex** of the heart.

The inferior margin of the ventricular region, which is thin, forms the inferior margin of the heart; and the left margin, which is thick and rounded, forms the greater part of the left margin of the heart.

The ventricular portion of the heart is divided into right and left chambers by the **ventricular septum**, which is placed obliquely, with one surface directed anteriorly and to the right, and the other posteriorly and to the left; it bulges into the right ventricle, and its lower margin lies to the right of the apex of the heart, which is formed entirely by the left ventricle. The margins of the septum are indicated on the two surfaces of the ventricular part of the heart by anterior and inferior interventricular sulci.

Ventriculus Dexter.—The **right ventricle** is triangular in form. Its base is directed upwards and to the right, and, in the greater part of its extent, it is continuous with the right atrium, with which it communicates by the atrio-ventricular orifice; but its left and anterior angle is free from the atrium, and gives origin to the pulmonary artery. Its inferior wall rests upon the diaphragm. The sterno-costal wall lies posterior to the lower part of the left half of the sternum and the cartilages of the fourth, fifth, and sixth ribs of the left side. The left or septal wall, which is directed posteriorly and to the left, bulges into its interior, and on that account the transverse section of the cavity has a semilunar outline. The cavity itself is a bent tube consisting of an inferior portion or **body** into which the atrio-ventricular orifice opens, and of an antero-superior part, the **infundibulum** or **conus arteriosus**, which terminates in the pulmonary artery.

In the angle between the two limbs is a thick ledge of muscle, the **supraventricular crest.**

The **right atrio-ventricular orifice** is guarded by a **tricuspid valve.** The three cusps are an *anterior,* which intervenes between the atrio-ventricular orifice and the infundibulum, a *medial* or *septal,* and an *inferior.* Each cusp consists of a fold of endocardium, strengthened by a little intermediate fibrous tissue. The bases of the cusps are generally continuous with one another at the atrio-ventricular orifice, where they are attached to a fibrous ring, but they may be separated by small intermediate cusps which fill the angles between the main segments. The apices of the cusps project into the ventricle. The margins, which are thinner than the central portions, are notched and irregular. The atrial surfaces are smooth. The ventricular surfaces are roughened, and, like the margins and apices, they give attachment to fine tendinous cords, the **chordæ tendineæ.** The opposite extremities of the chordæ tendineæ are attached to muscular bundles, the **musculi papillares,** which project from the wall into the cavity of the ventricle (Fig. 724). semi-lunar

The **pulmonary orifice,** which lies anterior and to the left of the tricuspid orifice, is guarded by a **pulmonary valve** composed of three semilunar segments, two of which are placed anteriorly and one posteriorly. The convexity or outer border of each semilunar segment is attached to the wall of the pulmonary artery. The inner border is free, and it presents at its centre a small nodule, the **nodulus valvulæ semilunaris.** On each side of the nodule there is a small, thin marginal segment, of semilunar form, the **lunule.** Each segment of the valve is formed by a layer of endocardium on its ventricular surface, an endothelial layer of the inner coat of the artery on its arterial surface, and an intermediate stratum of fibrous tissue. Both the attached and the free margins of the cusps are strengthened by fibrous bands, and strands of condensed fibrous tissue radiate from the outer border of each cusp to the nodule, but they do not enter the lunulæ. When the valve closes the noduli are closely apposed, the lunulæ of the adjacent segments of the valve are pressed together, and both noduli and lunulæ project vertically upwards into the interior of the artery.

The cavity of the right ventricle is lined with endocardium; the walls are smooth in the conus arteriosus, but are rendered rugose and sponge-like in the body by the inward projection of numerous muscular bundles, the **trabeculæ carneæ.** The fleshy trabeculæ are of two kinds: the simpler are merely columns raised in relief on the wall of the ventricle; those of the other class are rounded bundles, free in the middle, but attached at each end to the wall of the ventricle. One special bundle of the second group, called the **moderator band,** is attached by one extremity to the septum, and by the other to the sterno-costal wall, at the base of the anterior papillary muscle; it tends to prevent over-distension of the cavity. In addition to the trabeculæ carneæ conical muscular eminences, the **musculi papillares,** project into the cavity of the ventricle. The bases of the papillary muscles are continuous with the wall of the ventricle, and their apices terminate in numerous chordæ tendineæ which are attached to the apices, the borders, and ventricular surfaces of the cusps of the tricuspid valve.

The musculi papillares of the right ventricle are—(1) a large anterior muscle, from which the chordæ pass to the anterior and inferior segments of the valve; (2) a smaller and more irregular inferior muscle, sometimes represented by two or more segments, from which chordæ pass to the inferior and medial cusps; and (3) a group of muscular bundles, varying in size and number, which spring from the septum and are united by chordæ to the anterior and medial cusps.

The walls of the right ventricle, the septal excepted, are much thinner than those of the left, but the trabeculæ carneæ are coarser and less numerous in the right than in the left ventricle.

Ventriculus Sinister.—The **left ventricle** is a conical chamber, and its cavity is oval in transverse section. The base is directed upwards and posteriorly, and in the greater part of its extent it is continuous with the corresponding atrium, with which it communicates through the mitral orifice; but anteriorly and to the right of its communication with the atrium it is continued into the ascending aorta.

The **mitral orifice** is oval; its long axis runs obliquely from above downwards and to the right, and it is guarded by a valve consisting of two cusps, which is known as the **bicuspid** or **mitral valve.** The two cusps of the valve are triangular and of unequal size. The smaller of the two is placed to the left and inferiorly; and the larger, placed to the right and anteriorly, between the mitral and aortic orifices, is known as the **aortic cusp.** The bases of the cusps are either continuous with one another, at their attachments to the fibrous ring around the mitral orifice, or they are separated by small intermediate cusps of irregular form and size. The apices of the cusps project into the cavity of the ventricle. The atrial surfaces are smooth; the ventricular surfaces are roughened by the attachments of the chordæ tendineæ, which are connected also with the irregular and notched margins and with the apices. The structure is the same as that of the cusps of the tricuspid valve, but the ventricular surface of the anterior cusp is relatively smooth; therefore the blood flow into the aorta is not impeded.

The **aortic orifice** is circular; it lies immediately anterior and to the right of the mitral orifice, from which it is separated by the anterior cusp of the mitral valve, and it is guarded by the **aortic valve,** formed of three semilunar segments, one of which is placed anteriorly and the other two posteriorly. The structure and attachments of the cusps of the aortic valve are similar to those of the cusps of the pulmonary valve (see p. 873).

The cavity of the left ventricle is separable, like that of the right, into two portions, the body and the aortic vestibule; the latter is a small section placed immediately below the aortic orifice; its walls are non-contractile, consisting of fibrous and fibro-cartilaginous tissue. The wall of the cavity is lined by endocardium. The inferior wall and the apex are rendered sponge-like by numerous fine trabeculæ carneæ, whilst the upper part of the sterno-costal wall and the septum are relatively smooth.

There are two papillary muscles of much larger size than those met with in the right ventricle—an anterior and an inferior; each is connected by chordæ tendineæ with both cusps of the mitral valve.

The walls of the left ventricle are three times as thick as those of the right ventricle, and they are thickest in the region of the widest portion of the cavity, which is situated about a fourth of its length from the base. The muscular portion of the wall is thinnest at the apex, but the thinnest portion of the boundary lies at the upper part of the septum, and it consists entirely of fibrous tissue; this part is occasionally deficient, and an aperture is left through which the cavities of the two ventricles communicate.

The **ventricular septum** is a musculo-membranous partition. It is placed obliquely, so that one surface looks anteriorly and to the right, and bulges into the right ventricle, whilst the other looks posteriorly and to the left and is concave towards the left ventricle. Its sterno-costal and inferior margins correspond respectively with the anterior and the inferior portions of the interventricular sulcus, and it extends from the right of the apex to the interval between the pulmonary, the aortic, and the atrio-ventricular orifices. The main part of its extent is muscular, and is developed from the wall of the ventricular part of the heart; but its upper and posterior portion, the **pars membranacea,** which is developed from the septum of the truncus arteriosus, is entirely fibrous, and constitutes the thinnest portion of the ventricular walls. The pars membranacea lies between the aortic vestibule of the left ventricle, on the left, and the upper part of the right ventricle and the lower and left part of the right atrium, on the right.

STRUCTURE OF THE HEART.

The walls of the heart consist mainly of peculiar striped muscle, the **myocardium,** which is enclosed between the visceral layer of the pericardium, or **epicardium,** externally, and the **endocardium** internally. The muscular fibres differ from those of ordinary voluntary striped muscle in several ways: they are shorter, many of them being oblong cells, with forked extremities which are closely cemented to similar processes of adjacent cells; they form a reticulum, and the nuclei lie in the centres of the cells. Moreover, still more peculiar fibres, the **fibres of Purkinje**, are found immediately beneath the subendocardial tissue. The fibres of Purkinje are large cells which unite with one another at their extremities; their central portions consist of granular protoplasm, in which sometimes one but more frequently two nuclei are embedded, and the peripheral portion of each cell is transversely striated. These cells, in short, present, in a permanent form, a condition which is transitory in all other striped muscle cells.

The reticulating cardiac muscle cells are grouped in sheets and strands which have a more or less characteristic and definite arrangement in different parts of the heart; they are separated and at the same time bound together by intervening lamellæ of fine connective tissue in which elastic fibrils are present; by careful dissection, and after special methods of preparation, it is possible to recognise many layers and bundles, some of which are, however, probably artificially produced.

In the **atria** the muscular fasciculi fall naturally into two groups: (*a*) superficial fibres common to both atria; (*b*) deep fibres special to each atrium.

The **superficial fibres** are most numerous on the sterno-costal aspect and in the neighbourhood of the coronary sulcus. They run transversely across the atria and a few of them dip into the interatrial septum.

The deep fibres are—(1) looped fibres. The extremities of the looped fibres are attached to the fibrous rings around the atrio-ventricular orifices and the fibres pass antero-posteriorly over the atria. (2) Annular fibres which surround (*a*) the extremities of the large vessels which open into the atria; (*b*) the auricles; (*c*) the fossa ovalis.

In the **ventricles** the muscular fasciculi form more or less definite V-shaped loops which commence from and end at the fibrous rings which surround the large orifices at the bases of the ventricles. In their courses the loops embrace the cavities of either one or both ventricles, one stem of each loop lying on the outer surface of the heart and the other in the interior, and some of the loops possess very acute whilst others have very open bends.

The superficial fibres on the sterno-costal surface pass towards the left, those on the inferior surface towards the right. At the apex all are coiled into a whorl or *vortex* through which they pass into the interior of the ventricular walls and run towards the base, some in the septum and others in the papillary muscles. The various bundles which have been described can, according to Mall, be resolved into two main systems. One system arises from the conus arteriosus and the root of the aorta, that is from the remains of the primitive aortic trunk: it is called the "bulbo-spiral" system. The other springs from the region of the primitive venous sinus and is termed the "sino-spiral." Both systems are separable into superficial and deep portions, and the general plan of more or less spirally curved V-shaped loops is retained in each, but the details of the arrangement are too complicated for consideration within the limits of an ordinary text-book (see *Amer. Journ. of Anat.* vol. ii., 1910–1911).

The **Atrio-Ventricular Bundle.**—It would appear from the preceding description that the muscle-fibres of the atria and the ventricles are entirely separated from one another by the fibrous rings which surround the atrio-ventricular orifices; that, however, is not the case, for the two groups are connected together by a bundle of muscle fibres of pale colour and rudimentary structure, which lies immediately adjacent to the endocardium and constitutes the atrio-ventricular bundle.

The bundle commences in a nodular enlargement which lies in the lower part of the wall of the right atrium, close to the base of the medial cusp of the tricuspid valve. From that point the bundle runs along the posterior and lower borders of the membranous part of the ventricular septum to the upper and posterior part of the muscular portion of the septum, where it divides into right and left branches. The right branch runs along the right side of the ventricular septum to the moderator band, along which it passes into the anterior papillary muscle of the right ventricle. The left branch runs along the left side of the septum and both branches give off numerous ramifications, by means of which the main bundle is associated with all parts of the walls of the two ventricles.

Both the function and the origin of the atrio-ventricular bundle are uncertain. After the discovery of the bundle it was asserted that impulses were conveyed from the atria to the ventricles by the muscle fibres of the atrio-ventricular bundle and by them alone; more recently it has been shown that minute nerve fibrils are intimately intermingled with the muscle fibres of the bundle, and it has yet to be decided whether the impulses which pass from the atria to the ventricles, for the purpose of maintaining the proper sequence of the movements of the chambers, travel by the nerve fibrils or the muscle fibres or by both.

The atrio-ventricular bundle is probably a remnant of the muscular continuity which existed in the early stages of development between the atrial and ventricular chambers of the heart, but it may be, wholly or in part, a new formation.

The **epicardium**, or visceral portion of the pericardium, consists of white connective and of elastic tissue, the latter forming a distinct reticulum in the deeper part. The surface which looks towards the pericardial cavity is covered with flat polygonal endothelial plates.

The **endocardium** lines the cardiac cavities and is continuous with the inner coats of the vessels which enter and leave the heart. It is much thinner than the epicardium. It consists, like the tunica intima of the blood-vessels, of an inner lining of flat endothelial cells, a layer of fine subendothelial connective tissue, and an external elastic layer which usually assumes the form of a fenestrated membrane. The endocardium rests externally on a layer of fine subendocardial connective tissue which is continuous with the connective tissue lamellæ between the muscle layers of the heart. It contains blood-vessels and nerves which are absent from the endocardium.

Size of the Heart.—The heart is about 125 mm. (five inches) long, 87 mm. (three and a half inches) broad; its greatest depth from its sterno-costal to its diaphragmatic surface is 62 mm. (two and a half inches), and it is roughly estimated as being about the same size as the closed fist. The size, however, is variable, the volume increasing at first rapidly, and then gradually, with increasing age, from 22 cc. at birth to 155 cc. at the fifteenth year, and to 250 cc. by the twentieth year. From that period to the fiftieth year, when the maximum volume (280 cc.) is attained, the increase is much more gradual, and after fifty a slight decrease sets in. The volume is the same in both sexes up to the period of puberty, but thereafter it preponderates in the male.

Weight.—The average weight of the heart in the male adult is 310 grms. (11 ounces), and in the female adult 255 grms. (9 ounces); but the weight varies greatly, always, however, in definite relation to the weight of the body, the relative proportions changing at different periods of life. Thus at birth the heart weighs 24 grms. (13½ drachms), and its relation to the body weight is as 1 to 130, whilst in the adult the relative proportion is as 1 to 205. The heart is said to increase rapidly in weight up to the seventh year, then more slowly up to the age of puberty, when a second acceleration sets in; but after the attainment of adult life the increase, which continues till the seventieth year, is very gradual.

The above changes affect the whole heart, but the several parts also vary in their relation to one another at different periods of life. During fœtal life the right atrium is heavier than the left; in the first month after birth the two become equal; at the second year the right again begins to preponderate, and it is heavier than the left during the remainder of life. In the latter part of fœtal life the two ventricles are equal; after birth the left grows more rapidly than the right, until, at the end of the second year, a position of stability is gained, when the right is to the left as 1 to 2, and this proportion is maintained until death.

Capacity.—During life the capacity of the ventricles is probably the same, and each is capable of containing from three to four ounces of blood, whilst the atria are a little less capacious. After death the cavity of the right ventricle appears larger than that of the left.

Vascular Supply of the Heart.—The walls of the heart are supplied by the **coronary arteries** (p. 884), the branches of which pass through the interstitial tissue to all parts of the muscular substance and to the subendocardial and subepicardial tissues; the endocardium and the valves are devoid of vessels. The capillaries, which are numerous, form a close-meshed network around the muscular fibres. Sometimes the valves contain a few muscular fibres, and in those cases they also receive some minute vessels. The majority of the veins of the heart end in the coronary sinus, which opens into the lower part of the right atrium; some few very small veins, however, open directly into the right atrium, and others are said to end in the left atrium, and in the cavities of the ventricles.

Lymphatics of the Heart.—Lymphatic vessels are freely distributed throughout the whole substance of the heart. They all communicate with the superficial network which lies beneath the epicardium. The efferent vessels from the subepicardial network accompany the coronary arteries to the coronary sulcus and pass thence to the anterior mediastinal glands.

Nerves of the Heart.—The heart receives its nerves from the superficial and deep cardiac plexuses. The former lies beneath the aortic arch and the latter between the arch and the bifurcation of the trachea. Through the plexuses it is connected with the vagus, the accessory (through the vagus), and the sympathetic nerves. After leaving the cardiac plexuses many of the nerve-fibres enter the walls of the atria and anastomose together in the subepicardial tissue, forming a plexus in which many ganglion cells are embedded, especially near the terminations of the inferior vena cava and the pulmonary veins. From the subepicardial atrial plexus, nerve filaments, on which nerve ganglion cells have been found, pass into the substance of the atrial walls.

Other fibres from the cardiac plexuses accompany the coronary arteries to the ventricles, and upon those also ganglion cells are found in the region immediately below the coronary sulcus.

The nerve-fibres which issue from the gangliated plexuses of the heart are non-medullated. They form fine plexuses round the muscle fibres, and they terminate either in fine fibrils on the surfaces of the muscle fibres, or in nodulated ends which lie in contact with the muscle cells.

Abnormalities of the Heart.—The heart may be transposed from the left to the right side of the body, a condition which is usually associated with general transposition of the viscera, and with the presence of a right instead of a left aortic arch.

The external form of the heart does not as a rule vary much, but occasionally the apex is slightly bifid, a character it normally possesses at an early stage of its development, and which is retained in the adult in many cetaceans and sirenians. The internal conformation of the heart deviates from the normal much more frequently; more particularly is this the case with regard to the septa which separate the right from the left chambers. The interatrial septum may be entirely absent, as in fishes; it may be fenestrated and incomplete, as in some amphibians; or the foramen ovale may remain patent, as in amphibians and reptiles.

The interventricular septum may be absent, as in fishes and amphibians, or incomplete, as in reptiles; when incomplete, it is usually the "pars membranacea septi" which is deficient, but perforations are occasionally found in the muscular portion.

The communication between the infundibular part of the right ventricle and the body of the ventricle may be constricted or the infundibular part may be entirely cut off from the remainder of the cavity.

PERICARDIUM.

The **pericardium** is a fibro-serous sac which surrounds the heart. It lies in the middle mediastinum, and is attached below to the diaphragm, and above and posteriorly to the roots of the great vessels. Anteriorly and posteriorly it is in relation with the structures in the corresponding mediastina and laterally it is in close apposition with the pleural sacs.

The **fibrous pericardium** is a strong fibrous sac of conical form; its base is attached to the central tendon and to the adjacent part of the muscular substance of the diaphragm, and it is pierced by the inferior vena cava. At its apex and posteriorly it is gradually lost upon the great vessels which enter and emerge from the heart, giving sheaths to the aorta, the two branches of the pulmonary artery, the superior vena cava, the four pulmonary veins, and the ligamentum arteriosum. Its anterior surface forms the posterior boundary of the anterior mediastinum, and it is attached, above and below, by the superior and inferior sterno-pericardial ligaments, to the sternum. In the greater part of its extent it is separated from the anterior wall of the thorax by the anterior margins of the lungs and pleural sacs, but it is in direct relation with the left half of the lower portion of the body of the sternum and, in many cases, with the medial ends of the cartilages of the fourth, fifth, and sixth ribs of the left side and the left transversus

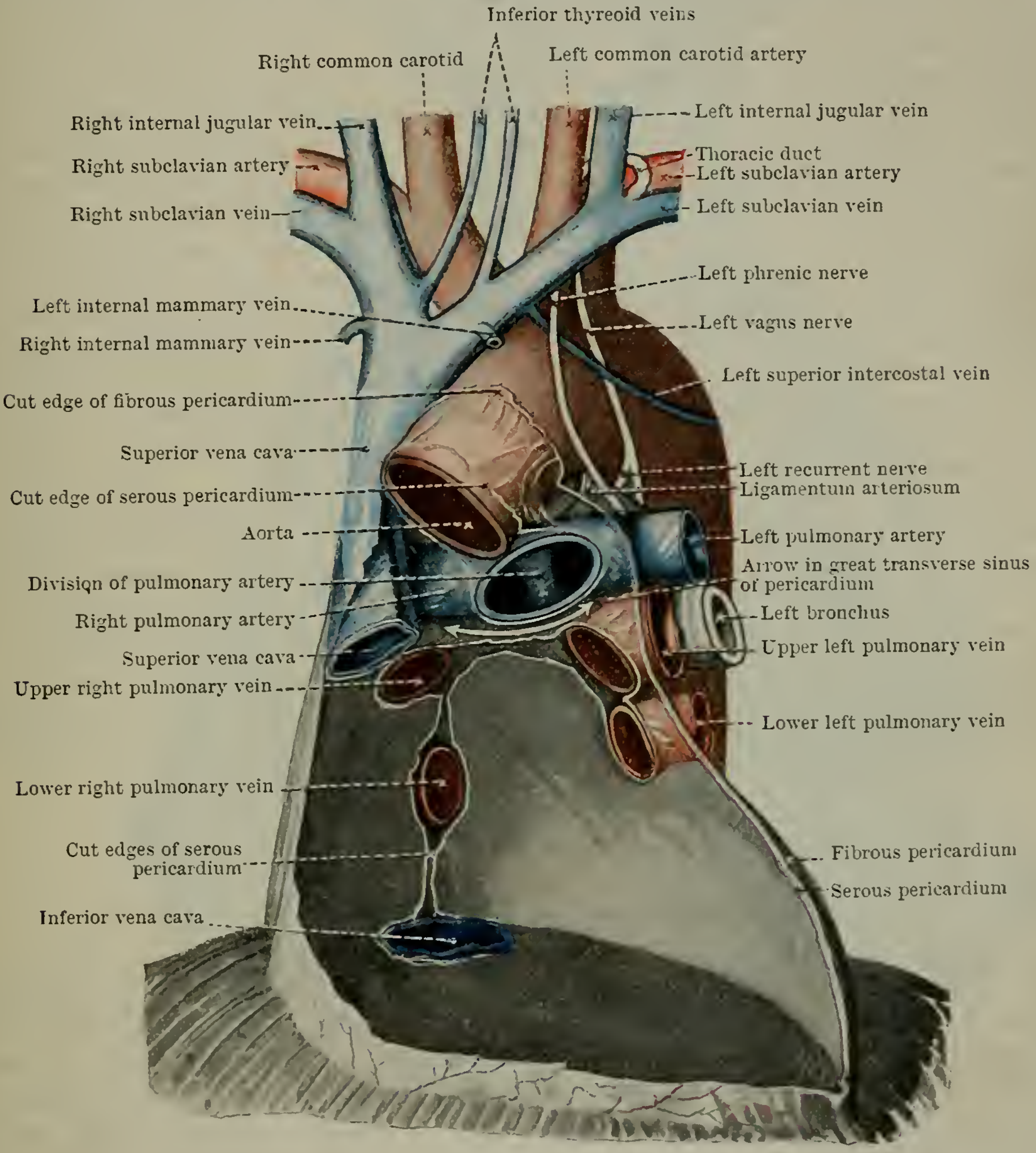
Inferior thyreoid veins
Right common carotid
Left common carotid artery
Right internal jugular vein
Left internal jugular vein
Right subclavian artery
Thoracic duct
Left subclavian artery
Right subclavian vein
Left subclavian vein
Left phrenic nerve
Left internal mammary vein
Left vagus nerve
Right internal mammary vein
Left superior intercostal vein
Cut edge of fibrous pericardium
Superior vena cava
Left recurrent nerve
Cut edge of serous pericardium
Ligamentum arteriosum
Aorta
Left pulmonary artery
Division of pulmonary artery
Arrow in great transverse sinus of pericardium
Right pulmonary artery
Left bronchus
Superior vena cava
Upper left pulmonary vein
Upper right pulmonary vein
Lower left pulmonary vein
Lower right pulmonary vein
Cut edges of serous pericardium
Fibrous pericardium
Serous pericardium
Inferior vena cava

FIG. 727.—POSTERIOR WALL OF THE PERICARDIUM AFTER THE REMOVAL OF THE HEART. Showing the relation of the serous pericardium to the great vessels.

thoracis muscle. Its posterior surface forms the anterior boundary of the posterior mediastinum; it is in relation with the œsophagus and the descending aorta, both of which it separates from the back of the left atrium. Each lateral aspect is in close contact with the mediastinal portion of the parietal pleura, the phrenic nerve and its accompanying vessels intervening. The inner surface of the fibrous sac is lined by the serous pericardium, which is closely attached to it.

The **serous pericardium** is a closed sac containing a little fluid (liquor pericardii). It is surrounded by the fibrous pericardium and invaginated by the heart. It is, therefore, separable into two portions—the parietal, which lines the inner surface of the fibrous sac, and the visceral, which ensheathes, or partially ensheathes, the heart and the great vessels; but the two portions are, of course, continuous with one another where the serous layer is reflected on to the great vessels as they pierce the fibrous layer. The majority of the great vessels receive only partial coverings from the visceral layer: thus, the superior vena cava is covered anteriorly and on each side; the pulmonary veins anteriorly, above, and below; and the inferior vena cava anteriorly and on each side. The aorta and the pulmonary artery are enclosed together in a complete sheath of the visceral layer. Therefore, when the pericardial sac is opened from the front, it is possible to pass the fingers behind them and in front of the atria, from the right to the left side, through a passage called the **great transverse sinus** of the pericardium (Fig. 727). The spaces or pouches which intervene between the vessels which receive partial coverings from the serous pericardium are also called sinuses; and the largest of them, which is bounded below and on the right by the inferior vena cava, and above and on the left by the left inferior pulmonary vein, is known as the **great oblique sinus.** It passes upwards and to the right behind the left atrium, and lies anterior to the œsophagus and the descending thoracic aorta.

A small fold of the serous pericardium, the **vestigial fold,** passes from the left pulmonary artery to the left superior pulmonary vein, posterior to the left extremity of the transverse sinus. It merits special attention because it encloses a fibrous strand, the *ligamentum venæ cavæ sinistræ.* This is a remnant of the left superior vena cava or duct of Cuvier, which atrophied at an early period of fœtal life.

Structure.—The fibrous pericardium consists of ordinary connective tissue fibres felted together into a dense, unyielding membrane. The serous pericardium is covered on its inner aspect by a layer of flat endothelial cells. The endothelium rests upon a basis of mixed white and elastic fibres in which run numerous blood-vessels, lymphatics, and nerves.

ARTERIÆ.

ARTERIA PULMONALIS.

The **pulmonary artery** springs from the anterior and left angle of the base of the right ventricle, at the termination of the conus arteriosus. It is slightly larger at its commencement than the aorta, and is dilated, immediately above the cusps of the valve, into three pouches, the **sinuses** of the pulmonary artery. It runs upwards and posteriorly, towards the concavity of the aortic arch, curving from the front round the left side of the ascending aorta to reach a plane posterior to the latter; and it terminates, by dividing into right and left branches, opposite the fifth thoracic vertebræ. Its length is a little more than two inches.

Relations.—The pulmonary artery is enclosed within the fibrous pericardium, and is enveloped, along with the ascending aorta, in a common sheath of the visceral layer of the serous pericardium. It lies behind the anterior extremity of the second left intercostal space, from which it is separated by the anterior margins of the left lung and pleural sac.

Its posterior relations are the bulb of the aorta, the anterior wall of the left atrium, and the first part of the left coronary artery. To the right it is in relation with the right coronary artery, the auricle of the right atrium, and the ascending aorta, and to the left with the left coronary artery and the auricle of the left atrium. Immediately above its bifurcation, between it and the aortic arch, is the superficial cardiac plexus.

The **right branch of the pulmonary artery** is longer and larger than the left. It passes to the hilum of the right lung, forming one of the constituents of the root of the lung, and, after entering the lung, it descends, with the main bronchus, to the lower extremity of the organ (Fig. 728).

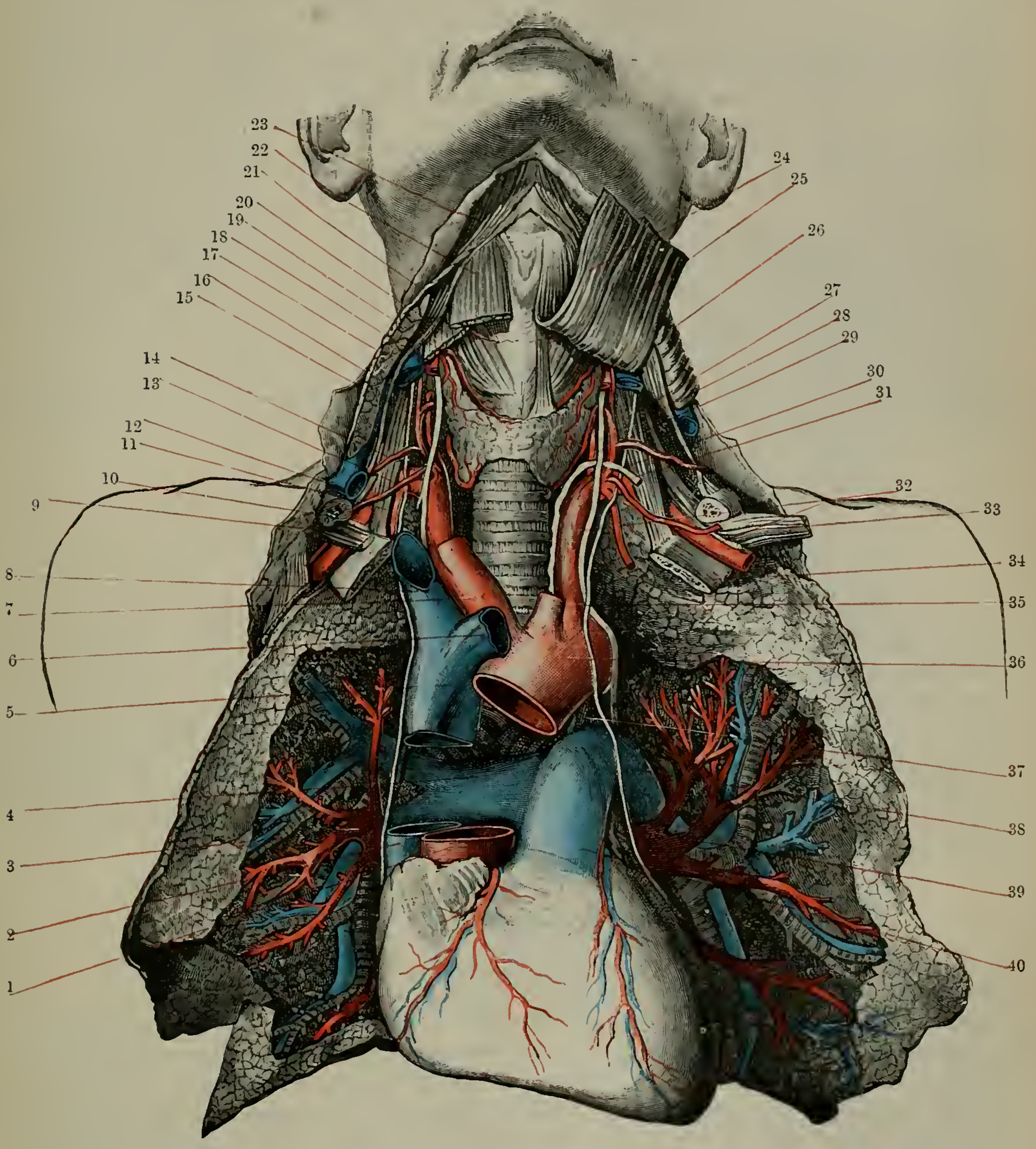

Fig. 728.—The Pulmonary Arteries and Veins and their Relations in a Formalin-hardened Preparation.

The ascending aorta and part of the superior vena cava have been removed.

1. Aorta.
2. Superior vena cava.
3. Upper right pulmonary vein.
4. Right pulmonary artery.
5. Superior vena cava.
6. Left innominate vein.
7. Innominate artery.
8. Right innominate vein.
9. Subclavius muscle.
10. Clavicle.
11. Internal mammary artery.
12. Subclavian vein.
13. Transverse scapular artery.
14. Transverse cervical artery.
15. Vertebral artery.
16. Inferior thyreoid artery.
17. Internal jugular vein.
18. Common carotid artery.
19. Superior thyreoid artery.
20. Sterno-thyreoid muscle.
21. Omo-hyoid muscle.
22. Sterno-hyoid muscle.
23. Platysma.
24. Sterno-hyoid muscle.
25. Sterno-thyreoid muscle.
26. Sterno-mastoid muscle.
27. Phrenic nerve.
28. Vagus nerve.
29. Vertebral artery.
30. Inferior thyreoid artery.
31. Thoracic duct.
32. Left subclavian artery.
33. Subclavius muscle.
34. 1st rib.
35. Left common carotid artery.
36. Aorta.
37. Ligamentum arteriosum.
38. Left pulmonary artery.
39. Upper left pulmonary vein.
40. Pulmonary artery.

Relations.—Before it enters the lung the right pulmonary artery passes posterior to the ascending aorta, the superior vena cava, and the upper right pulmonary vein. At first, it lies below the arch of the aorta and the right bronchus, anterior to the œsophagus, and above the left atrium and the lower right pulmonary vein ; then it crosses anterior to the right bronchus, immediately below the eparterial branch of that bronchus, and reaches the hilum of the lung. After it has passed through the hilum the artery descends, in the lung, posterior and lateral to the main bronchus and between its ventral and dorsal branches.

Branches.—Before entering the hilum it gives off a large branch to the upper lobe of the right lung which accompanies the eparterial bronchus, and in the substance of the lung it gives off numerous branches which correspond with and accompany the dorsal, ventral, and accessory branches of the right bronchus. (See Respiratory System.)

The **left branch of the pulmonary artery**, shorter, smaller, and somewhat higher in position than the right, passes laterally and posteriorly from the bifurcation of the pulmonary stem, and runs, in the root, to the hilum of the left lung; it then descends, in company with the main bronchus, to the lower end of the lung.

Relations.—Before it enters the lung it is crossed, *anteriorly*, by the upper left pulmonary vein; *posterior to* it, are the left bronchus and the descending aorta; *above*, are the aortic arch, to which it is connected by the ligamentum arteriosum, and the left recurrent nerve; *below*, it is in relation with the lower left pulmonary vein. After entering the lung it descends, like the right pulmonary artery, posterior and lateral to the stem bronchus, and between its ventral and dorsal branches.

Branches.—Just before it passes through the hilum it gives off a branch to the upper lobe of the left lung, and in the substance of the lung its branches correspond with the ventral, dorsal, and accessory branches of the bronchial tube.

THE SYSTEMIC ARTERIES.

AORTA.

The **aorta** is the main trunk of the general arterial system. It commences at the base of the left ventricle and ascends, with an inclination to the right, to the level of the second right costal cartilage; then it curves backwards and to the left, until it reaches the left side of the lower border of the fourth thoracic vertebra; there it turns downwards and descends, through the thorax into the abdomen, where it terminates, on the left of the median plane, at the level of the fourth lumbar vertebra, by bifurcating into the two common iliac arteries. The portion of the aorta which is situated in the thorax is, for convenience, termed the *thoracic aorta*, and the rest of the vessel is known as the *abdominal aorta*.

AORTA THORACALIS.

The thoracic aorta is subdivided into aorta ascendens, arcus aortæ, and aorta descendens.

Aorta Ascendens.—The **ascending aorta** lies in the middle mediastinum. It springs from the base of the left ventricle, posterior to the left margin of the sternum, opposite the lower border of the third left costal cartilage and at the level of the body of the sixth thoracic vertebra. From its origin it passes upwards, anteriorly, and to the right, and it terminates in the arch of the aorta, posterior to the right margin of the sternum, at the level of the second costal cartilage. Its *length* is from 50 to 56 mm. (2 to 2¼ inches), and its diameter is 28 mm. (1⅛ inches). In the adult it is a little narrower at its commencement than the pulmonary artery is, but in old age it enlarges and exceeds the latter vessel in size. The diameter, however, is not uniform throughout the whole length of the ascending aorta. Its dilated commencement, the **bulbus aortæ**, has three secondary dilatations, the **sinus aortæ** (Valsalva) in its wall, immediately opposite the semilunar cusps of the aortic valve; one is anterior in position, and two are situated posteriorly. At a higher level there is a diffuse bulging of the right wall, which is known as the *great sinus* of the aorta.

Relations.—The ascending aorta is completely enclosed within the fibrous pericardium which blends above with the sheath of the vessel, and it is enveloped, together with the stem of the pulmonary artery, in a tubular prolongation of the serous pericardium. At its origin it has the pulmonary artery in front, the transverse sinus of the pericardium and the anterior wall of the left atrium behind, and the right atrium on its right side. In the upper part of its course the ascending aorta is overlapped by the anterior margins of the right lung and right pleural sac, whilst posterior to it are the right atrium, the right branch of the pulmonary artery, the right bronchus, and the left margin of the superior vena cava. The superior vena cava lies on the right side, and partly posterior to the upper part of the ascending aorta, whilst the pulmonary artery is at first anterior to it and then, at a higher level, on its left side.

Branches.—Two branches arise from the ascending aorta, viz., the right and the left coronary arteries. The right coronary artery springs from the anterior, and the left from the left posterior sinus of the aorta (Fig. 725).

Arcus Aortæ.—The arch of the aorta lies in the superior mediastinum, posterior to the lower part of the manubrium sterni, and connects the ascending with the descending aorta. It commences posterior to the right margin of the sternum, on a level with the second costal cartilage, and extends to the level of the left side of the lower border of the fourth thoracic vertebra. As its name implies, it forms an arch; and the arch makes two curves, one with the convexity upwards (Fig. 727), and the other with the convexity forwards and to the left. From its origin it runs for a short distance upwards, posteriorly, and to the left, anterior to the trachea; then it passes posteriorly, round the left side of the trachea to the left side of the body of the fourth thoracic vertebra (Fig. 729). Finally it turns downwards to become continuous with the descending aorta.

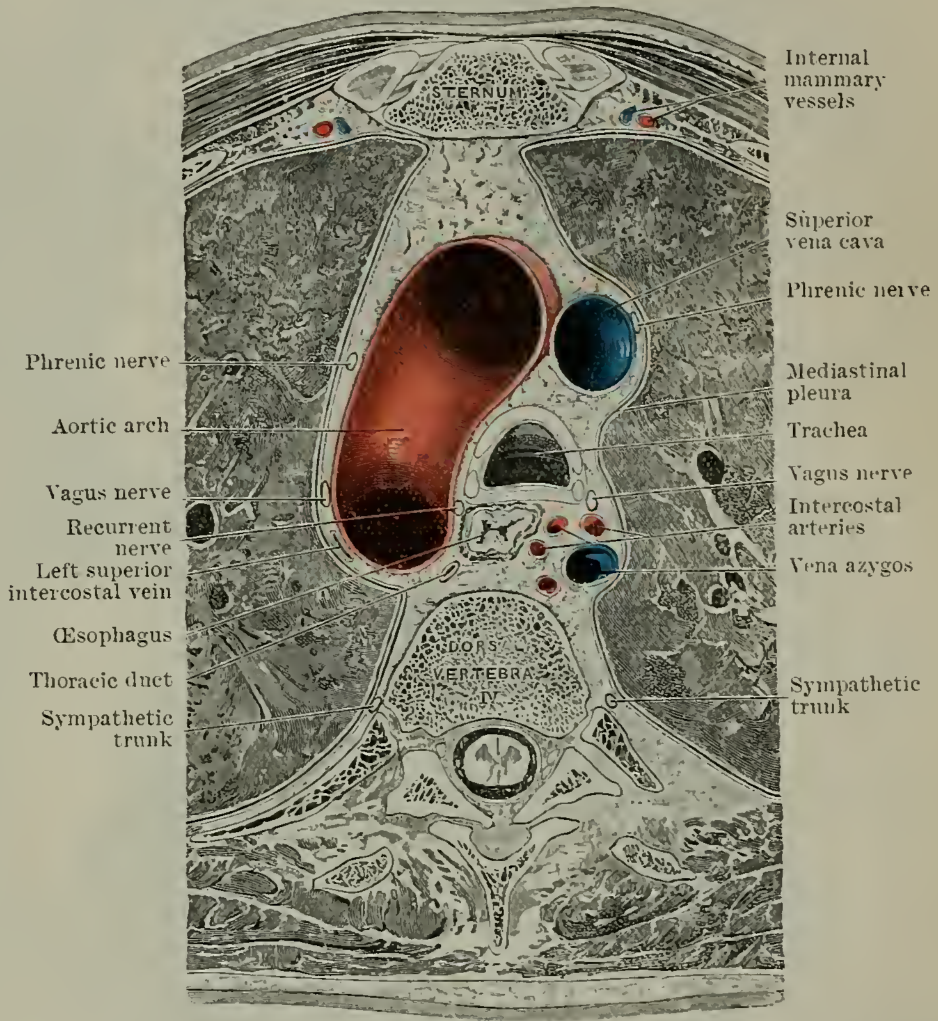

Fig. 729.—Transverse Section through the Superior Mediastinum at the Level of the Fourth Thoracic Vertebra.

At its commencement it has the same diameter as the ascending aorta, 28 mm. ($1\frac{1}{8}$ inches), but after giving off three large branches, the diameter is reduced to 23 mm. (a little less than one inch).

Relations.—It is overlapped anteriorly and on the left side by the right and left lungs and pleural sacs, but much more by the left than the right, and in the interval between and posterior to the anterior borders of the pleural sacs it is covered by the remains of the thymus. As it turns backwards it is crossed vertically, on the left side, by four nerves in the following order from before backwards:—the left phrenic, the inferior cervical cardiac branch of the left vagus, the superior cardiac branch of the left sympathetic, and the trunk of the left vagus. The left superior intercostal vein passes obliquely upwards and to the right, across it, between the left vagus and left phrenic nerves.

Posterior to, and *to the right side* of the arch, are the trachea, the deep cardiac plexus, the left recurrent nerve, the left border of the œsophagus, and the thoracic duct. *Above* are its three large branches—the innominate, the left common carotid, and the left subclavian arteries; and crossing anterior to their roots is the left innominate vein. *Below* is the bifurcation of the pulmonary artery and the root of the left lung; the ligamentum arteriosum, which is also below, attaches it to the commencement of the left pulmonary artery, whilst to the right of the ligament lies the superficial cardiac plexus, and to its left the left recurrent nerve.

Branches.—The three great vessels which supply the head and neck, part of the thoracic wall, and the upper extremities—viz. the innominate, the left common carotid, and the left subclavian arteries—arise from the aortic arch.

Aorta descendens.—The thoracic portion of the **descending aorta** lies in the posterior mediastinum; it extends from the termination of the arch, at the lower border of the left side of the fourth thoracic vertebra, to the aortic opening in the diaphragm, where, opposite the twelfth thoracic vertebra, it becomes continuous with the abdominal portion. Its length is from 17·5 to 20 cm. (seven to eight inches), and its diameter diminishes from 23 mm. at its commencement to 21 mm. at its termination.

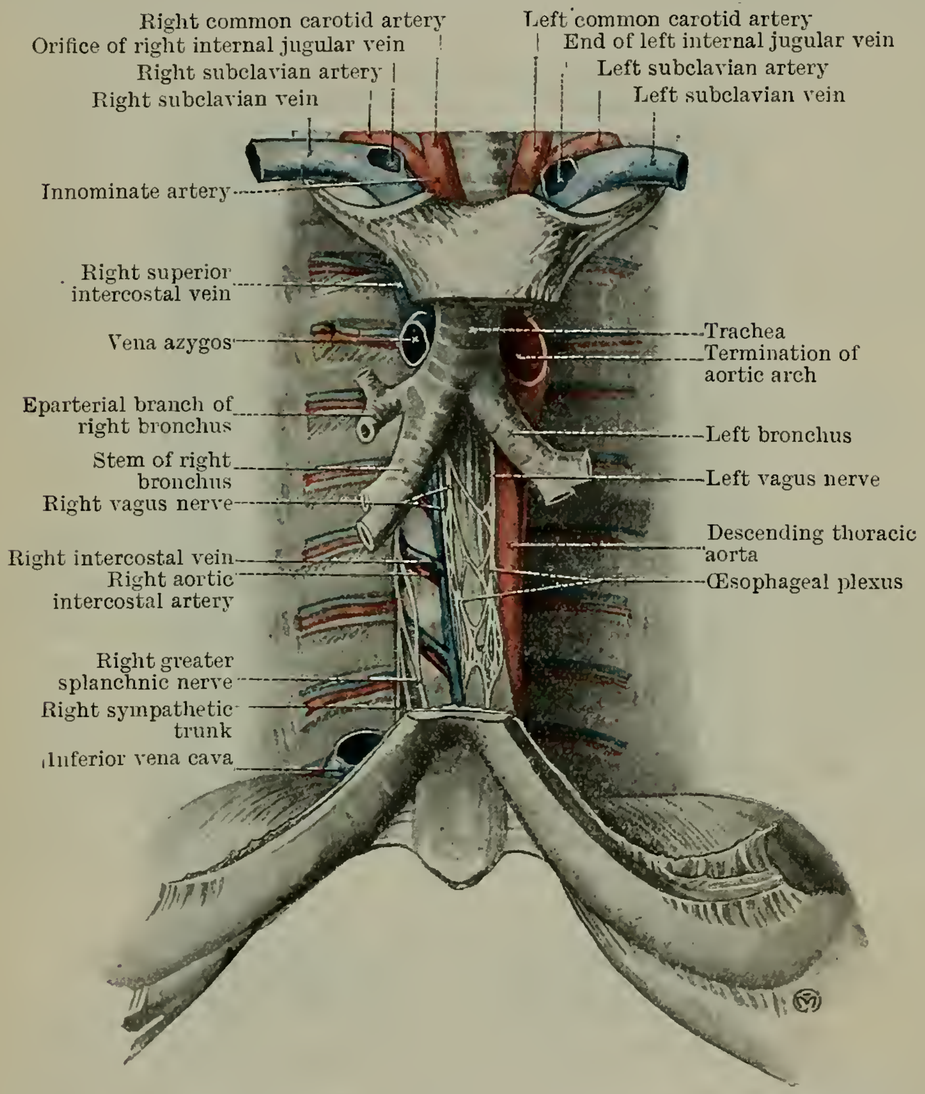
Right common carotid artery
Orifice of right internal jugular vein
Right subclavian artery
Right subclavian vein
Left common carotid artery
End of left internal jugular vein
Left subclavian artery
Left subclavian vein
Innominate artery
Right superior intercostal vein
Vena azygos
Eparterial branch of right bronchus
Stem of right bronchus
Right vagus nerve
Right intercostal vein
Right aortic intercostal artery
Right greater splanchnic nerve
Right sympathetic trunk
Inferior vena cava
Trachea
Termination of aortic arch
Left bronchus
Left vagus nerve
Descending thoracic aorta
Œsophageal plexus

Fig. 730.—Dissection of the Posterior Mediastinum and the Posterior Part of the Superior Mediastinum, from the Anterior Aspect.

Relations.—Immediately *posterior to* it are the vertebral column and the anterior longitudinal ligament. It rests also on the accessory hemiazygos and the hemiazygos veins, whilst from its posterior aspect the aortic intercostal branches are given off.

Anteriorly it is in relation, from above downwards, with the root of the left lung, the pericardium, which separates it from the back of the left atrium, the œsophagus with the œsophageal plexus of nerves, and the crura of the diaphragm which separate it from the caudate lobe of the liver. On the *left side* are the left lung and pleura. On the *right side* the thoracic duct and the vena azygos form immediate relations along its whole length. The œsophagus also lies to the right of the upper part of the descending aorta, whilst the right lung and pleura are in relation below.

Branches.—Nine pairs of aortic intercostal arteries, two left bronchial arteries, four or five œsophageal, some small pericardial, and a few posterior mediastinal and superior phrenic branches, usually arise from the thoracic part of the descending aorta.

AORTA ABDOMINALIS.

The abdominal portion of the descending aorta lies in the epigastric and umbilical regions of the abdomen. It extends from the middle of the lower border of the last thoracic vertebra to the body of the fourth lumbar vertebra, where, to the left of the median plane, it bifurcates into the right and left common iliac arteries.

The point of division is a little below and to the left of the umbilicus, opposite a line drawn transversely across the abdomen on a level with the highest points of the iliac crests.

At its commencement it is 21 mm. in diameter, but after the origin of two large branches, the cœliac and the superior mesenteric arteries, it diminishes considerably, and then retains a fairly uniform diameter to its termination.

Relations.—*Posteriorly*, it is in contact with the upper four lumbar vertebræ and intervening fibro-cartilages, the anterior longitudinal ligament, and the left lumbar veins; the lumbar and the middle sacral arteries spring from the posterior surface of the vessel. *Anteriorly*, and in close relation with it, there are from above downwards the following structures: the cœliac axis and cœliac plexus, the pancreas and splenic vein, the superior mesenteric artery, the left renal vein, the third part of the duodenum, the root of the mesentery, the aortic plexus, the inferior mesenteric artery, the peritoneum and coils of small intestine. More superficially the stomach, the transverse colon, and the greater and lesser omenta are in front. On the *right side*, in the upper part of its extent, are the thoracic duct and cisterna chyli, the vena azygos, and the right crus of the diaphragm, the latter separating it from the right cœliac ganglion and from the upper part of the

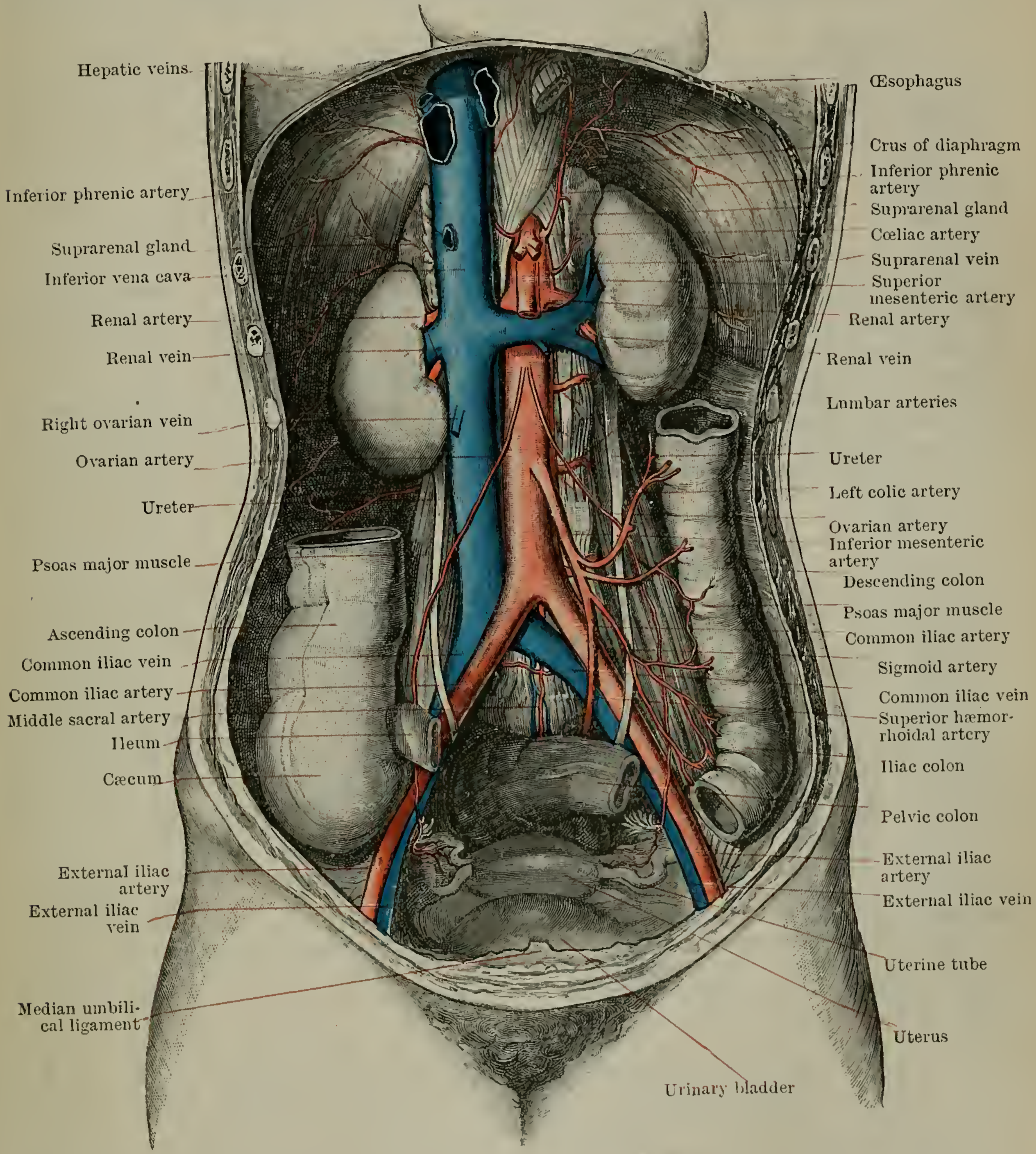

FIG. 731.—THE ABDOMINAL AORTA AND ITS BRANCHES IN A FORMALIN-HARDENED PREPARATION.

inferior vena cava. Its lower part is in direct relation, on the right side, with the inferior vena cava. On the *left side*, the left crus of the diaphragm with the left cœliac ganglion, and the terminal portion of the duodenum, are in close relation with its upper part, whilst in the lower portion of its extent the peritoneum and some coils of the small intestine are in contact with it. Lumbar lymph glands lie around it, on all sides.

Branches.—The branches form two groups, visceral and parietal, and each group consists of paired and unpaired vessels, as follows:—

Visceral.		Parietal.	
Unpaired.	**Paired.**	**Unpaired.**	**Paired.**
Cœliac	Suprarenal	Middle sacral (which is the original continuation)	Inferior phrenic
Superior mesenteric	Renal		
Inferior mesenteric	Testicular or ovarian		Lumbar (four pairs) Common iliac

Abnormalities of the Pulmonary Artery and Aorta.—The pulmonary artery and the aorta may arise by a common stem, as in fishes and some amphibians, and the common stem may spring either from the right or the left ventricle, or from both. In these cases the truncus arteriosus has remained undivided, and the normal position of the interventricular septum in relation to the lower orifice of the aortic bulb has been altered.

Again, owing to malposition of the aortic septum, the pulmonary artery may spring from the left ventricle and the aorta from the right ventricle. In some cases the root of the pulmonary artery is obliterated, and the blood passes to the lungs along the patent ductus arteriosus.

Occasionally the arch of the aorta is on the right side instead of the left, a condition which is normal in birds. More rarely there are two permanent aortic arches, right and left, as in reptiles; the œsophagus and trachea in these cases are enclosed in a vascular collar, the two arches unite dorsally, and the beginning of the descending aorta is double. Quite independent of this condition, however, the two primitive dorsal aortæ sometimes fail, either altogether or partially, to unite together, and the descending aorta is accordingly represented, to a corresponding extent, by two tubes. A more common, though still rare, form of double aorta is that due to the persistence, in whole or in part, of the septum formed by the fused walls of the primitive dorsal aortæ from which the descending aorta is developed.

The length of the descending aorta is determined largely by the extent to which fusion of the two primitive aortæ takes place. Accordingly, when this deviates from the normal, the termination of the descending aorta is at a correspondingly higher or lower level than usual, and resulting from this the lengths of the common iliac arteries are almost invariably proportionately modified. The bifurcation of the aorta may be as low as the fifth lumbar vertebra; less frequently it is higher than usual; it is rare, however, to find it as high as the third, and still more rare to find it at the level of the second, lumbar vertebra.

The aorta, instead of bifurcating into two common iliac arteries, may terminate in a common iliac artery on one side and a hypogastric artery on the opposite side, the external iliac artery on the irregular side arising, at a higher level, as a branch of the aortic stem. This arrangement approaches the condition met with in carnivores and many other mammals, in which the aorta bifurcates into two hypogastric arteries, the external iliacs arising from the aorta at a higher level as lateral branches; it is probably due either to a fusion of the secondary roots of the umbilical arteries of opposite sides or to a caudal continuation of the fusion of the primitive dorsal aortæ.

BRANCHES OF THE ASCENDING AORTA.

Arteriæ Coronariæ.

The coronary arteries are two in number, a right and a left; they are distributed almost entirely to the heart, but give also some small branches to the roots of the great vessels, and to the pericardium (Figs. 721, 722, and 725).

The **right coroanry artery** springs from the anterior aortic sinus. It runs forwards, between the root of the pulmonary artery and the auricle of the right atrium, to the coronary sulcus, in which it passes downwards and to the right to the junction of the right and inferior margins of the heart. There it turns to the left, in the inferior part of the coronary sulcus, as far as the posterior end of the inferior interventricular sulcus, where it gives off its interventricular branch and then ends by anastomosing with the circumflex branch of the left coronary artery. It is accompanied by branches from the cardiac plexus and the right coronary vein.

Branches.—The **interventricular** branch runs forwards in the inferior interventricular sulcus; it supplies both ventricles, and anastomoses, at the apex of the heart, with the interventricular branch of the left coronary artery.

Aortic and **pulmonary twigs** are distributed to the roots of the aorta and pulmonary artery respectively. A **right atrial branch** passes upwards on the anterior surface of the right atrium, between it and the ascending aorta; one or more **anterior ventricular** branches, of small size, descend on the anterior surface of the right ventricle; a branch of larger size, the **right marginal artery**, runs along the inferior margin of the heart and gives branches to both surfaces of the right ventricle.

The **left coronary artery** arises from the left posterior aortic sinus. Its short trunk runs forwards, between the root of the pulmonary artery and the auricle of the left atrium, to the coronary sulcus at the upper end of the anterior interventricular groove, where it divides into a circumflex and an interventricular branch.

Branches.—The **circumflex branch** runs to the left margin of the heart, and there turns to the inferior surface where it comes into relation with the coronary sinus; it ends by anastomosing with the right coronary artery. It supplies branches to the left atrium, the left margin of the heart, and the posterior part of the inferior surface of the left ventricle. The **interventricular terminal branch** passes down the anterior interventricular sulcus to the apex of the heart, where it anastomoses with the interventricular branch from the right coronary; it supplies both ventricles, and is accompanied by cardiac nerves and by the great cardiac vein.

A **left atrial branch** or branches of small size pass to the wall of the left atrium, and small **aortic** and **pulmonary branches** are also given to the roots of the aorta and pulmonary artery.

Abnormalities.—The **coronary or cardiac arteries** may arise by a single stem. When arising separately both may spring from the same aortic sinus; or again, their interventricular and circumflex branches may arise as distinct vessels from a single aortic sinus. This variability is not very remarkable, seeing that the arteries in question are merely enlarged "vasa vasorum" raised to a position of special importance by the development of the heart.

BRANCHES OF THE ARCH OF THE AORTA.

The branches which arise from the arch of the aorta supply the head and neck, the upper extremities, and part of the body wall.

They are three in number, viz., the **innominate**, the **left common carotid**, and the **left subclavian arteries**. The innominate is a short trunk, from the termination of which the right common carotid and the right subclavian arteries spring (Figs. 727 and 728); thus there is, at first, a difference between the stem vessels of opposite sides, but the subsequent course and the ultimate distribution of those vessels closely correspond.

Variations.—The **branches of the arch of the aorta** are sometimes increased and sometimes decreased in number.

The highest number recorded is six, viz., right subclavian, right vertebral, right common carotid, left common carotid, left vertebral, and left subclavian. Apparently this condition is the result of the absorption into the arch of the innominate artery and of the roots of the subclavian arteries, to points beyond the origins of the vertebrals. By variations of this process of absorption other combinations may be produced; thus, instead of the roots of the subclavian arteries being absorbed, the right common carotid and innominate arteries may alone be absorbed, in which case the five following branches spring separately from the arch of the aorta: right subclavian, right external carotid, right internal carotid, left common carotid, and left subclavian. The trunk most commonly absorbed is the initial part of the left subclavian; the number of branches then arising from the arch of the aorta is four, the additional vessel being the left vertebral, which arises between the left common carotid and the left subclavian. Occasionally the usual three branches from the arch are increased to four by the formation of a new vessel, the "thyreoidea ima." This may be placed between the innominate and left carotid trunks, in which case it represents a persistent ventral visceral branch from the ventral root of the fourth left aortic arch; in other cases the thyreoidea ima springs from the innominate artery and represents a ventral visceral branch of the ventral root of the fourth *right arch*. Very rarely the right vertebral artery arises separately, and forms a fourth branch of the arch of the aorta, the rest of the branches being normal. This condition cannot be accounted for by any modification of the ordinary developmental processes. It may possibly be due to the persistence of an irregular or unimportant anastomosis between the ventral root of an aortic arch and the seventh somatic segmental artery.

Decrease in the number of branches from the arch of the aorta is most frequently due to fusion of the ventral roots of the fourth aortic arches, the result being that a stem is formed common to the right subclavian and the right and left common carotid arteries; whilst the left subclavian, arising separately, is the only other branch which springs from the arch of the aorta.

If the fusion of the ventral roots proceeds further and includes those of the third arches, the result, as regards the branches given off from the arch of the aorta, is the same, viz., there is a common stem for the right subclavian and both carotids, and a separate left subclavian trunk; but the common stem now gives off the right subclavian artery, and then continues as a single vessel for some distance before it divides into the two common carotids, of which the left crosses in front of the trachea. This arrangement is common in many quadrumana and in some other mammals.

It is only in rare cases when the number of branches from the arch of the aorta is reduced to two, that these consist of a right subclavian artery and of a single stem common to the two carotids and the left subclavian artery. In such cases, however, the right common carotid crosses in front of the trachea, and the variation is one of practical importance, but it does not appear to exist as a normal condition in any mammal. Probably it is due to fusion of the ventral roots of the fourth aortic arches, with absorption of the left fourth arch and the left subclavian into the stem so formed, whilst the right subclavian is relatively displaced. The two common carotids may arise by a common stem, and the left subclavian arise separately from the arch of the aorta, whilst the right subclavian springs from the descending aorta. This arrangement probably results from the disappearance of the fourth right arch, the fusion of the ventral roots of the fourth arches of opposite sides and the persistence of the dorsal roots of the right fourth and sixth arches. (See Development of Vascular System.)

Sometimes two innominate arteries, right and left, replace the usual three branches of the arch of the aorta. This is the normal arrangement in bats, moles, and hedgehogs. It is obviously the result of the disappearance of that portion of the arch which intervenes between the left carotid and left subclavian arteries, and the consequent fusion of these two vessels.

In a similar way may be explained the rarer condition in which the three ordinary branches of the arch arise by one single stem, which divides into right and left innominate arteries. In most ruminants, in the horse and in the tapir, this arrangement is constant.

It will be evident that other combinations and modifications may be met with in the branches of the arch of the aorta as the result of fusions and absorption.

The **right subclavian** or the right vertebral may spring from the commencement of the descending aorta.

ARTERIA ANONYMA.

The **innominate artery** (Fig. 727) arises, posterior to the middle of the manubrium sterni, from the convexity of the arch of the aorta near its right or anterior extremity, and it ends opposite the right sterno-clavicular articulation, where it divides into the right subclavian and right common carotid arteries.

Course.—The trunk measures from 37 to 50 mm. in length; it runs upwards, posteriorly, and laterally, in the superior mediastinum, to the root of the neck.

Relations.—*Posterior.*—It is in contact behind, with the trachea below and with the right pleural sac above.

Anterior.—The left innominate vein crosses in front of the lower part of the artery and above that the sterno-thyreoid muscle separates it from the sterno-hyoid and the right sterno-clavicular joint. The remains of the thymus, which separate it from the manubrium sterni, are also in front.

Right Lateral.—The right innominate vein and the upper part of the superior vena cava are on the right side of the artery.

Left Lateral.—On its left side is the origin of the left common carotid artery, whilst at a higher level the trachea is in contact with it.

Branches.—As a rule the innominate artery does not give off any branches except its two terminals, but occasionally it furnishes an additional branch, the thyreoidea ima.

Abnormalities.—From what has already been said, with reference to the branches of the arch of the aorta, it will be noted that the innominate artery may be absent. On the other hand there may be two innominate arteries, a right and a left, each ending in corresponding common carotid and subclavian trunks, and the two vessels may themselves arise by a common stem.

The branches given off by the innominate artery may be increased in number, or the innominate may vary from the normal only as regards length. As a consequence of such modifications in length, the origins of the right common carotid and right subclavian arteries may be situated at a higher or lower level than usual, whilst, in the absence of the innominate artery, both these branches may arise directly from the aorta.

The **thyreoidea ima** is an inconstant and slender vessel. When present it may arise from the arch of the aorta, but it springs usually from the lower part of the innominate. It passes upwards, anterior to the trachea, through the anterior part of the superior mediastinum and the lower part of the neck, and gives off branches to the lateral lobes and isthmus of the thyreoid body and to the trachea.

THE ARTERIES OF THE HEAD AND NECK.

The vessels distributed to the head and neck are chiefly derived from the carotid trunks; there are, however, in addition, other vessels which arise from the main arterial stems of the upper extremities, and it will be advantageous to describe the most important of those, viz., the vertebral arteries, with the carotid system. The smaller additional branches will be considered along with the remaining branches of the subclavian arteries.

The **carotid system of arteries** consists, on each side, of a **common carotid trunk**, which divides into **internal** and **external carotid arteries**, from which numerous branches are given off (Figs. 726, 727, 730, 732).

The internal carotid arteries are distributed, almost entirely, to the contents of the cranial cavity, internal to the dura mater, and to the structures in the cavity of the orbit. The external carotid arteries, on the other hand, supply structures of the head and neck more externally situated.

It is to be noted, however, that the vascular supply of the brain is not wholly derived from the internal carotid vessels, but that it is contributed to, largely, by the vertebral arteries also.

ARTERIÆ CAROTIDES COMMUNES.

The right and the left **common carotid arteries** are of unequal length. The right common carotid commences at the bifurcation of the innominate artery posterior to the right sterno-clavicular articulation; the left arises in the superior mediastinum, from the arch of the aorta; but each terminates at the level of the upper border of the thyreoid cartilage; the left artery has thus a short intra-thoracic course, and, so far, its relations call for separate consideration; whilst in the rest of its course it passes upwards in the neck, like the right common carotid, and has almost similar relations.

Thoracic Portion of the Left Common Carotid.—The thoracic or mediastinal portion of the left common carotid artery extends from the upper aspect of the aortic arch, immediately posterior and to the left of the origin of the innominate artery, to the left sterno-clavicular articulation, where the cervical portion commences. It is from 25 to 37 mm. (1 or 1½ inches) in length, and it runs upwards and slightly laterally through the upper part of the superior mediastinum. It lies on a more posterior plane than the innominate artery.

Relations.—*Posterior.*—The vessel is in contact posteriorly, and from below upwards, with the trachea, the left recurrent nerve, the œsophagus, and the thoracic duct; and the thoracic part of the left subclavian artery is a postero-lateral relation.

Anterior.—The left innominate vein runs obliquely across the anterior aspect of the artery, upon which cardiac branches from the left vagus and sympathetic descend vertically. These structures, together with the remains of the thymus and the anterior margins of the left lung and pleura, separate the artery from the manubrium sterni, and from the origins of the sterno-hyoid and sterno-thyreoid muscles.

Medial.—The innominate artery below, and the trachea above, are on the right side.

Lateral.—The left pleura, and, on a posterior plane, the left phrenic and vagus nerves and the left subclavian artery are on its left side.

Cervical Portion of the Left Common Carotid Artery.—The cervical part of the left common carotid artery is about 85 mm. (three and a half inches) long; it extends from the left sterno-clavicular articulation to the level of the upper border of the thyreoid cartilage and the lower border of the third cervical vertebra, where it ends by dividing into the external and internal carotid arteries.

Course.—It runs upwards, laterally, and backwards, through the muscular and in the lower portion of the carotid divisions of the anterior triangle of the neck. Below it is separated from its fellow of the opposite side by the trachea and the œsophagus, and above by the relatively wide pharynx.

Relations.—It is enclosed, together with the internal jugular vein and the vagus nerve, in a sheath of deep cervical fascia—the **carotid sheath.**

Posterior.—The longus colli and scalenus anterior, below, and the longus capitis, above, are separated from the posterior surface of the artery and its sheath by the prevertebral fascia and the sympathetic trunk. The vertebral artery and the thoracic duct are posterior to it at the level of the seventh cervical vertebra; the inferior thyreoid artery crosses behind it, either between it and the vertebral or between it and the transverse process of the sixth cervical vertebra, and the vagus nerve lies postero-lateral to it.

Superficial.—The descendens branch of the hypoglossal nerve lies superficial to the artery, usually outside the sheath, but sometimes enclosed in it (Fig. 732). Opposite the sixth cervical vertebra the omo-hyoid muscle and the sterno-mastoid branch of the superior thyreoid artery cross superficial to the carotid artery, which is overlapped, above the omo-hyoid muscle, by the anterior border of the sterno-mastoid and by cervical lymph glands. It is frequently crossed, in that part of its extent, by the superior thyreoid vein. Below the omo-hyoid the artery is covered by the sterno-thyreoid, the sterno-hyoid, and the sterno-mastoid muscles, and it may be overlapped by the lateral lobe of the thyreoid gland; it is also crossed, deep to the muscles, by the middle thyreoid vein, whilst occasionally a communication between the common facial and anterior jugular veins descends anterior to the artery along the anterior border of the sterno-mastoid. Just above the sternum the anterior jugular vein is in front of the artery, but separated from it by the sterno-hyoid and sterno-thyreoid muscles.

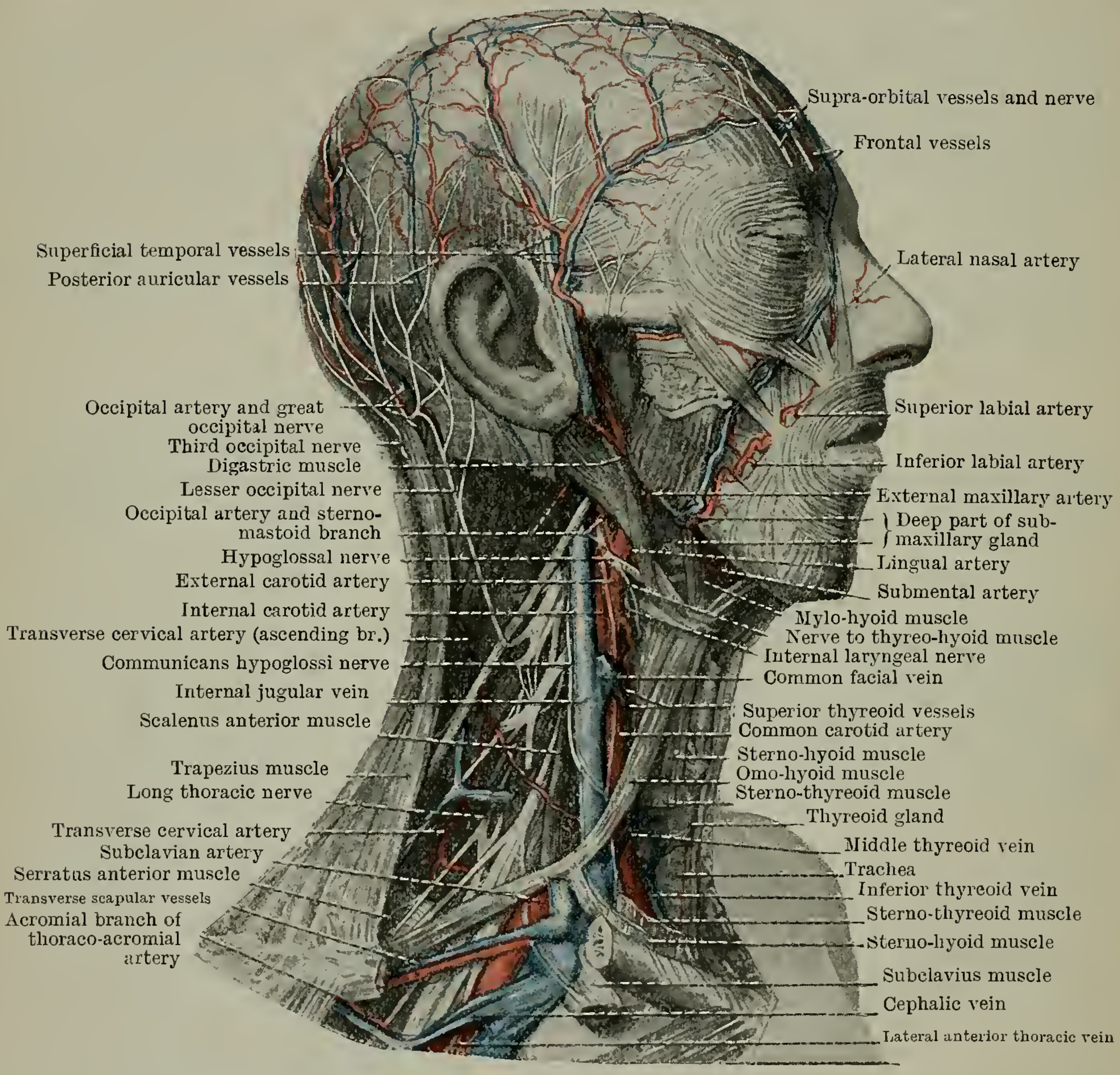

FIG. 732.—DISSECTION OF THE HEAD AND NECK SHOWING THE COURSE OF THE INTERNAL JUGULAR VEIN.

Medial.—The trachea and œsophagus, with the recurrent nerve in the angle between them, are medial to the lower part of the artery; the larynx and pharynx are medial to its upper part. The carotid gland or glomus caroticum lies on the medial side of the termination of the artery.

Lateral.—The internal jugular vein occupies the lateral part of the carotid sheath. The vein lies not only to the lateral side of the artery, but also slightly in front of it, especially in the lower part of the neck.

Branches.—As a rule no branches are given off from either of the common carotid arteries, except the terminal branches and some minute twigs from each to the corresponding carotid sheath and glomus caroticum.

The **right common carotid artery**, as already stated, differs as regards origin from the left common carotid. In length and general position it corresponds with the cervical portion of the left common carotid, and its relations also are very similar. Such differences as exist may be briefly summarised as follows: The internal jugular vein on both sides lies lateral to the artery; on the left side in the lower part of the neck it is also anterior to the artery, whilst on the right side the vein is separated from the lateral surface of the artery, at its lower end, by a well-marked interval in which the vagus nerve appears. The thoracic duct does not come into relation with the right common carotid, and there is also a difference in the relations of the recurrent nerves to the arteries on the two sides. On the left side the nerve crosses posterior to the mediastinal part of the left artery, and lies medial to its cervical part, whilst the corresponding nerve on the right side passes posterior to the lower part of the carotid artery in the neck to reach its medial side, and the œsophagus has a less intimate relation with the right than with the left common carotid artery.

Abnormalities.—The right common carotid artery may arise separately from the arch of the aorta, then it may be the first, or, much more rarely, the second branch. In the former case the fourth right aortic arch has been obliterated, and the right subclavian artery springs from the descending aorta; in the latter case either the innominate stem has been absorbed into the arch of the aorta, or the ventral root of the fourth right aortic arch has fused with part of an elongated fourth left arch.

Whether arising as the first or second branch, the origin may be to the left of the median plane, and the trunk may pass in front of the trachea, or behind the œsophagus, before it ascends into the neck.

The left common carotid artery varies, as regards its origin, much more frequently than the right vessel; not uncommonly, and apparently because of the fusion of the ventral roots of the fourth aortic arches, it arises from a stem common to it and to the right common carotid and right subclavian arteries.

Both common carotids may vary as regards their termination. They may divide at a higher or lower level than usual, the former more commonly than the latter; whilst in a few exceptional cases the common carotid does not divide, but is continued directly into the internal carotid, and from this the branches usually given off by the external carotid are derived.

This arrangement is probably due to obliteration of the ventral roots of the first and second aortic arches, the arches persisting and being divided into the branches which generally arise from their ventral extremities.

Usually the common carotids give off no branches, but not infrequently one or more of the branches of the external carotids arise from them.

ARTERIA CAROTIS EXTERNA.

The **external carotid artery** (Figs. 732, 733) is the smaller of the two terminal branches of the common carotid; its length is about 62 mm. (2½ inches). It extends from the upper border of the thyreoid cartilage to the back of the neck of the mandible, where it terminates by dividing into the superficial temporal and the internal maxillary arteries.

Course.—It commences in the carotid triangle, passes upwards, medial to the posterior belly of the digastric and the stylo-hyoid muscles and the lower part of the postero-medial surface of the parotid gland, then it enters a groove in the medial border of the gland, through which it passes to the upper part of the antero-medial surface posterior to the neck of the mandible, where it terminates.

At its commencement it lies somewhat anterior and medial to the internal carotid artery, but it inclines posteriorly as it ascends, and thus becomes superficial to the internal carotid. Its course is indicated by a line drawn from the lobule of the ear to the posterior extremity of the greater cornu of the hyoid bone.

Relations.—*Posterior.*—In the lower part of its extent it is in close relation with the internal carotid, and in the upper part of its course with the antero-medial surface of the parotid gland.

Medial.—At its commencement the fibres of the inferior constrictor muscle are in contact with its medial side, but at a higher level the structures which intervene between it and the internal carotid—viz., the stylo-pharyngeus muscle, the tip of the styloid process, the stylo-glossus muscle, the glosso-pharyngeal nerve, and the pharyngeal branch of the vagus—separate it from the wall of the pharynx; whilst medial both to it and to the internal carotid artery are the external and internal laryngeal branches of the superior laryngeal nerve.

Superficial.—In the carotid triangle it is overlapped by the anterior border of the sterno-mastoid, and it is crossed, immediately below the level of its occipital branch, by the hypoglossal nerve. It is also crossed by the lingual and common facial veins, and sometimes by the superior thyreoid vein also. At the level of the angle of the mandible it passes under cover of the posterior belly of the digastric and the stylo-hyoid muscles, which separate it from the medial surface of the internal pterygoid muscle. As it emerges from under cover of the stylo-hyoid it enters a groove in the parotid gland, and as it lies in the gland the posterior facial vein (temporo-maxillary) descends superficial to the artery, and both the artery and the vein are crossed, superficially, by the branches of the facial nerve.

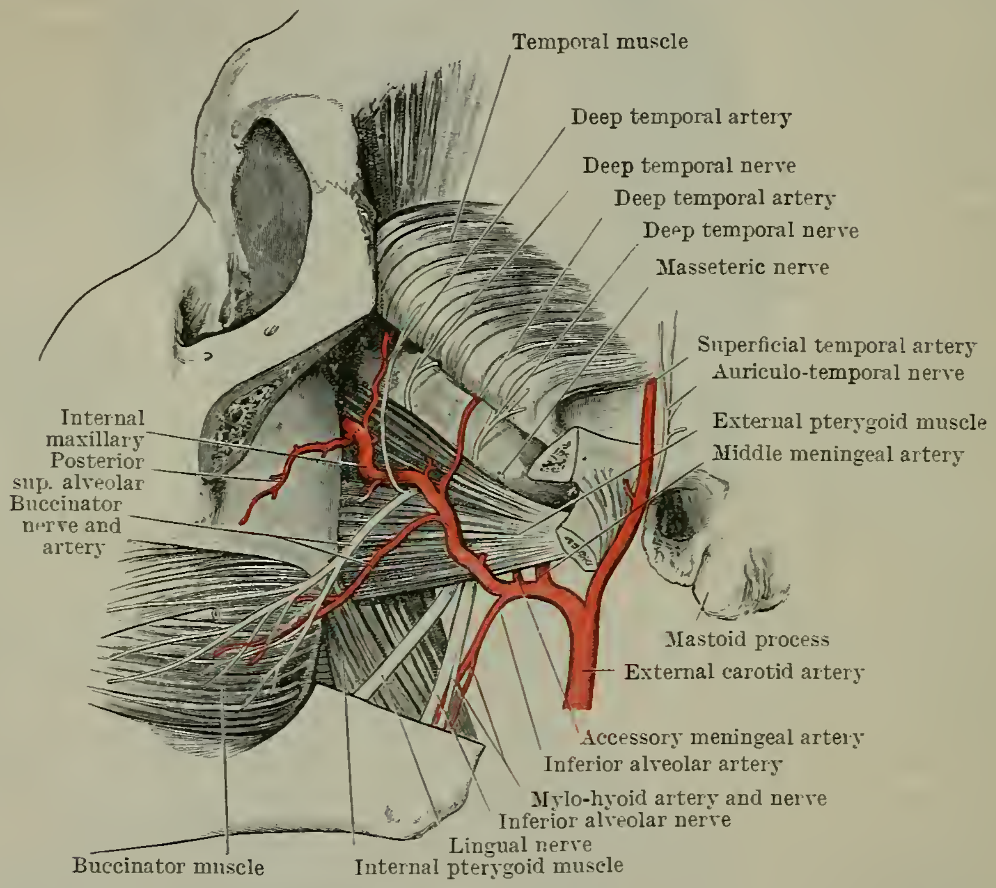

Fig. 733.—Dissection Showing the Termination of the External Carotid Artery and the First and Second Parts of the Internal Maxillary Artery.

Branches.—Eight branches arise from the external carotid artery; of these, three—the superior thyreoid, the lingual, and the external maxillary—spring from its anterior aspect in the carotid triangle; two arise from its posterior aspect, viz., the occipital and the posterior auricular, the former commencing below the posterior belly of the digastric and the latter above it; one from its medial side, viz., the ascending pharyngeal, which arises in the carotid triangle; and two from its termination, viz., the superficial temporal and the internal maxillary.

Abnormalities.—The external carotid artery may be absent, or it may, in rare cases, arise directly from the arch of the aorta. The number of its branches may be diminished either by fusion of their roots or by transference to the internal or common carotid arteries. On the other hand, the number of its branches may be increased; thus, the sterno-mastoid artery, the hyoid branch usually given off by the superior thyreoid artery, or the ascending palatine branch of the external maxillary, may arise from it. Sometimes the branches may arise in the usual way, but may deviate from the course generally taken; more particularly is this the case with the internal maxillary artery, which may pass either between the heads, or entirely lateral or medial to both heads of the external pterygoid muscle.

BRANCHES OF THE EXTERNAL CAROTID ARTERY.

(1) The **superior thyreoid artery** (Figs. 732 and 734) springs from the anterior aspect of the lower part of the external carotid artery, just below the tip of the greater cornu of the hyoid bone, and it terminates at the upper extremity of the corresponding lobe of the thyreoid gland by dividing into terminal branches.

Course.—From its commencement, in the carotid triangle, the artery runs downwards and forwards to its termination.

Relations.—*Medially* it is in relation with the inferior constrictor muscle and the external laryngeal branch of the superior laryngeal nerve.

Superficially it is covered, at its origin, by the anterior border of the sterno-mastoid; afterwards, for a short distance, by fascia, platysma, and skin, and in the lower part of its extent by the omo-hyoid, the sterno-hyoid, and the sterno-thyreoid muscles, and it is overlapped by an accompanying vein.

Branches.—(1) *In the carotid triangle*—(*a*) A **hyoid branch** runs along the lower border of the greater cornu of the hyoid bone, under cover of the thyreo-hyoid muscle, to anastomose with its fellow of the opposite side and with the hyoid branch of the lingual artery. It supplies the thyreo-hyoid muscle and membrane.

(*b*) The **superior laryngeal branch** runs forwards, deep to the thyreo-hyoid muscle. It pierces the hyo-thyreoid membrane, in company with the internal laryngeal nerve, supplies the muscles, ligaments, and mucous membrane of the larynx, and anastomoses with its fellow of the opposite side, with branches of the crico-thyreoid artery, and with the terminal branches of the inferior thyreoid artery.

(*c*) The **sterno-cleido-mastoid branch** passes downwards and posteriorly, along the upper border of the anterior belly of the omo-hyoid muscle and across the common carotid artery, to the deep surface of the sterno-mastoid muscle. It anastomoses, in the sterno-mastoid, with branches of the occipital and transverse scapular arteries.

(2) *In the muscular triangle*—(*d*) A **crico-thyreoid branch** passes anteriorly, either superficial or deep to the sterno-thyreoid. It crosses the crico-thyreoid muscle to anastomose, in front of the crico-thyreoid ligament, with its fellow of the opposite side, and, by branches which perforate the crico-thyreoid ligament, with laryngeal branches of the superior and inferior thyreoid arteries. It supplies the adjacent muscles and membrane.

(*e*) The **terminal branches** are **anterior, medial,** and **lateral.**

The **anterior terminal branch** descends along the anterior border of the corresponding lobe of the thyreoid gland, and the upper border of the thyreoid isthmus, to anastomose with its fellow of the opposite side. The **medial branch** is the largest; it is distributed to the medial surface of the lobe. The **lateral branch,** which ramifies in the lateral surface of the corresponding lobe, is the smallest. All three terminal branches supply glandular branches to the thyreoid gland. They anastomose with each other and with branches from the inferior thyreoid artery.

(2) The **lingual artery** (Figs. 732 and 734) springs from the anterior aspect of the external carotid, opposite the tip of the greater cornu of the hyoid bone, and terminates, as the arteria profunda linguæ, which ends beneath the tip of the tongue, where it anastomoses with its fellow of the opposite side.

Course.—Whilst in the carotid triangle, the *first part of the artery* forms a loop with the convexity upwards. The *second part* passes forwards, medial to the hyo-glossus muscle, immediately above the greater cornu of the hyoid bone, to the anterior border of the hyo-glossus, where it gives off a sublingual branch and becomes the arteria profunda linguæ. The profunda linguæ artery passes obliquely forwards and upwards, under cover of the anterior border of the hyo-glossus, and then turns directly forwards on the under surface of the tongue to the tip, lying between the inferior lingualis laterally and the genio-glossus medially.

Relations.—The first part of the lingual artery is crossed superficially by the hypoglossal nerve, and is covered by skin, fascia, and the platysma; it rests medially against the middle constrictor of the pharynx. The second part is deeper. It lies between the middle constrictor medially and the hyo-glossus laterally, and is separated by the latter from the hypoglossal nerve, the vena comitans hypoglossi, and the lower part of the submaxillary gland. The profunda artery of the tongue ascends almost vertically, parallel with and medial to the anterior fibres of the hyo-glossus, which are covered by the mylohyoid, and between the hyo-glossus and the genio-glossus; then it runs forwards between the inferior lingualis and the genio-glossus muscles, and is covered, on its lower surface, by the mucous membrane of the tongue. Thus, at its termination, near the frenulum linguæ, it is comparatively superficial.

Branches.—(*a*) The **ramus hyoideus**, a small branch which arises in the carotid triangle and runs along the upper border of the greater cornu of the hyoid bone. It anastomoses with its fellow of the opposite side and with the hyoid branch of the superior thyreoid artery.

(*b*) The **dorsalis linguæ** is a branch of moderate size which arises from the second part of the artery and is not uncommonly double. It ascends, between the hyo-glossus and the genio-glossus, to the dorsum of the tongue, where it branches and anastomoses with its fellow of the opposite side around the foramen cæcum. It supplies the posterior part of the tongue as far back as the epiglottis, and sends branches, posteriorly, to the palatine tonsil which anastomose with the tonsillar twigs of the ascending palatine branch of the external maxillary and with the ascending pharyngeal artery.

(*c*) A **sublingual branch** arises at the lower part of the anterior border of the hyoglossus muscle and runs anteriorly and upwards, between the mylo-hyoid and the genioglossus, to the sublingual gland, which it supplies; it also supplies the mylo-hyoid, the genio-glossus, and the genio-hyoid muscles. It anastomoses with its fellow of the opposite side, with the arteria profunda by a branch which it sends along the frenulum linguæ, and, through the mylo-hyoid muscle, with the submental branch of the external maxillary.

(3) The **external maxillary artery** (O.T. **Facial**) (Fig. 733) arises from the front of the external carotid, immediately above the lingual. It ends at the angle of the mouth, where it becomes the angular artery.

Course.—It commences in the carotid triangle, immediately above the lingual, and passes upwards to the angle of the mandible, on the lateral surface of the middle constrictor muscle. Still ascending, it lies between the posterior belly of the digastric and the stylo-hyoid muscles laterally, and the superior constrictor medially, and it is separated from the palatine tonsil by the superior constrictor. When it reaches the upper border of the stylo-hyoid it enters a groove in the posterior part of the submaxillary gland and runs downwards and anteriorly, between the lateral surface of the gland and the internal pterygoid muscle, to the posterior end of the lower border of the body of the mandible. There it pierces the deep cervical fascia, turns round the inferior border of the mandible, at the anterior border of the masseter, enters the face and continues upwards and forwards to its termination.

Relations.—In the carotid triangle the artery is comparatively superficial, except just at its origin, which is overlapped by the anterior fibres of the sterno-mastoid muscle. As it ascends it is in relation, on the medial side, with the middle and superior constrictor muscles, and, as already stated, the superior constrictor separates it from the palatine tonsil. Its relations between the point where it passes medial to the posterior belly of the digastric and the point where it turns round the lower border of the mandible have been given in the description of its course.

After turning round the lower border of the body of the mandible, which it grooves slightly, the artery becomes more superficial than in any other part of its course, being covered only by platysma, fascia, and skin. At that point the anterior facial vein is immediately posterior to the artery, lying on the surface of the masseter. In the face the artery lies between the platysma, the risorius, the zygomaticus major, and the infraorbital section of the quadratus labii superioris, which, with skin and fascia, are superficial to it, and the buccinator and the musculus caninus, which are deeper. The termination of the artery is in the substance of the quadratus labii superioris.

The anterior facial vein, though still posterior to the artery in the face, runs a somewhat straighter course, and is situated at some little distance from it.

Branches.—Four named branches are given off in the neck, and several in the face.

In the Neck.—(*a*) The **ascending palatine branch** (Fig. 735) is a small artery which arises from the external maxillary under cover of the posterior belly of the digastric. It ascends, and, after passing between the stylo-glossus and the stylo-pharyngeus muscles, reaches the apex of the petrous portion of the temporal bone, where it turns downwards, accompanying the levator veli palatini muscle, pierces the pharyngeal aponeurosis, and enters the soft palate.

It supplies the lateral wall of the upper part of the pharynx, the soft palate, the palatine tonsil, and the auditory tube, and it anastomoses with the tonsillar branch of the external maxillary, the dorsalis linguæ, the descending palatine branch of the internal maxillary, and with the ascending pharyngeal artery, which sometimes replaces it.

(*b*) The **tonsillar branch**, a small artery which arises close to the ascending palatine. It passes upwards between the internal pterygoid and the stylo-glossus, pierces the superior constrictor, and terminates in the palatine tonsil. It supplies the middle and superior constrictor muscles, and it anastomoses with the dorsalis linguæ, with the ascending palatine branch, and with the ascending pharyngeal artery.

(*c*) The **submaxillary** or **glandular branch** is frequently represented by two or three small twigs which pass directly into the submaxillary gland.

(*d*) The **submental branch** arises from the external maxillary just as the latter vessel turns round the inferior border of the mandible. It is the largest branch given off in the neck, and it runs forwards, on the lateral surface of the mylo-hyoid muscle, and medial to the upper part of the submaxillary gland, to the symphysis menti; there it turns upwards, round the margin of the mandible, and it terminates by anastomosing with branches of the mental and inferior labial arteries. In the neck the submental artery supplies the mylo-hyoid muscle, and the submaxillary and sublingual glands, the latter by a branch which perforates the mylo-hyoid muscle. It anastomoses with the mylo-hyoid branch of the inferior alveolar and with the sublingual artery. In the face it supplies the structures of the lower lip, and anastomoses with the mental branch of the inferior alveolar, and with the inferior labial branches of the external maxillary artery.

In the Face.—(*e*) The **inferior labial branch** arises from the front of the external maxillary artery below the level of the angle of the mouth. It runs medially, deep to the triangularis, the quadratus labii inferioris, and the orbicularis oris. In the substance of the lower lip it lies close to the mucous membrane and anastomoses, in the median plane, with its fellow of the opposite side. It supplies the structures in its immediate neighbourhood.

(*f*) The **superior labial** springs from the front of the external maxillary about the level of the angle of the mouth. It runs medially, between the orbicularis oris and the mucous membrane of the upper lip, to the median plane, supplying the skin, muscles, and mucous membrane of the upper lip, and, by a *septal branch*, the lower and anterior part of the septum of the nose. It anastomoses with its fellow of the opposite side, with the lateral nasal, and, on the septum nasi, with the septal branch of the spheno-palatine artery.

(*g*) The **masseteric branch**, sometimes represented by several twigs, arises from the posterior aspect of the facial trunk, a short distance above the lower margin of the mandible. It passes upwards and posteriorly, across the masseter, and anastomoses with the transverse facial artery.

(*h*) The **buccal** is an inconstant branch which, when present, arises from the posterior aspect of the external maxillary artery above the masseteric branch. It runs upwards and posteriorly, across the buccinator muscle, to anastomose with the buccinator branch of the internal maxillary artery.

(*i*) The **lateral nasal** springs from the external maxillary at the point where it becomes the angular. It ramifies on the ala of the nose, supplying the skin, muscles, and alar cartilages, and anastomosing with the angular branch, with the dorsal nasal branch of the ophthalmic, and with branches of the spheno-palatine artery.

(*j*) The **angular artery** is the continuation of the external maxillary beyond the origin of the lateral nasal branch. It runs upwards, in the angular head of the quadratus labii superioris, to the medial commissure of the eye, where it anastomoses with the lateral nasal, and with the nasal and palpebral branches of the ophthalmic artery.

In addition to the above-named branches another branch, formerly called the inferior labial, springs from the anterior aspect of the external maxillary below the level of the alveolar border of the mandible. This vessel runs medially, under cover of the muscles of the lower lip, and it anastomoses with the mental branch of the inferior alveolar artery, with the inferior labial, and with its fellow of the opposite side.

(4) The **occipital artery** (Figs. 732, 734, 735) arises from the posterior aspect of the external carotid artery, below the posterior belly of the digastric muscle, and terminates, near the medial end of the superior nuchal line of the occipital bone, by dividing into medial and lateral terminal branches.

Course.—It commences in the carotid triangle and runs upwards and posteriorly, parallel with and under cover of the posterior belly of the digastric, to the interval between the transverse process of the atlas and the base of the skull; there it turns posteriorly, in a groove on the lower surface of the mastoid portion of the temporal bone; as it leaves the groove it alters its direction and runs upwards and medially, on the superior oblique muscle, to the junction of the medial and intermediate thirds of the superior nuchal line of the occipital bone, where it pierces the deep fascia of the neck and enters the superficial fascia of the scalp.

Relations.—In the first or ascending part of its course the occipital artery crosses successively the internal carotid artery, the hypoglossal nerve, the vagus nerve, the internal jugular vein, and the accessory nerve; it is covered by the lower fibres of the posterior belly of the digastric, and the anterior part of the sterno-mastoid muscle, and, close to its origin, it is crossed by the hypoglossal nerve. In the second and more horizontal part of its course, it is still under cover of the sterno-mastoid and digastric, and lies, medially, against the rectus capitis lateralis, which separates it from the vertebral artery. In the third part of its course it rests upon the superior oblique and semispinalis capitis, under cover of the sterno-mastoid, the splenius capitis, and the longissimus capitis muscles. Near its termination it is crossed by the great occipital nerve, and it passes either through the trapezius or between the trapezius and the sterno-mastoid, and pierces the deep fascia of the neck before it enters the superficial fascia of the scalp.

Branches.—(*a*) **Muscular branches** go to the surrounding muscles. The **sterno-mastoid branch** is the most important of this group; it springs from the commencement of the occipital, is looped downwards across the hypoglossal nerve, and is continued downwards and posteriorly, below and anterior to the accessory nerve, into the sterno-mastoid muscle, where it anastomoses with the sterno-mastoid branch of the superior thyreoid artery. It is sometimes represented by two or more small branches.

(*b*) The **meningeal** are irregular branches given off from the occipital, anterior to the mastoid process. They enter the posterior fossa of the skull through the hypoglossal canal, or through the jugular foramen; they supply the upper part of the internal jugular vein, the sigmoid part of the transverse sinus, and the dura mater in the posterior fossa of the skull, and they anastomose with the middle meningeal and with meningeal branches of the ascending pharyngeal artery.

(*c*) The **mastoid**, a small and inconstant branch which arises posterior to the mastoid process. It enters the posterior fossa of the skull through the mastoid foramen, supplies the dura mater, and anastomoses with branches of the middle meningeal artery.

(*d*) The **descending branch** is given off from the occipital upon the surface of the superior oblique. It passes medially, and at the lateral border of the semispinalis capitis it divides into superficial and deep branches. The superficial branch runs over the semispinalis capitis, between it and the trapezius, and anastomoses with the superficial cervical artery. The deep branch passes between the semispinalis capitis and the underlying semispinalis cervicis, and anastomoses with branches of the vertebral and profunda cervicis arteries.

(*e*) The **auricular** is an inconstant branch which, as a rule, is only given off from the occipital when the posterior auricular artery is absent. It ramifies over the mastoid part of the temporal bone, and supplies the medial surface of the auricle.

(*f*) The **terminal branches** (rami occipitales) are medial and lateral. They ramify in the superficial fascia of the posterior part of the scalp, where they anastomose with the posterior auricular and superficial temporal arteries. Both branches are accompanied by branches of the great occipital nerve. The medial branch gives off a meningeal twig, which passes into the skull through the parietal foramen, to supply the walls of the superior sagittal sinus and to anastomose with the middle meningeal artery.

(5) The **posterior auricular artery** (Figs. 732, 734, 735) springs from the posterior aspect of the external carotid immediately above the posterior belly of the digastric muscle, and it terminates between the mastoid process and the back of the auricle by dividing into mastoid and auricular branches.

Course and Relations.—Commencing at the upper border of the posterior belly of the digastric, it runs upwards and posteriorly, under cover of the postero-medial surface of the parotid gland, to the interval between the mastoid process and the external acoustic meatus. It is accompanied in the terminal part of its course by the posterior auricular branch of the facial nerve.

Branches.—(*a*) **Muscular branches** are given to the sterno-mastoid, the digastric, and the styloid group of muscles.

(*b*) **Parotid branches** pass to the lower and posterior part of the parotid gland.

(*c*) A **stylo-mastoid branch** is given off at the lower border of the external acoustic meatus. It runs upwards, by the side of the facial nerve, enters the stylo-mastoid foramen, and ascends, in the canalis facialis (Fallopius), to the upper part of the medial wall of the tympanum, where it terminates by anastomosing with the petrosal branch of the middle meningeal artery. It supplies branches to the external acoustic meatus, the mastoid cells, the vestibule, and semicircular canals, the stapedius muscle, and a *posterior tympanic branch* which anastomoses with the anterior tympanic branch of the internal maxillary, forming, in young subjects, a vascular circle around the membrana tympani; other branches anastomose with tympanic branches from the internal carotid and the ascending pharyngeal arteries, and with the internal auditory branch of the basilar.

(*d*) The **auricular branch** ascends medial to the posterior auricular muscle. It gives branches to the auricle and to the scalp in the posterior part of the temporal region, which anastomose with the superficial temporal and occipital arteries. The auricular branches supply both surfaces of the auricle, piercing or turning round the margins of the cartilage to gain the lateral surface, and they anastomose with the anterior auricular branches of the superficial temporal artery.

(*e*) The **occipital branch** runs upwards and posteriorly along the insertion of the sterno-mastoid muscle. It supplies the sterno-mastoid and occipitalis muscles, and the skin, and it anastomoses with the occipital artery.

(6) **The Ascending Pharyngeal Artery** (Fig. 735).—This artery arises from the medial surface of the lower part of the external carotid, and its terminal branches are distributed to the wall of the pharynx and in the soft palate.

Course.—It commences in the carotid triangle, usually as the first or second branch of the external carotid, and it ascends on the wall of the pharynx to the apex of the petrous portion of the temporal bone.

Relations.—Medially it is in relation with the constrictor muscles of the pharynx. Posterior to it are the transverse processes of the cervical vertebræ, the sympathetic trunk, and the longus capitis. Laterally it is in relation with the internal carotid artery, and it is crossed by the stylo-pharyngeus muscle, the glossopharyngeal nerve, and the pharyngeal branch of the vagus.

Branches.—The branches of this artery are very irregular and inconstant, but the following have received names:—

(*a*) **Pharyngeal Branches.**—Small twigs which ramify on the walls of the pharynx and supply the middle and superior constrictor muscles, the palatine tonsil, and the lower part of the auditory tube (O.T. Eustachian). They anastomose with branches of the superior thyreoid, lingual, and external maxillary arteries.

(*b*) **Prevertebral.**—Small branches distributed to the prevertebral muscles and fascia, the deep cervical glands, and the large nerve trunks. They anastomose with the ascending cervical and vertebral arteries.

(*c*) **Posterior Meningeal.**—One or more small branches which enter the cranium by the hypoglossal canal, the jugular, or the lacerate foramen, and supply the dura mater. They anastomose with branches of the middle meningeal and vertebral arteries.

(*d*) **Inferior Tympanic.**—A small artery which accompanies the tympanic branch of the glossopharyngeal nerve to the tympanic cavity, where it anastomoses with the other tympanic arteries.

(*e*) **Palatine.**—A very variable artery which sometimes replaces the ascending palatine branch of the external maxillary artery. When present it springs from the upper part of the ascending pharyngeal artery, pierces the pharyngeal aponeurosis above the upper border of the superior constrictor muscle, and descends into the soft palate with the levator veli palatini muscle. It supplies the mucous membrane of the supero-lateral part of the pharyngeal wall and the tissues of the soft palate, and it anastomoses with the palatine branches of the internal maxillary, the external maxillary and the lingual arteries.

(7) The **superficial temporal artery** (Fig. 732), one of the terminal branches of the external carotid, commences between the upper part of the antero-medial surface of the parotid gland, and the neck of the mandible, and terminates in the scalp, from 25 to 50 mm. (1 or 2 inches) above the zygomatic arch, by dividing into a parietal and a frontal branch.

Course.—The artery ascends over the posterior root of the zygoma, and passes into the superficial fascia of the temporal region. It is accompanied by the auriculo-temporal nerve and by the superficial temporal vein, which usually lies posterior to it. As it crosses the zygoma it is covered by the skin alone, and it may be easily compressed against the subjacent bone.

Branches.—(*a*) **Parotid.**—Small branches to the upper part of the parotid gland.

(*b*) **Articular**—to the mandibular articulation.

(*c*) **Anterior Auricular.**—Small branches to the lateral surface of the auricle and to the external acoustic meatus. They anastomose on the surface of the auricle with branches of the posterior auricular artery, and in the external acoustic meatus with branches of the internal maxillary artery.

(*d*) **Transverse Facial.**—A branch of moderate size which emerges from under cover of the upper part of the anterior border of the parotid gland. It runs forwards across the masseter, below the zygoma and above the parotid duct, accompanied by zygomatic branches of the facial nerve, which may lie either above or below it. It supplies the parotid gland, the masseter, parotid duct, and the skin, and it terminates in branches which anastomose with the infra-orbital and buccinator branches of the internal maxillary artery and with the buccal and masseteric branches of the external maxillary artery.

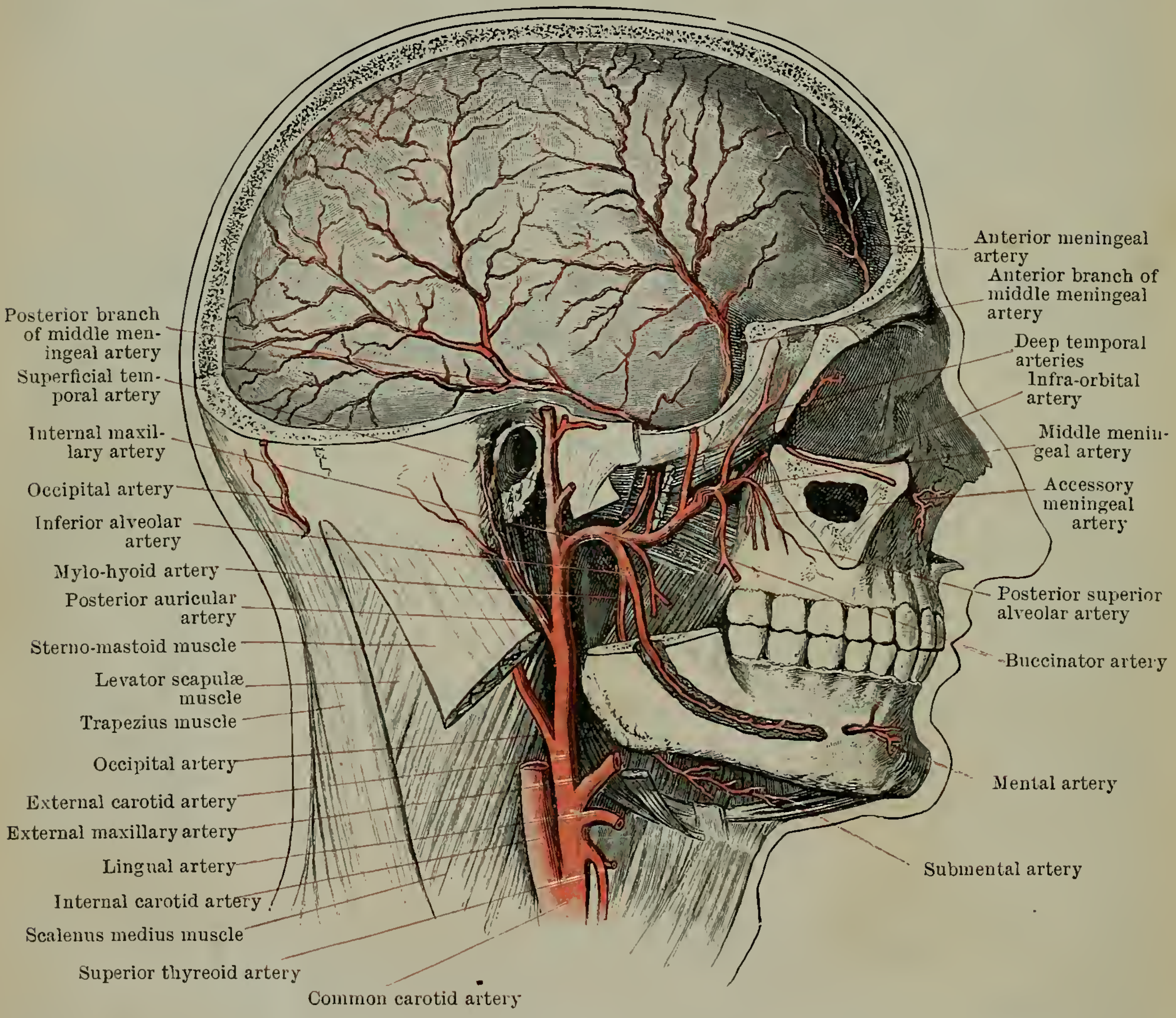

Fig. 734.—The External Carotid, Internal Maxillary, and Meningeal Arteries.

(*e*) **Middle Temporal.**—A branch which usually springs from the commencement of the superficial temporal. It crosses the zygoma, pierces the temporal fascia and the temporal muscle, and terminates in the temporal fossa by anastomosing with the deep temporal branches of the internal maxillary artery.

(*f*) **Zygomatico-orbital.**—This branch may spring directly from the superficial temporal, but it is frequently a branch of the middle temporal. It runs anteriorly, above the zygoma, between the two layers of the temporal fascia. It supplies branches to the orbicularis oculi, and anastomoses, through the zygomatic bone and round the outer margin of the orbit, with the lacrimal and palpebral branches of the ophthalmic artery.

(*g*) The **frontal branch** runs forwards and upwards, in a tortuous course, through the superficial fascia of the scalp towards the frontal tuberosity, lying at first upon the temporal fascia, and then upon the galea aponeurotica. It supplies the frontalis and the orbicularis oculi, and anastomoses with the lacrimal and supra-orbital branches of the ophthalmic artery, with the parietal terminal branch of the superficial temporal, and with its fellow of the opposite side.

(*h*) The **parietal branch**, less tortuous than the frontal, runs upwards and posteriorly in the superficial fascia of the scalp. It anastomoses, anteriorly, with the frontal terminal branch, posteriorly with the posterior auricular and occipital arteries, and, across the median line, with its fellow of the opposite side. It supplies the skin and fascia, and the anterior and superior muscles of the auricle.

(8) The **internal maxillary artery** commences between the antero-medial surface of the parotid gland and the neck of the mandible, and terminates in the pterygo-palatine fossa (Fig. 733).

Course and Relations.—Although the internal maxillary artery is only a short trunk it has many important relations, in the consideration of which it is convenient to divide the vessel into three parts. The **first part** extends from the back of the neck of the mandible into the infratemporal fossa, as far as the lower border of the external pterygoid muscle. It lies between the spheno-mandibular ligament and the neck of the mandible, along with the auriculo-temporal nerve and the internal maxillary vein. The **second part** is in the infratemporal fossa, and runs upwards and anteriorly. It may lie on the lateral or the medial side of the lower head of the external pterygoid muscle. In the former case it is situated between the temporal and external pterygoid muscles, and in the latter between the external pterygoid muscle and the branches of the mandibular division of the trigeminal nerve. The **third part** passes between the upper and the lower heads of the external pterygoid, and through the pterygo-maxillary fissure into the pterygo-palatine fossa.

Branches.—*From the first part.*—(*a*) **Deep auricular.** A small branch which arises from the commencement of the artery and passes upwards to the external acoustic meatus. It supplies the mandibular joint, the parotid gland, the external acoustic meatus, and the superficial surface of the tympanic membrane. It anastomoses with branches of the superficial temporal and posterior auricular arteries.

(*b*) The **anterior tympanic**, a variable and small branch. It runs upwards and posteriorly, traverses the petro-tympanic fissure (Glaserian), and enters the tympanum through its lateral wall. In the tympanic cavity it anastomoses with tympanic branches from the internal carotid and ascending pharyngeal arteries, and with the stylo-mastoid branch of the posterior auricular, forming with the latter, in young subjects, a circular anastomosis around the tympanic membrane.

(*c*) **Middle Meningeal.**—The largest branch of the internal maxillary. It ascends between the external pterygoid muscle laterally and the spheno-mandibular ligament and the tensor veli palatini medially; passes between the two roots of the auriculo-temporal nerve and through the foramen spinosum, and enters the middle fossa of the cranial cavity. Before it enters the skull it lies posterior to the third division of the trigeminal nerve, and is accompanied by a vein which also passes through the foramen spinosum. In the middle cranial fossa it passes for a short distance anteriorly, in a groove on the great wing of the sphenoid, between the dura mater and the bone, and divides into anterior and posterior terminal branches.

Branches.—(i.) **Superficial Petrosal.**—A small branch which arises from the middle meningeal soon after it enters the cranium. It passes through the hiatus canalis facialis and anastomoses with the stylo-mastoid branch of the posterior auricular artery; it also sends some small branches into the tympanic cavity.

(ii.) **Ganglionic.**—Minute branches which supply the semilunar ganglion and the roots of the fifth cerebral nerve.

(iii.) **Superior Tympanic.**—A small twig which reachse the tympanic cavity through the canal for the tensor tympani muscle, or through the petro-squamous suture.

(iv.) **Orbital.**—An anastomosing branch which arises, occasionally, from the anterior terminal branch. It passes through the superior orbital fissure into the orbit, and anastomoses with the lacrimal artery.

(v.) **Anterior terminal**, the larger of the two terminal branches, passes upwards along the great wing of the sphenoid to the sphenoidal angle of the parietal bone, where it is sometimes enclosed in a distinct bony canal; it is continued upwards, a short distance behind the anterior border of the parietal bone, almost to the vertex of the skull, sending branches forwards into the anterior, and backwards towards the posterior cranial fossa.

(vi.) The **posterior terminal branch** passes posteriorly from the great wing of the sphenoid to the squamous part of the temporal bone, beyond which it ascends to the middle of the inner surface of the parietal bone. It sends branches upwards to the vertex, and backwards towards the posterior cranial fossa.

By means of its various branches the middle meningeal artery anastomoses with its fellow of the opposite side, with meningeal branches from the occipital, ascending pharyngeal, ophthalmic, and lacrimal arteries; also with the stylo-mastoid branch of the posterior auricular, through the substance of the temporal bone, with the accessory meningeal artery, and the deep temporal arteries. The anterior and posterior branches of the middle meningeal arteries and their ramifications are separated from the bone by corresponding veins.

(*d*) An **accessory meningeal branch** may arise either directly from the first part of the internal maxillary or from its middle meningeal branch. It passes upwards, on the medial side of the external pterygoid muscle, enters the middle fossa of the skull through the foramen ovale, supplies the semilunar ganglion and the dura mater, and terminates by anastomosing with branches of the middle meningeal and internal carotid arteries.

(*e*) The **inferior alveolar** is a branch of moderate size which passes downwards, between the spheno-mandibular ligament and the mandible, to the mandibular foramen. It is accompanied by the inferior alveolar nerve, which lies in front of it. After entering the foramen it descends in the mandibular canal, and terminates at the mental foramen by dividing into mental and incisive branches.

Branches.—Before it enters the mandibular foramen it gives off two branches.

(i.) The **lingual**, a small twig, to the buccal mucous membrane, which accompanies the lingual nerve. (ii.) The **mylo-hyoid**, a small branch which is given off immediately above the mandibular foramen. It pierces the spheno-mandibular ligament, and descends in the mylo-hyoid groove, in company with the mylo-hyoid nerve, to the floor of the mouth, where it anastomoses, on the superficial surface of the mylo-hyoid muscle, with the submental branch of the external maxillary artery.

In the mandibular canal the following branches are given off:—

(i.) **Molar branches** to the molar teeth. (ii.) **Premolar branches** to the premolar teeth. (iii.) The **incisive terminal branch**, which supplies the incisor and canine teeth and anastomoses with its fellow of the opposite side. (iv.) The **mental terminal branch**, which passes through the mental foramen, emerges beneath the quadratus labii inferioris, and anastomoses with its fellow of the opposite side, with the inferior labial, and with the submental arteries.

From the second part.—(*a*) The **masseteric**, a small branch which passes laterally, through the mandibular notch, to the deep surface of the masseter muscle. It anastomoses in the substance of the muscle with branches of the transverse facial and with the masseteric branches of the external maxillary artery.

(*b*) **Deep Temporal.**—Two in number, anterior and posterior. They ascend, in the temporal fossa, between the temporal muscle and the squamous portion of the temporal bone, supplying the muscle and anastomosing with the temporal and lacrimal arteries, and, through the substance of the temporal bone, with the middle meningeal artery.

(*c*) Small **pterygoid branches** supply the internal and external pterygoid muscles.

(*d*) The **buccinator branch**, a long, slender branch which passes obliquely forwards and downwards with the buccinator nerve. It supplies the buccinator muscle, the skin and mucous membrane of the cheek, and anastomoses with the buccal branches of the external maxillary artery.

From the third part.—(*a*) A **posterior superior alveolar branch** descends in the infratemporal fossa, on the posterior surface of the maxilla, and ends in branches which supply the molar and premolar teeth and the mucous membrane of the maxillary sinus; they also give twigs to the gums and to the buccinator muscle.

(*b*) An **infra-orbital branch** commences in the pterygo-palatine fossa. It enters the orbit through the inferior orbital fissure, and runs forwards in the infra-orbital groove and canal to the infra-orbital foramen, through which it emerges on the face, deep to the quadratus labii superioris. Whilst in the infra-orbital groove it gives branches to the inferior rectus and the inferior oblique muscles and the lacrimal gland. In the infra-orbital canal it gives small twigs to the incisor and canine teeth (aa. alveolares superiores anteriores) and to the maxillary sinus. In the face it sends branches upwards to the lower eyelid, to the lacrimal sac, and to the frontal process of the maxilla; these anastomose with branches of the ophthalmic and external maxillary arteries; other branches run downwards to the upper lip, where they anastomose with the superior labial artery;

lastly, some branches run laterally into the cheek to unite with the transverse facial and the buccinator arteries.

(*c*) The **descending palatine** runs downwards, through the pterygo-palatine fossa, enters the pterygo-palatine canal, and becomes the great palatine artery, which supplies the mucous membrane of the roof of the mouth. As it descends it gives off the artery of the pterygoid canal, and several small twigs which pass through the accessory palatine canals to supply the soft palate, and to anastomose with the ascending palatine and tonsillar branches of the external maxillary and with the ascending pharyngeal artery. The great palatine artery, which is the continuation of the descending palatine, runs forwards in the roof of the mouth, medial to the alveolar process, to terminate in a small branch, which ascends through the incisive foramen and anastomoses with the posterior artery of the septum nasi, which is a branch of the spheno-palatine artery. In its course forwards in the roof of the mouth the great palatine artery supplies the gums and the mucous membrane of the hard palate, and also the palatine and maxillary bones.

(*d*) The **artery of the pterygoid canal** is a long, slender branch, usually given off from the descending palatine; it runs backwards through the pterygoid canal with the corresponding nerve (Vidian), and supplies branches to the upper part of the pharynx, to the levator and tensor veli palatini muscles, and to the auditory tube. One of the latter branches passes along the wall of the auditory tube to the tympanic cavity, where it anastomoses with the other tympanic arteries.

(*e*) The **pharyngeal branch** is a small artery which runs backwards, with the pharyngeal branch of the spheno-palatine ganglion, through the pharyngeal canal to the roof of the pharynx. It supplies the upper and posterior part of the roof of the nose, the roof of the pharynx, the sphenoidal sinus, and the lower part of the auditory (Eustachian) tube, and anastomoses with the pterygoid branch of the internal carotid.

(*f*) The **spheno-palatine branch** springs from the termination of the internal maxillary artery. It passes medially, through the spheno-palatine foramen, into the nasal cavity, where it gives off (*a*) a branch to the sphenoidal sinus, and (*b*) a branch which may replace the pharyngeal artery and which has a similar course and distribution. Then it divides into lateral and septal posterior nasal branches. The **lateral posterior nasal branches** supply the lateral wall of the nasal cavity and the sinuses which open through it, and they anastomose with the posterior and anterior ethmoidal arteries and the lateral nasal branch of the external maxillary. The **septal posterior nasal branch** accompanies the posterior septal nerve across the roof of the nasal cavity and then anteriorly and downwards in the groove on the vomer. It anastomoses with the great palatine artery and the septal branch of the superior labial.

Abnormalities.—The external carotid artery may be absent, or it may, in rare cases, arise directly from the arch of the aorta. The number of its branches may be diminished either by fusion of their roots or by transference to the internal or common carotid arteries. On the other hand, the number of its branches may be increased; thus, the sterno-mastoid artery, the hyoid branch usually given off by the superior thyreoid artery, or the ascending palatine branch of the external maxillary, may arise from it. Sometimes the branches may arise in the usual way, but may deviate from the course generally taken; more particularly is this the case with the internal maxillary artery, which may pass either between the heads, or entirely lateral or medial to both heads of the external pterygoid muscle.

ARTERIA CAROTIS INTERNA.

The **internal carotid artery** (Figs. 732, 735, 736, and 739) commences at the termination of the common carotid, opposite the upper border of the thyreoid cartilage, and terminates in the middle fossa of the skull, close to the commencement of the stem of the lateral fissure (Sylvius), where it divides into the middle and anterior cerebral arteries.

Course.—From its origin in the carotid triangle it ascends to the base of the skull, lying first in the carotid triangle, medial to the anterior border of the sterno-mastoid, and then between the areolar tissue behind the lateral border of the pharynx, medially, and the posterior belly of the digastric and the styloid process and its muscles laterally. At its commencement it lies postero-lateral to the external carotid, but as it ascends it gradually passes to the medial side of the external carotid, from which it is separated by the styloid process, the stylopharyngeus muscle, the glossopharyngeal nerve, and the pharyngeal branch of the vagus.

At the base of the skull it enters the carotid canal, in which it ascends, anterior to the tympanum and the cochlea; then it turns antero-medially to the apex of the bone where it enters the foramen lacerum, through which it ascends, along the side of the body of the sphenoid, to the middle fossa of the cranium.

In the middle fossa it runs forwards, in the lateral wall of the cavernous sinus, to the small wing of the sphenoid; there it turns backwards along the medial border of the anterior clinoid process, which it grooves. At the posterior extremity of the process it turns upwards to its termination at the medial end of the stem of the lateral fissure (Sylvius), below the medial part of the anterior perforated substance.

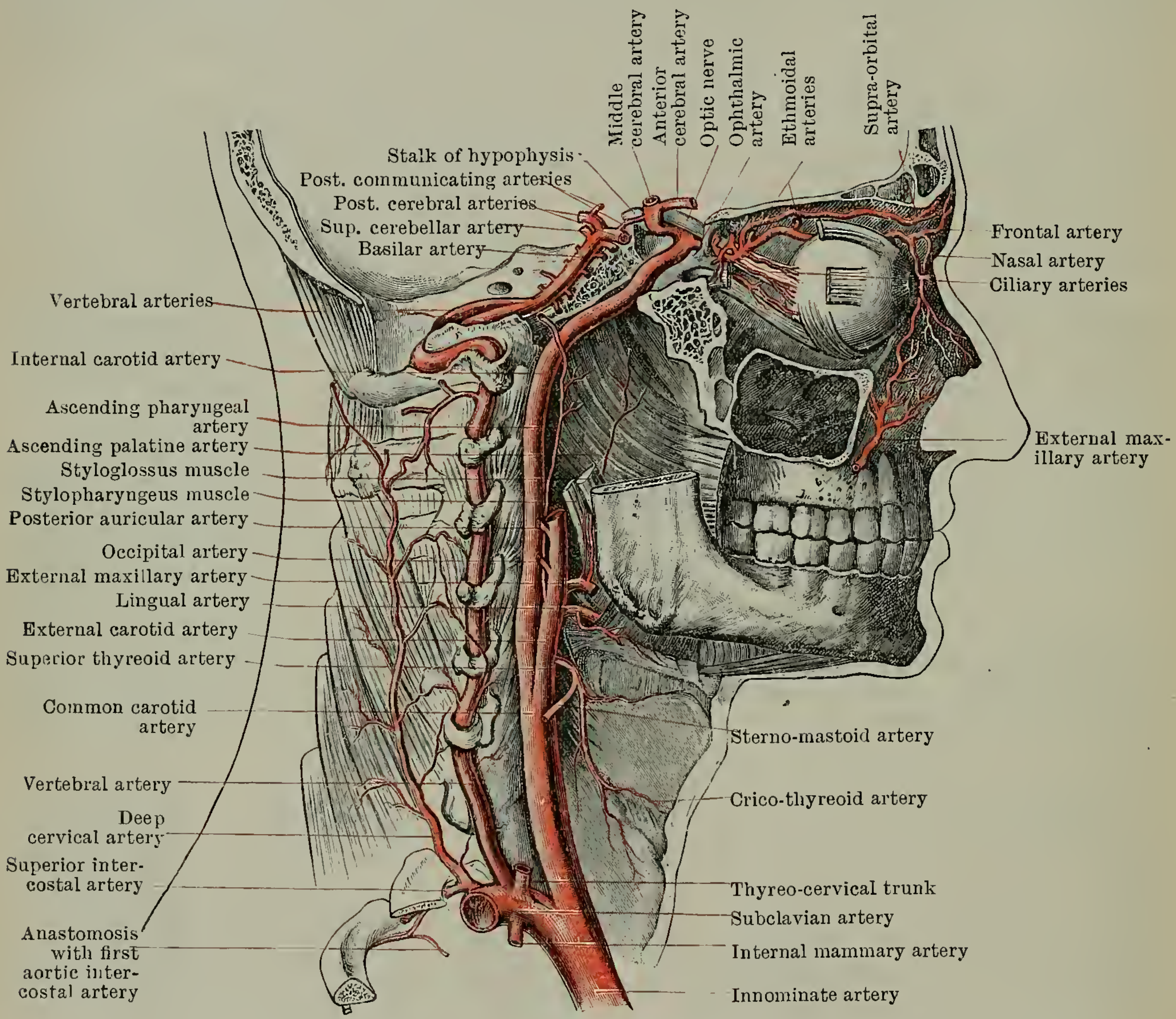

FIG. 735.—THE CAROTID, SUBCLAVIAN, AND VERTEBRAL ARTERIES AND THEIR MAIN BRANCHES.

Relations.—The relations of the various parts of the artery require separate consideration.

In the Neck.—Posterior.—The longus capitis, the prevertebral fascia, and the sympathetic trunk separate it from the transverse processes of the cervical vertebræ, and postero-lateral to it are the internal jugular vein and the vagus nerve. The accessory and the glossopharyngeal nerves are also postero-lateral to the artery for a short distance, in the upper part of the neck, where they intervene between it and the internal jugular vein. *Medial* or deep to the internal carotid is the external carotid artery for a short distance below, and afterwards the wall of the pharynx, the areolar tissue posterior to the wall of the pharynx, the ascending pharyngeal artery, the pharyngeal plexus of veins, and the external and internal laryngeal nerves. Just before it enters the temporal bone the levator palati muscle is to its medial side. *Lateral* or superficial to it are the sterno-mastoid, skin, and fasciæ, and it is crossed under cover of the sterno-mastoid, from below upwards, by the hypoglossal nerve, the occipital artery, and the posterior auricular artery. It is also crossed superficially, between the last-mentioned arteries, by the digastric and stylo-hyoid muscles, which separate it from the parotid gland, and below the digastric it is covered by the lower part of the postero-medial surface of the gland.

Passing obliquely across its anterior lateral surface, and separating it from the external carotid artery, are the following structures, viz., the stylo-pharyngeus, the styloid process, or the styloglossus muscle, and the glossopharyngeal nerve, the pharyngeal branch of the vagus, and some sympathetic twigs.

In the Carotid Canal.—The artery, as it passes upwards, is antero-inferior to the cochlea and the tympanum; postero-medial to the auditory (Eustachian) tube and the canal for the tensor tympani; and below the semilunar ganglion. The thin lamina of bone which separates it from the tympanum is frequently perforated, and that between it and the semilunar ganglion is frequently absent. In its course through the canal it is accompanied by small veins and sympathetic nerves. The veins receive tributaries from the tympanum, and communicate above with the cavernous sinus and below with the internal jugular vein. The nerves are branches of the nervus caroticus internus, which is the upward continuation of the sympathetic trunk; they form a plexus around the artery, called the internal carotid plexus.

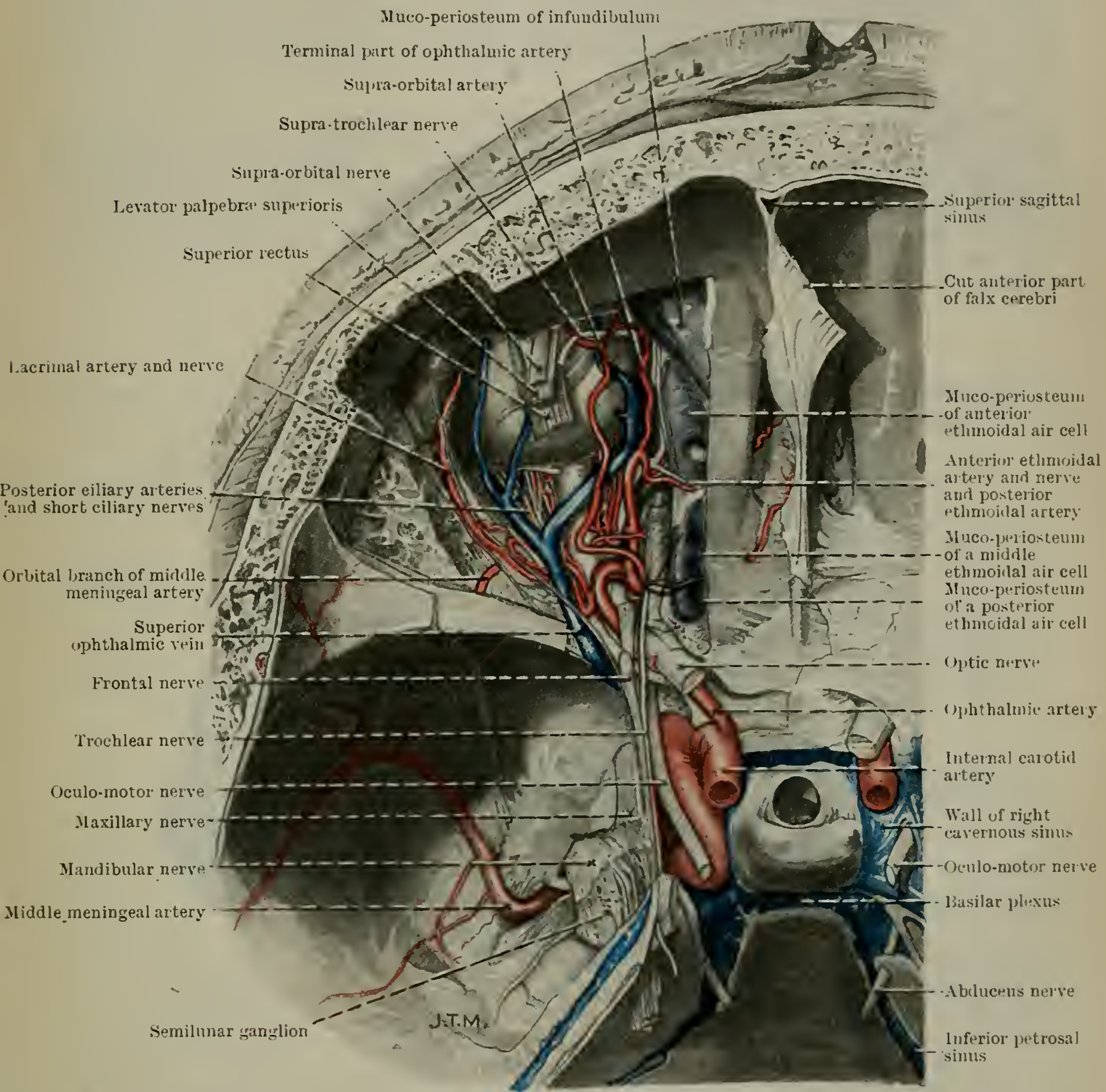
Muco-periosteum of infundibulum
Terminal part of ophthalmic artery
Supra-orbital artery
Supra-trochlear nerve
Supra-orbital nerve
Levator palpebræ superioris
Superior rectus
Lacrimal artery and nerve
Posterior ciliary arteries and short ciliary nerves
Orbital branch of middle meningeal artery
Superior ophthalmic vein
Frontal nerve
Trochlear nerve
Oculo-motor nerve
Maxillary nerve
Mandibular nerve
Middle meningeal artery
Semilunar ganglion
J.T.M.
Superior sagittal sinus
Cut anterior part of falx cerebri
Muco-periosteum of anterior ethmoidal air cell
Anterior ethmoidal artery and nerve and posterior ethmoidal artery
Muco-periosteum of a middle ethmoidal air cell
Muco-periosteum of a posterior ethmoidal air cell
Optic nerve
Ophthalmic artery
Internal carotid artery
Wall of right cavernous sinus
Oculo-motor nerve
Basilar plexus
Abducens nerve
Inferior petrosal sinus

FIG. 736.—DISSECTION OF THE ORBIT AND MIDDLE FOSSA OF THE CRANIUM. On the right side the trochlear nerve has been removed, and in the left orbit portions of the structures above the ophthalmic artery have been taken away. (Dr. E. B. Jamieson.)

As it enters the cavity of the cranium the internal carotid artery pierces the external layer of the dura mater and passes between the lingula and the sixth cerebral nerve laterally, and the posterior petrosal process of the body of the sphenoid medially.

In the Cranial Cavity.—The artery runs forwards, in the lateral wall of the cavernous sinus, in relation with the oculo-motor, trochlear, the ophthalmic division of the trigeminal, and the abducens nerves laterally, and with the endothelial wall of the sinus medially. When it reaches the lower root of the small wing of the sphenoid it turns upwards to the medial side of the anterior clinoid process, pierces the inner layer of the dura mater, and comes into close relation with the inferior surface of the optic nerve immediately posterior to the optic foramen. It then turns abruptly backwards below the optic nerve, and on the medial side of the anterior clinoid process which it frequently grooves; inclining laterally, it runs between the optic and oculo-motor nerves, and below the anterior perforated substance, to the medial end of the stem of the lateral fissure (Sylvius), where it turns upwards, at some distance from the corresponding lateral border of the optic chiasma, and, after piercing the arachnoid, divides into its two terminal branches, the anterior and middle cerebral arteries.

Abnormalities.—The internal carotid artery is rarely absent, but its absence has been noted upon one side, more commonly the left; and upon both sides. Occasionally it springs from the arch of the aorta, and in its course through the neck it may vary somewhat in length and in tortuosity. One or more of the branches usually derived from the external carotid artery may arise from it, and it sometimes gives off a large meningeal branch to the posterior fossa of the skull. Its posterior communicating branch may replace the posterior cerebral artery; on the other hand, the upper part of the internal carotid may be absent, and the posterior communicating artery may become the middle cerebral artery.

BRANCHES OF THE INTERNAL CAROTID ARTERY.

Branches are given off from the internal carotid in the temporal bone and in the cranium, but, as a rule, no regular branches are given off in the neck.

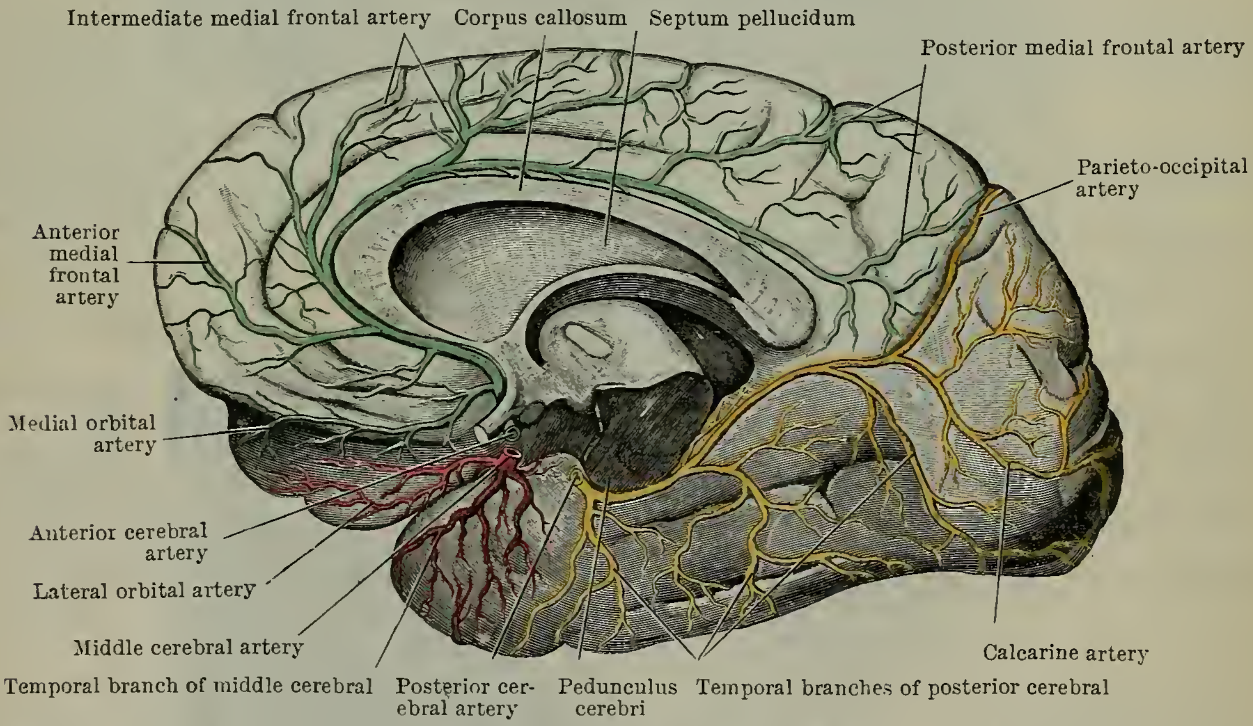
Intermediate medial frontal artery
Corpus callosum
Septum pellucidum
Posterior medial frontal artery
Parieto-occipital artery
Anterior medial frontal artery
Medial orbital artery
Anterior cerebral artery
Lateral orbital artery
Middle cerebral artery
Calcarine artery
Temporal branch of middle cerebral
Posterior cerebral artery
Pedunculus cerebri
Temporal branches of posterior cerebral

FIG. 737.—DISTRIBUTION OF THE CEREBRAL ARTERIES ON THE MEDIAL AND INFERIOR SURFACES OF THE CEREBRAL HEMISPHERES.

The anterior cerebral artery is coloured green, the middle cerebral artery red, and the posterior cerebral artery orange.

In the Temporal Bone.—(1) A **carotico-tympanic branch**, very small, perforates the posterior wall of the carotid canal, and anastomoses in the tympanum with the stylo-mastoid artery and with the tympanic branches of the internal maxillary and ascending pharyngeal arteries.

(2) A small and inconstant branch which accompanies the nerve of the pterygoid canal (Vidian); it anastomoses with a branch of the descending palatine artery.

In the Cranium.—(1) **Cavernous**, small branches to the walls of the cavernous sinus and to the oculo-motor, trochlear, trigeminal, and abducens nerves.

(2) Minute twigs which supply the semilunar ganglion.

(3) **Hypophyseal branches** pass to the hypophysis (O.T. pituitary body).

(4) **Meningeal branches** ramify in the dura mater of the middle cranial fossa, anastomosing with the branches of the middle and accessory meningeal arteries.

(5) The **ophthalmic artery** (Figs. 735, 736) springs from the antero-medial side of the internal carotid as it turns upwards on the medial side of the anterior clinoid process. It passes forwards and laterally, below the optic nerve and through the optic foramen into the orbital cavity. In the orbit it runs forwards, for a short distance, on the lateral side of the optic nerve, and it is in relation laterally with the ciliary ganglion and the lateral rectus muscle; turning upwards and medially, it crosses, between the optic nerve and the superior rectus, to the medial wall of the orbit, where it turns forwards to terminate at the anterior boundary of the cavity by dividing into frontal and dorsal nasal branches. It is accompanied, at first, by the naso-ciliary nerve, and, in the terminal part of its course, by the infra-trochlear nerve.

Branches.—The branches of the ophthalmic artery are numerous. (*a*) The **posterior ciliary**, usually six to eight in number, run forwards at the sides of the optic nerve; they soon divide into numerous branches which pierce the posterior part of the sclera; the majority terminate in the chorioid coat of the eye as the *short posterior ciliary arteries*, but two of larger size, the *long posterior ciliary arteries*, run forwards, one on each side of the eyeball, almost in the horizontal plane, between the sclera and the chorioid coat, to the periphery of the iris, where they divide. The resulting branches anastomose together and form a circle at the periphery of the iris, from which secondary branches run inwards and anastomose together in a second circle near the papillary margin of the iris.

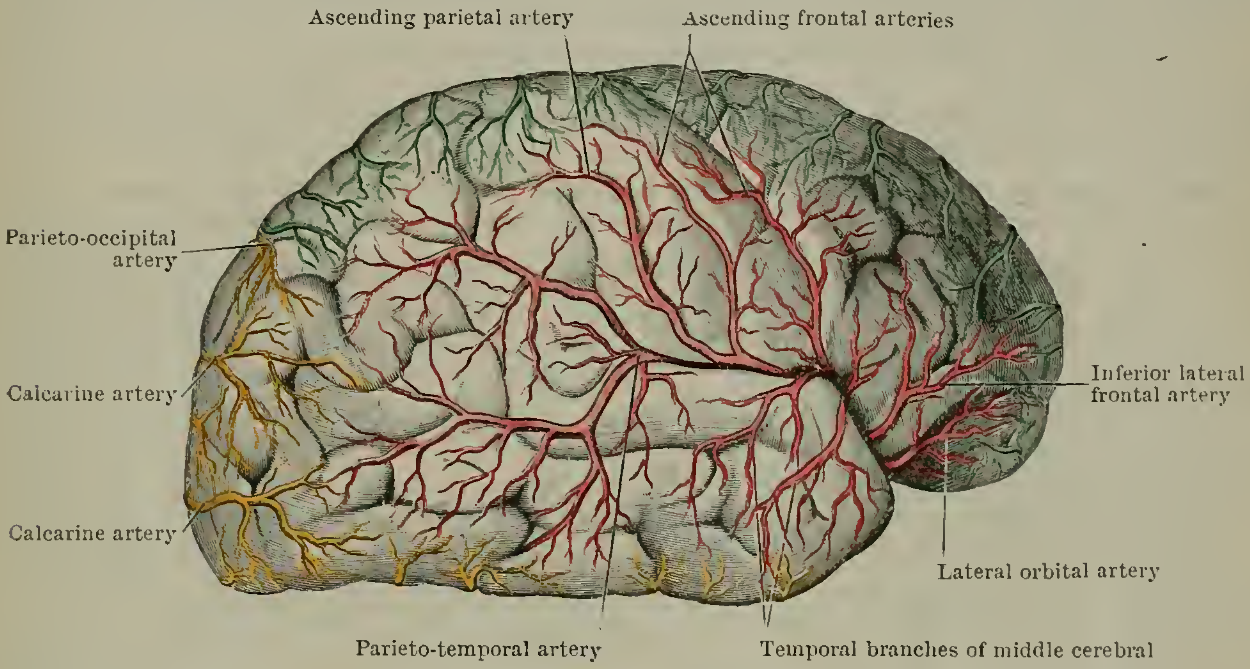
Ascending parietal artery
Ascending frontal arteries
Parieto-occipital artery
Calcarine artery
Calcarine artery
Inferior lateral frontal artery
Lateral orbital artery
Parieto-temporal artery
Temporal branches of middle cerebral

FIG. 738.—DISTRIBUTION OF CEREBRAL ARTERIES ON THE CONVEX SURFACE OF THE CEREBRUM.
Anterior cerebral artery is coloured green, the middle cerebral red, and the posterior cerebral orange.

(*b*) The **central artery of the retina** arises near to, or in common with, the preceding vessels. It pierces the infero-medial aspect of the optic nerve, about 12 mm. (half an inch) posterior to the sclera, and runs in its centre to the retina, where it breaks up into terminal branches.

(*c*) **Anterior Meningeal.**—A small branch which passes backwards through the superior orbital fissure into the middle fossa of the cranium, where it anastomoses with the middle and accessory meningeal arteries, and with the meningeal branches of the internal carotid and lacrimal arteries.

(*d*) The **lacrimal artery** arises from the ophthalmic on the lateral side of the optic nerve. It runs forwards, along the upper border of the lateral rectus, to the upper lateral angle of the orbit, and in its course gives off *glandular branches* to the lacrimal gland, *muscular branches* to the lateral and superior recti, *palpebral branches* to the upper eyelid and the upper and lateral part of the forehead, *temporal* and *zygomatic branches*, which accompany the zygomatico-temporal and zygomatico-facial branches of the zygomatic (temporo-malar) nerve, to the face and the infra-temporal fossa respectively; *anterior ciliary branches*, which perforate the sclera behind the corneo-scleral junction and anastomose with the posterior ciliary arteries; and a *recurrent meningeal branch*, which passes backwards, through the lateral part of the superior orbital fissure, to anastomose, in the middle fossa of the skull, with the middle meningeal artery.

(*e*) **Muscular.**—These branches are usually arranged in two sets, lateral and medial. The former supply the upper and lateral, and the latter the lower and medial orbital muscles. They anastomose with muscular branches from the lacrimal and the supra-orbital vessels, and they give off *anterior ciliary branches*.

(*f*) The **supra-orbital branch** is given off as the ophthalmic artery crosses above the optic nerve. It passes round the medial borders of the superior rectus and levator palpebræ muscles, and runs forwards, between the levator and the periosteum, to the supra-orbital notch, accompanying the frontal nerve and its supra-orbital branch. Passing through the notch it reaches the scalp, and, after it has perforated the frontalis muscle, it anastomoses with the frontal branches of the superficial temporal and ophthalmic arteries.

(*g*) **Anterior** and **posterior ethmoidal branches** arise from the ophthalmic as it runs forwards along the medial boundary of the orbit. They pass medially, between the superior oblique and the medial rectus. The posterior, which is much the smaller of the two, traverses the posterior ethmoidal canal, and supplies the posterior ethmoidal cells and the posterior and upper part of the lateral wall of the nasal cavity. The anterior ethmoidal artery passes through the anterior ethmoidal canal with the anterior ethmoidal nerve, enters the anterior fossa of the skull, and crosses the lamina cribrosa of the ethmoid to the nasal slit, through which it reaches the nasal cavity, where it descends, with the external branch of the nasal nerve, in a groove on the posterior surface of the nasal bone, and, finally, passes between the lateral cartilage and the lower border of the nasal bone to the tip of the nose. It supplies branches to the membranes of the brain in the anterior cranial fossa as well as to the anterior ethmoidal cells, the frontal sinus, the anterior and upper part of the nasal muco-periosteum, and the skin on the dorsum of the nose.

(*h*) **Palpebral branches**, upper and lower, are given off near the termination of the ophthalmic. They are distributed to the upper and lower eyelids, and they anastomose with the lacrimal, supra-orbital, and infra-orbital arteries.

(*i*) The **dorsal nasal terminal branch** passes out of the orbit above the medial tarsal ligament. It pierces the palpebral fascia, and terminates on the side of the nose by anastomosing with the angular branch of the external maxillary artery.

(*j*) The **frontal terminal branch** pierces the palpebral fascia at the upper and medial part of the orbit, and ascends, with the supra-trochlear nerve, in the superficial fascia of the anterior and medial part of the scalp, anastomosing with its fellow of the opposite side and with the supra-orbital artery.

Abnormalities.—The ophthalmic artery, as it traverses the orbit, may pass either above or below the optic nerve. It is occasionally replaced by a branch of the middle meningeal artery.

(6) The **posterior communicating artery** arises from the internal carotid near its termination. It runs backwards, below the optic tract and anterior to the pedunculus cerebri, and, passing above the oculo-motor nerve, joins the posterior cerebral artery forming part of the circulus arteriosus (Willis). It gives branches to the optic chiasma, the optic tract, the pedunculus cerebri, the interpeduncular region, the internal capsule, and the optic thalamus. The posterior communicating artery varies much in size; it may be small on one or both sides, sometimes it is very large on one side; occasionally it replaces the posterior cerebral artery, and it sometimes arises from the middle cerebral artery.

(7) The **chorioidal** is a small branch, which also arises near the termination of the internal carotid; it passes backwards and laterally, between the pedunculus cerebri and the uncus, to the lower and anterior part of the chorioidal fissure which it enters, and it terminates in the chorioidal plexus in the inferior cornu of the lateral ventricle. It supplies the optic tract, the pedunculus cerebri, the uncus, the posterior part of the internal capsule, the tail of the caudate nucleus, part of the lentiform nucleus, and the amygdaloid nucleus.

(8) The **anterior cerebral artery** is the smaller of the two terminal branches of the internal carotid. It passes forwards and medially, above the optic chiasma and in front of the lamina terminalis, to the commencement of the longitudinal fissure; there it turns round the genu of the corpus callosum, and runs backwards to the parietal lobe of the brain. At the commencement of the longitudinal fissure it is closely connected with its fellow of the opposite side by a wide but short **anterior communicating artery**, and in the remainder of its course it is closely accompanied by its fellow artery of the opposite side.

Branches.—Branches of all the cerebral arteries are distributed both to the basal ganglionic masses of the brain and to the cerebral cortex; they therefore form two distinct groups which do not communicate with one another—(*a*) **central** or **basal**; (*b*) **cortical.**

The branches of the anterior cerebral include:

(*a*) *Central or basal Branches.*—The **antero-medial basal arteries**, a small group of vessels, constitute the basal branches of the anterior cerebral artery; they pass upwards into the base of the brain, in front of the optic chiasma, and supply the rostrum of the corpus callosum, the lamina terminalis, the head of the caudate nucleus, the anterior part of the lentiform nucleus and internal capsule, the columns of the fornix, the septum pellucidum, and the anterior commissure.

(*b*) *Cortical Branches.* — (b^1) **Medial orbital**, one or more small branches which supply the medial orbital convolution, the gyrus rectus, and the olfactory lobe.

(b^2) **Anterior medial frontal**, one or more branches which are distributed to the anterior and lower part of the medial surface of the superior frontal gyrus, and to the anterior portions of the superior and middle frontal gyri on the lateral surface of the hemisphere.

(b^3) An **intermediate medial frontal** is distributed to the posterior part of the medial lateral surfaces of the superior frontal gyrus and to the upper parts of the anterior and posterior central gyri.

(b^4) The **posterior medial frontal** runs backwards to the præcuneus. It supplies the corpus callosum, the præcuneus, and the upper part of the superior parietal lobule.

(9) **Arteria Cerebri Media.**—The **middle cerebral artery** is the larger of the two terminal branches, and the more direct continuation of the internal carotid artery. It passes laterally, in the stem of the lateral fissure (Sylvius), to the surface of the insula, and it divides, in the posterior part of the circular sulcus (Reil), into parieto-temporal and temporal terminal branches.

Branches.—(*a*) The **central** or **basal**, which constitute the **antero-lateral basal arteries**, are numerous and very variable in size. They arise at the base of the brain, in the region of the anterior perforated substance. Two sets, known as the medial and the lateral striate arteries, are distinguishable.

(a^1) The **medial striate arteries** pass upwards through the two medial segments of the lentiform nucleus (globus pallidus) and the internal capsule to terminate in the caudate nucleus. They supply the anterior portions of the lentiform and caudate nuclei and of the internal capsule.

(a^2) The **lateral striate arteries** pass upwards through the lateral segment (putamen) of the lentiform nucleus, or between it and the external capsule, and they form two sets: an anterior, the lenticulo-striate, and a posterior, the lenticulo-optic; both sets traverse the lentiform nucleus and the internal capsule, but the *lenticulo-striate arteries* terminate in the caudate nucleus, and the *lenticulo-optic* in the thalamus. One of the lenticulo-striate arteries, which passes in the first instance round the lateral side of the lentiform nucleus, and afterwards through its substance, is larger than its companions; it frequently ruptures, and is known as the "artery of cerebral hæmorrhage."

(*b*) *Cortical branches* are given off as the middle cerebral artery passes over the surface of the insula at the bottom of the lateral fissure, as follows:—

(b^1) The **lateral orbital** runs forwards and laterally, and is distributed to the lateral part of the orbital surface of the frontal lobe and to the inferior frontal gyrus.

(b^2) The **inferior lateral frontal**, which supplies the inferior and middle frontal gyri.

(b^3) The **ascending frontal**, which turns round the upper margin of the lateral fissure, and is distributed to the anterior central gyrus and to the posterior part of the middle frontal gyrus.

(b^4) The **ascending parietal branch** emerges from the lateral fissure (Sylvius) and passes upwards along the posterior border of the posterior central gyrus, supplying that gyrus and the superior parietal lobule.

(b^5) The **temporal branch** passes out of the lateral fissure, and turns downwards to supply the superior and middle temporal gyri.

(b^6) The **parieto-temporal branch** continues backwards, in the direction of the main stem of the middle cerebral artery, and emerges from the posterior end of the lateral fissure; it supplies the inferior parietal lobule, part of the lateral surface of the occipital lobe, and the posterior part of the temporal lobe.

Abnormalities.—The anterior cerebral branch of the internal carotid may be absent, or rather it may arise from the corresponding artery of the opposite side; or there may be three anterior cerebral arteries, the third arising from the anterior communicating artery which connects the two anterior cerebrals together.

ARTERIA VERTEBRALIS.

The **vertebral artery** (Figs. 735 and 739) is the first branch given off from the subclavian trunk; it arises from the upper and posterior part of the parent stem, opposite the interval between the anterior scalene and the longus colli muscles, and terminates at the lower border of the pons (Varolii) by uniting with its fellow of the opposite side to form the basilar artery.

Course and Relations.—The vertebral artery is divisible into four parts.

The **first part** runs upwards and backwards, between the scalenus anterior and the lateral border of the longus colli, to the foramen in the transverse process of the sixth cervical vertebra. It is surrounded by a plexus of sympathetic nerve fibres, is covered anteriorly by the vertebral and internal jugular veins, and it may be crossed anteriorly by the inferior thyreoid artery. On the left side the terminal part of the thoracic duct also passes anterior to it. The **second part** runs upwards through the foramina in the transverse processes of the upper six cervical vertebræ. As far as the second cervical vertebra its course is almost vertical; as it passes through the transverse process of the epistropheus, however, it is directed obliquely upwards and laterally to the atlas. It is surrounded by a plexus of sympathetic nerve fibres, and also by a plexus of veins. The artery lies anterior to the trunks of the cervical nerves, and medial to the intertransverse muscles. The **third part** emerges from the foramen in the transverse process of the atlas, between the anterior division of the sub-occipital nerve medially and the rectus capitis lateralis laterally, and runs almost horizontally backwards and medially, round the lateral and posterior aspects of the corresponding superior articular process of the atlas. In this part of its course it enters the sub-occipital triangle, where it lies in the groove on the upper surface of the posterior arch of the atlas (sulcus arteriæ vertebralis). It is separated from the bone by the sub-occipital nerve, and is overlapped superficially by the adjacent borders of the superior and inferior oblique muscles. Finally, this part of the artery passes anterior to the oblique ligament of the atlas and enters the vertebral canal.

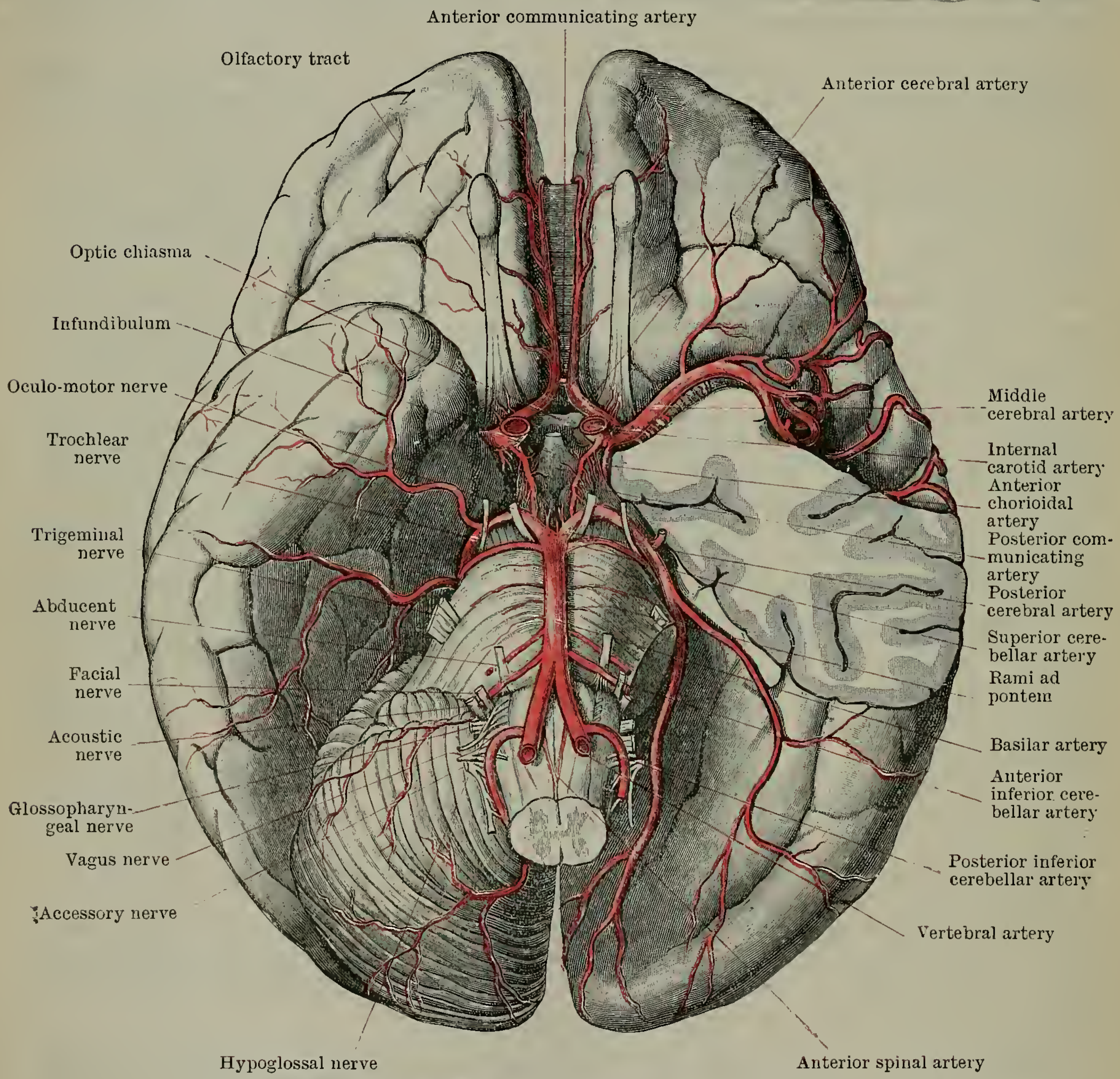

FIG. 739.—THE ARTERIES OF THE BASE OF THE BRAIN. THE CIRCULUS ARTERIOSUS (WILLIS).

The **fourth part** pierces the spinal dura mater and runs upwards into the cranial cavity. It passes between the roots of the hypoglossal nerve, posteriorly, and the first dentation of the ligamentum denticulatum, anteriorly, pierces the arachnoid, and, gradually inclining to the front of the medulla oblongata, reaches the lower border of the pons, where it unites with its fellow of the opposite side to form the basilar artery.

Abnormalities.—The vertebral artery may have a double origin—one from the subclavian, and one from the inferior thyreoid artery or from the aorta.

The right vertebral may arise from the common carotid or from the arch of the aorta. Occasionally it springs from the descending aorta, an arrangement associated with the persistence of the dorsal roots of the fourth and fifth right arches.

The left vertebral artery not infrequently springs from the arch of the aorta, arising between the left common carotid and left subclavian arteries; this is evidently due to the absorption of the stem of the seventh segmental artery into the aortic arch. Very exceptionally the left vertebral is a branch of an intercostal artery.

In its course upwards either vertebral artery may enter the vertebrarterial foramen of any of the lower six cervical vertebra.

The cases in which it does not enter one of the lowest of these are apparently associated with its formation, in part, from the precostal instead of from the postcostal anastomosing channels.

The artery may enter the vertebral canal with the second instead of with the first cervical nerve, or, after leaving the foramen in the transverse process of the third vertebra, it may divide into two branches, one of which accompanies the second and the other the first cervical nerve; the two branches unite together again in the vertebral canal to form a single trunk.

Sometimes, though rarely, it gives off superior intercostal and inferior thyreoid branches. The upper end of one of the vertebrals is sometimes very small, or it may be entirely wanting; in the latter case the basilar artery is formed by the direct continuation of the opposite vertebral.

Branches.—*From the first part.*—As a rule there are only a few small **muscular twigs** from this portion of the artery.

From the second part.—(1) **Muscular branches** which vary in number and size. They supply the deep muscles of the neck, and anastomose with the profunda cervicis, the ascending cervical, and the occipital arteries.

(2) **Spinal branches** pass from the medial side of the second part of the vertebral artery, through the intervertebral foramina, into the vertebral canal, where they give off twigs which pass along the roots of the spinal nerves to reinforce the anterior and posterior spinal arteries; they supply the bodies of the vertebrae and the intervertebral fibro-cartilages, and they anastomose with corresponding arteries above and below.

From the third part.—(1) **Muscular branches** to the sub-occipital muscles.

(2) **Anastomotic branches** which unite with the descending branch (O.T. princeps cervicis) of the occipital and with the profunda cervicis artery.

From the fourth part.—(1) **Meningeal.**—One or two small branches given off before the vertebral artery pierces the dura mater. They ascend into the posterior fossa of the skull, where they anastomose with meningeal branches of the occipital and ascending pharyngeal arteries, and occasionally with branches of the middle meningeal artery.

(2) **Posterior Spinal.**—The posterior spinal branch springs most commonly from the posterior inferior cerebellar branch of the vertebral (Stopford, 1916), but occasionally it arises from the vertebral directly. It runs downwards upon the side of the medulla oblongata and the spinal medulla, either in front of or behind the posterior nerve-roots. It is a slender artery, which is continued to the lower part of the spinal medulla by means of reinforcements from the spinal branches of the vertebral and intercostal arteries. It gives off branches to the pia mater, which form more or less regular anastomoses on the medial and lateral sides of the posterior nerve-roots, and it ends by joining the anterior spinal artery.

(3) The **anterior spinal branch** arises near the termination of the vertebral. It runs obliquely downwards and medially, in front of the medulla oblongata, and unites with its fellow of the opposite side to form a single anterior spinal artery, which descends along the anterior median fissure of the spinal medulla, and is continued as a fine vessel along the filum terminale. The anterior spinal artery is reinforced as it descends by anastomosing twigs from the spinal branches of the vertebral, intercostal, and lumbar arteries. It gives off branches which pierce the pia mater and supply the spinal medulla, and it unites below with the posterior spinal arteries.

(4) The **posterior inferior cerebellar** is the largest branch of the vertebral artery. It arises a short distance below the pons and passes obliquely backwards round the medulla oblongata, at first between the fila of the hypoglossal nerve, and then between the fila of the accessory and vagus nerves, into the vallecula of the cerebellum, where it divides into lateral and medial terminal branches.

The trunk of the artery gives branches to the medulla oblongata and to the chorioid plexus of the fourth ventricle. Some of these branches supply the nuclei of the glossopharyngeal, the vagus, and the accessory nerves, the spino-thalamic, spino-cerebellar, rubro-spinal, olivo-cerebellar tracts, and possibly also the vestibular root of the acoustic and the spinal root of the fifth nerve (Bury and Stopford). The medial terminal runs backwards between the inferior vermis and the hemisphere of the cerebellum; it supplies the former structure, and anastomoses with its fellow of the opposite side. The lateral branch passes to the lower surface of the hemisphere and anastomoses with the superior cerebellar artery.

Arteria Basilaris.—The **basilar artery** is formed by the junction of the two vertebral arteries; it commences at the lower border and terminates at the upper border of the pons (Varolii), bifurcating at its termination into the two posterior cerebral arteries.

Course and Relations.—It runs upwards, in the median part of the cisterna pontis, in a shallow groove on the front of the pons, behind the sphenoidal section of the basi-cranial axis and between the two abducent nerves.

Abnormalities.—The basilar artery may be double in part or the whole of its extent, or its cavity may be divided by a more or less complete septum. It may terminate in one instead of two posterior cerebral arteries, the missing vessel being supplied by the enlargement of the posterior communicating branch of the internal carotid.

Branches.—(1) **Pontine**, a series of small arteries which pass across the front and round the sides of the pons, supplying the pons, the brachia pontis (O.T. middle peduncles of the cerebellum), and the roots of the trigeminal nerve.

(2) The **internal auditory**, a pair of long slender branches. Each internal auditory branch may spring either from the basilar or from the anterior inferior cerebellar artery of the same side (Stopford, 1916). It enters the corresponding internal acoustic meatus with the facial and acoustic nerves, and, after it has passed through the lamina cribrosa, it is distributed to the internal ear.

(3) The **anterior inferior cerebellar**, two branches which arise, one on each side, from the middle of the basilar artery. They pass backwards, on the anterior parts of the lower surfaces of the lateral lobes of the cerebellum, and anastomose with the posterior inferior cerebellar branches of the vertebral arteries.

(4) The **superior cerebellar** branches, two in number, arise near the termination of the basilar. Each passes laterally, at the upper border of the pons, directly below the oculo-motor nerve of the same side, and, after turning round the lateral side of the pedunculus cerebri, below the trochlear nerve, it reaches the upper surface of the cerebellum, where it divides into a medial and a lateral branch. The medial branch supplies the upper part of the vermis, and the anterior medullary velum. The lateral branch is distributed over the upper surface of the lateral lobe; it anastomoses with the inferior cerebellar arteries.

(5) The **posterior cerebral arteries** (Figs. 737 and 739) are the two terminal branches of the basilar. They run backwards and upwards, between the peduncles of the cerebrum and the uncinate gyri and parallel to the superior cerebellar arteries, from which they are separated by the oculo-motor and trochlear nerves. Each posterior cerebral artery is connected with the internal carotid by the posterior communicating artery; it gives branches to the inferior surface of the cerebrum, and is continued backwards, beneath the splenium of the corpus callosum, to the calcarine fissure, where it divides into calcarine and parieto-occipital branches, which pass to the lateral surface of the occipital lobe. It supplies the medial and tentorial surfaces of the occipital lobe and the posterior part of its lateral surface.

Branches.—(A) *Central or basal.*—This group includes (a^1) A **postero-medial** set of small vessels which pass, on the medial side of the corresponding cerebral peduncle, to the posterior perforated substance. They supply the peduncle, the posterior part of the thalamus, the corpora mamillaria, and the walls of the third ventricle.

(a^2) A **postero-lateral** set of small vessels, which pass round the lateral side of the peduncle. They supply the corpora quadrigemina, the brachia, the pineal body, the peduncle, the posterior part of the thalamus, and the corpora geniculata.

(a^3) A **posterior chorioidal** set of small branches which pass through the upper part of the chorioidal fissure; they enter the posterior part of the tela chorioidea of the third ventricle, and end in the chorioid plexus, in the body of the lateral ventricle, and the upper part of its inferior cornu. They also supply the adjacent parts of the fornix.

(B) *Cortical.*—(b^1) The **anterior temporal**, frequently a single branch of variable size, but not uncommonly replaced by several small branches. It supplies the anterior parts of the uncus, the hippocampal gyrus, and the fusiform gyrus.

(b^2) The **posterior temporal** is a larger branch than the anterior. It supplies the posterior part of the hippocampal gyrus, part of the fusiform gyrus, and the lingual gyrus.

(b^3) The **calcarine branch** is the continuation of the posterior cerebral artery along the calcarine fissure, it is especially associated with the supply of the visual area of the cortex of the brain. It supplies the cuneus, the lingual gyrus, and the posterior part of the lateral surface of the occipital lobe.

(b^4) The **parieto-occipital branch**, smaller than the calcarine, passes along the corresponding fissure to the cuneus and præcuneus.

Circulus Arteriosus (Willis) (Fig. 739).—The cerebral arteries of opposite sides are intimately connected together at the base of the brain by anastomosing channels. Thus, the two anterior cerebral arteries are connected with one another by the anterior communicating artery, whilst the two posterior cerebrals are in continuity through the basilar artery from which they arise. There is also a free anastomosis on each side between the carotid system of cerebral arteries and the vertebral system by means of the posterior communicating arteries, which connect the internal carotid trunks and posterior cerebral arteries.

The vessels referred to form the so-called **circulus arteriosus** which is situated at the base of the brain, in the interpeduncular and chiasmatic subarachnoid cisterns. It encloses the following structures: the posterior perforated substance, the corpora mamillaria, the tuber cinereum, the infundibulum, and the optic chiasma. The "circle" is irregularly polygonal in outline, and is formed posteriorly by the termination of the basilar and by the two posterior cerebral arteries, postero-laterally by the posterior communicating arteries and the internal carotids, antero-laterally by the anterior cerebral arteries, and in front by the anterior communicating artery.

It is stated that this free anastomosis equalises the flow of blood to the various parts of the cerebrum, and provides for the continuation of a regular blood-supply if one or more of the main trunks should be obstructed.

ARTERIES OF THE UPPER EXTREMITY.

The main arterial stem of each upper extremity passes through the root of the neck, traverses the axillary space, and is continued through the arm to the forearm. In the forearm its extent is short, for it terminates, opposite the neck of the radius, by bifurcating into the radial and ulnar arteries, which run through the forearm to the hand. That portion of the common trunk which lies in the root of the neck is known as the **subclavian artery**, the part in the axillary space is termed the **axillary artery**, whilst the remaining part is called the **brachial artery**.

ARTERIÆ SUBCLAVIÆ.

On the right side the subclavian artery (Figs. 727, 728, 730, and 732) commences at the termination of the innominate artery, posterior to the sterno-clavicular articulation, whilst that on the left side arises from the arch of the aorta, behind the upper half of the manubrium sterni.

The right artery is about 75 mm. (3 inches) long; it lies in the root of the neck. The left artery is about 100 mm. (4 inches) long, and is situated not only in the root of the neck, but also in the superior mediastinal part of the thorax. In the root of the neck each artery arches laterally, across the apex of the lung and behind the anterior scalene muscle, and is divided into three parts, which lie respectively to the medial side, behind, and to the lateral side of the muscle. The extent to which the arch rises above the level of the clavicle varies; not uncommonly it reaches the level of the lower part of the thyreoid gland. The first parts of the subclavian arteries differ materially from each other both in extent and relations. The relations of the second and third parts are similar on the two sides.

The **first part of the left subclavian artery** springs from the arch of the aorta, posterior to the commencement of the left common carotid and on the left side of the trachea. It ascends almost vertically, in the superior mediastinum, to the root of the neck, where it arches upwards and laterally to the medial border of the scalenus anterior muscle.

Relations.—*Posterior.*—In the superior mediastinum it is in relation with the lung and pleura.

Anterior. — In front are the left vagus, the left superior cardiac branch of the sympathetic, the left inferior cardiac branch of the vagus, the left phrenic nerve, and the left common carotid artery. It is also crossed obliquely by the left vagus nerve, and it is overlapped on the left side by the left lung and pleura.

Medial.—Medially it is in relation, from below upwards, with the trachea, the left recurrent nerve, the œsophagus, and the thoracic duct, the latter lying in a plane posterior to the œsophagus and the artery.

Laterally it is closely invested by the left pleura, and it ascends in a groove on the medial aspect of the left lung.

At the root of the neck, as it turns laterally, it lies behind the commencement of the left innominate vein, and the termination of the left vertebral vein, the phrenic nerve, the sterno-thyreoid and sterno-hyoid muscles, the anterior jugular vein, and, more superficially, the sterno-mastoid muscle and the deep cervical fascia; the thoracic duct arches obliquely over it; and it lies in front of the apex of the pleural sac and lung.

The **first part of the right subclavian artery** (Fig. 728) extends from the back of the right sterno-clavicular articulation to the medial border of the scalenus anterior. It is thus limited to the root of the neck.

Relations.—*Posterior.*—Behind this part of the artery, and intervening between it and the upper two thoracic vertebræ, are the recurrent nerve, the posterior part of the ansa subclavia, and the apex of the right pleural sac. *Anterior.*—In front it is in relation with the right vagus, the cardiac branches of the vagus and the sympathetic, the anterior portion of the ansa subclavia, the internal jugular and vertebral veins, and more superficially the sterno-hyoid and sterno-thyreoid muscles, the anterior jugular vein, the sternal end of the clavicle, the sterno-clavicular ligaments, and the sterno-mastoid muscle. The recurrent nerve passes *below* it and intervenes between it and the apex of the pleural sac.

The **second part of the subclavian artery**, on *each side*, extends from the medial to the lateral border of the scalenus anterior, behind which it lies.

Relations.—Posteriorly and *below* it is in relation with the pleural sac. Anteriorly it is covered by the anterior scalene and the sterno-mastoid muscles. The anterior scalene separates it from the subclavian vein, which lies at a slightly lower level, from the transverse cervical and transverse scapular arteries, from the anterior jugular vein, and, on the right side, from the phrenic nerve.

The **third part of the subclavian artery** is the most superficial portion. It extends from the lateral border of the anterior scalene to the outer border of the first rib, lying partly in the clavicular portion of the posterior triangle of the neck and partly behind the clavicle and the subclavius muscle.

Relations.—It rests upon the upper surface of the first rib. Immediately *posterior* to it is the lowest trunk of the brachial plexus, which separates it from the middle scalene muscle. *Anterior* to it, and at a slightly lower level, lies the subclavian vein. The external jugular vein crosses the medial part of this portion of the artery, and just before its termination it receives the transverse cervical and transverse scapular veins; those vessels also pass superficial to the artery, which is thus covered superficially by venous trunks; it is also crossed vertically, behind the veins, by the nerve to the subclavius muscle. The lateral section of this part of the artery lies posterior to the clavicle and the subclavius muscle. It is crossed anteriorly by the transverse scapular artery, but the layer of deep cervical fascia which binds the posterior belly of the omo-hyoid to the posterior border of the subclavian groove intervenes between the two vessels. More superficially the third part of the artery is covered by the superficial layer of the deep fascia, the supra-clavicular branches of the cervical nerves, the platysma, and the skin.

Abnormalities.—The variations, so far as regards the origins of the subclavian arteries, have already been mentioned (p. 885). Other interesting modifications are met with in respect of its position and branches.

The subclavian artery may reach as high as 25 or 37 mm. (1-1½ in.) above the clavicle, though as a rule it does not reach higher than 19 mm. above that bone. On the other hand, it may not rise even to the level of the upper border of the clavicle. These differences appear to be associated with the descent of the clavicle and sternum, which occurs as age increases.

The artery may pass in front of or through the scalenus anterior instead of behind it, or the vein may accompany it behind the muscle.

The branches of the subclavian artery may be modified with reference to their points of origin; thus, those of the first part may be further medial or lateral than usual, the transverse scapular or some other branch of the thyreo-cervical trunk may arise separately from the third part of the subclavian, and not uncommonly the descending branch of the transverse cervical artery is a branch of that part. The abnormalities of the vertebral branch have already been described; those of the thyreo-cervical trunk and its branches are numerous but not important.

BRANCHES OF THE SUBCLAVIAN ARTERY.

(1) The **vertebral artery** is distributed almost entirely to the head and neck, and its chief function is to supply the posterior part of the brain. Its description has therefore been given with that of the other cerebral arteries (see p. 905).

(2) The **thyreo-cervical trunk** (Figs. 728 and 735) arises close to the medial border of the scalenus anterior, from the upper and front part of the subclavian artery, directly above the origin of the internal mammary artery. After a short upward course of about 4 mm. (two lines), it ends, under cover of the internal jugular vein, by dividing into three branches—viz., the inferior thyreoid, the transverse cervical, and the transverse scapular.

(A) The **inferior thyreoid artery** (Figs. 728, 732) ascends along the anterior border of the scalenus anterior, and turns medially, opposite the cricoid cartilage, to the middle of the posterior border of the corresponding lobe of the thyreoid gland; it then curves medially and downwards, and descends to the lower end of the lobe of the thyreoid gland, where it divides into ascending and inferior terminal branches.

Relations.—*Posterior* are the vertebral artery, and the longus colli muscle; the recurrent nerve passes either anterior or posterior to the vessel, opposite the lower border of the thyreoid gland. It is covered *anteriorly* by the carotid sheath, which contains the common carotid artery, the internal jugular vein, and the vagus nerve; the middle cervical ganglion of the sympathetic lies in front of the artery as it bends medially; and on the left side the thoracic duct also passes in front of it.

Branches.—It gives off the following branches:—

(*a*) **Muscular.**—Numerous small branches pass to the scalenus anterior, the longus colli, the infra-hyoid muscles, and the inferior constrictor of the pharynx.

(*b*) The **ascending cervical** usually springs from the inferior thyreoid near its origin, but it may arise separately from the thyreo-cervical trunk. It ascends, parallel with and medial to the phrenic nerve, in the angle between the longus capitis and the scalenus anterior, to both of which it gives branches. It also gives off spinal branches which pass through the intervertebral foramina to the vertebral canal. It anastomoses with branches of the vertebral, occipital, ascending pharyngeal, and deep cervical arteries.

(*c*) **Œsophageal.** — Small branches given to the walls of the œsophagus, which anastomose with the œsophageal branches of the thoracic aorta.

(*d*) **Tracheal branches** are distributed to the trachea; they anastomose with branches of the superior thyreoid and with the bronchial arteries.

(*e*) An **inferior laryngeal branch** accompanies the recurrent nerve to the lower part of the larynx. It enters the larynx, at the lower border of the inferior constrictor, gives branches to its muscles and mucous membrane, and anastomoses with the laryngeal branch of the superior thyreoid artery.

(*f*) The **ascending terminal branch** supplies the posterior and lower part of the thyreoid gland, and anastomoses with branches of the superior thyreoid artery.

(*g*) The **inferior terminal branch** is distributed to the lower and medial part of the corresponding lobe of the thyreoid gland. It anastomoses with its fellow of the opposite side and with branches of the superior thyreoid artery.

(B) The **transverse cervical artery** (Figs. 728 and 732) arises from the thyreo-cervical trunk and runs upwards and posteriorly across the posterior triangle of the neck to the anterior border of the trapezius; there it divides into a ramus ascendens (O.T. superficial cervical) and a ramus descendens (O.T. posterior scapular). It is very variable in size, and not infrequently the ramus descendens arises separately from the third part of the subclavian.

Immediately after its origin, under cover of the internal jugular vein, it crosses the scalenus anterior, lying superficial to the phrenic nerve and under cover of the sterno-mastoid muscle; on the left side it is also crossed, superficially, by the terminal part of the thoracic duct. Passing from beneath the sterno-mastoid, it enters the lower part of the posterior triangle of the neck, where it lies upon the trunks of the brachial plexus, and as it runs upwards and backwards to its termination it passes medial to the posterior belly of the omo-hyoid.

The ascending branch may be a separate vessel which springs from the thyreo-cervical trunk and takes the course described, whilst the descending branch arises from the third part of the subclavian artery and lies at a lower level. In such cases the upper of the two vessels is called the **superficial cervical artery** and the lower the **transverse cervical artery**. If the superficial cervical artery is absent it is replaced by the ascending branch of the transverse cervical.

Branches.—(*a*) Small **muscular branches** to the surrounding muscles.

(*b*) The **ascending branch**, usually a slender branch, passes beneath the trapezius; it sends branches upwards and downwards, superficial to the levator scapulæ and upon the splenius; the ascending branches anastomose with the descending branch of the occipital artery, and the descending branches accompany the accessory nerve and anastomose with the descending branch and transverse scapular artery.

(*c*) The **descending branch** runs downwards, deep to the levator scapulæ and the rhomboid muscles, close to the vertebral border of the scapula. It runs parallel with, and a short distance away from, the dorsal scapular nerve (O.T. nerve to the rhomboid muscles), and it sends branches into the supraspinous, the infraspinous, and the subscapular fossæ, which anastomose with branches of the transverse scapular and subscapular arteries. It also sends branches backwards, through and between the rhomboid muscles, which anastomose with the branches of the ascending division of the transverse cervical and with the posterior branches of the intercostal arteries.

(C) The **transverse scapular artery** (**O.T. supra-scapular**) springs from the thyreo-cervical trunk and terminates in the infraspinous fossa of the scapula. As a rule it is smaller than the transverse cervical artery.

Commencing behind the internal jugular vein, it crosses the scalenus anterior and phrenic nerve, and is covered superficially by the sterno-mastoid and the anterior jugular vein; on the left side it lies behind the termination of the thoracic duct also. Continuing, laterally, behind the clavicle, and crossing superficial to the third part of the subclavian artery and the cords of the brachial plexus, it reaches the scapular notch and passes over the superior transverse ligament. Then it descends, with the suprascapular nerve, through the supraspinous fossa and deep to the supraspinatus muscle, and after passing through the great scapular notch, deep to the inferior transverse ligament, it enters the infraspinous fossa, where it anastomoses with the circumflex scapular branch of the subscapular artery and with twigs of the descending branch of the transverse cervical artery.

Branches.—(*a*) **Muscular**, to the sterno-mastoid, the subclavius, and the muscles on the dorsum of the scapula.

(*b*) The **medullary**, a small branch to the clavicle.

(*c*) The **suprasternal**, to the sternal end of the clavicle and the sterno-clavicular joint.

(*d*) **Acromial branches**, which ramify over the acromion, anastomosing with the acromial branches of the thoraco-acromial and the posterior circumflex arteries.

(*e*) **Articular**, to the acromio-clavicular and shoulder-joints.

(*f*) The **subscapular**, which is given off as the artery passes over the superior transverse ligament. It passes down into the subscapular fossa, gives branches to the subscapularis, and it anastomoses with the branches of the subscapular artery and the descending branch of the transverse cervical artery.

(*g*) **Supraspinous**, which ramify in the supraspinous fossa, supplying the muscle, and anastomosing with the descending branch of the transverse cervical.

(*h*) **Terminal branches** ramify in the infraspinous fossa, and anastomose with the circumflex scapular and with branches of the descending branch of the transverse cervical artery.

(3) The **internal mammary artery** (Figs. 728, 735) arises from the lower and anterior part of the subclavian, at the medial border of the scalenus anterior and

immediately below the origin of the thyreo-cervical trunk. It terminates, behind the medial extremity of the sixth intercostal space, by dividing into the musculophrenic and the superior epigastric arteries.

The artery passes at first downwards, forwards, and medially, lying upon the pleura, and behind the innominate vein, the sternal extremity of the clavicle, and the cartilage of the first rib; it is crossed obliquely, from the lateral to the medial side, by the phrenic nerve, which usually passes anterior to it. From the cartilage of the first rib it descends vertically, about 12 mm. (half an inch) from the border of the sternum, and lies, in the upper part of its course, in front of the pleura, and, in the lower part, in front of the transversus thoracis muscle. It is covered anteriorly by the cartilages of the upper six ribs, the intervening intercostal muscles, and the terminal portions of the intercostal nerves; and it is accompanied by

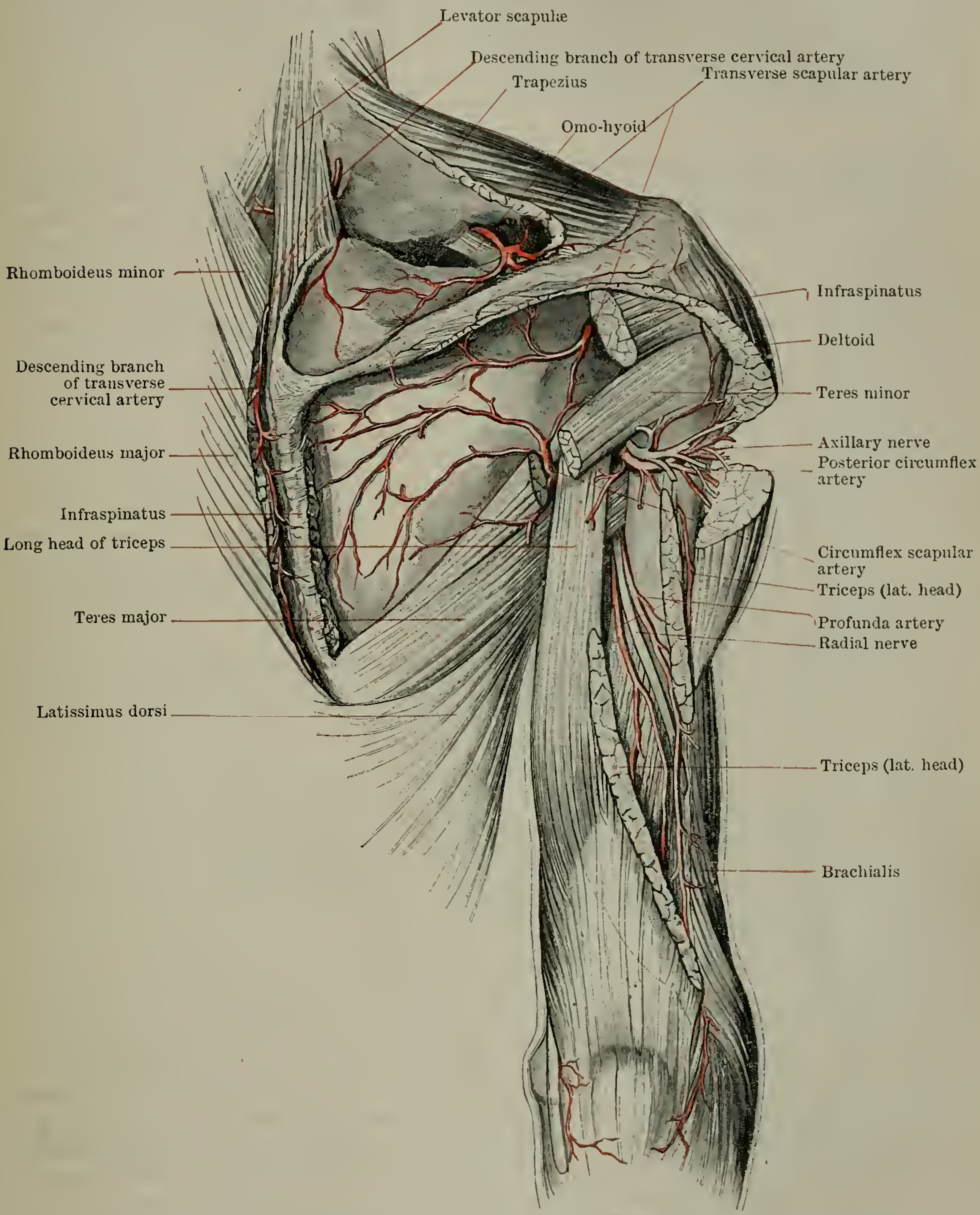

FIG. 740.—DISSECTION OF THE BACK OF THE SHOULDER AND ARM, showing the anastomosing vessels on the dorsum of the scapula, and the posterior humeral circumflex and the profunda arteries.

two venæ comites, which unite together above, and on its medial side, to form a single trunk which terminates in the innominate vein.

Abnormalities.—The internal mammary artery, though usually a branch of the first part of the subclavian, is very variable as regards its origin. It may arise from the second or third parts, or from the thyreo-cervical, or it may spring from the aorta, or from the innominate or axillary arteries. All these variations are due to obliteration of the normal origin and the opening up of anastomoses. The internal mammary artery sometimes descends in front of the cartilages of one or more of the lower true ribs; and occasionally it gives off a large lateral branch (a. mammaria lateralis) which descends on the inner side of the chest wall, close to the mid-axillary line,—a point of importance in paracentesis.

A few cases have also been noticed in which a bronchial artery has arisen from the internal mammary.

Branches.—(*a*) The **pericardiaco-phrenic** (O.T. **comes nervi phrenici**) is a long slender branch which is given off from the upper part of the internal mammary. It accompanies the phrenic nerve, through the superior and middle mediastina, to the diaphragm, where it anastomoses with the inferior phrenic and musculo-phrenic arteries. In its course downwards this branch gives off numerous small rami to the pleura and pericardium, which anastomose with offsets of the mediastinal and pericardial branches of the aorta and internal mammary arteries, and also with the bronchial arteries, forming the wide-meshed *subpleural plexus* of Turner.

(*b*) **Anterior mediastinal branches**, small and numerous, pass to the areolar tissue of the anterior mediastinum and supply the areolar tissue and the sternum.

(*c*) **Thymic.**—Small twigs which supply the thymus.

(*d*) **Bronchial.**—One or several small branches which pass to the lower end of the trachea and to the bronchi.

(*e*) The **intercostal** are two in number in each of the upper six intercostal spaces. They pass laterally and, for a short distance, they lie either between the pleura and the internal intercostal muscles or between the transversus thoracis and the internal intercostal muscles; they then pierce the internal intercostal muscles, and ramify between them and the external intercostal muscles, anastomosing with the aortic and superior intercostal arteries and their collateral branches.

(*f*) The **perforating branches**, one in each of the upper six intercostal spaces, are small vessels which pass forwards, with the anterior branches of the thoracic nerves, piercing the internal intercostal muscle, the anterior intercostal membrane, and the pectoralis major. They terminate in the skin and subcutaneous tissue. They supply twigs to the sternum, and those in the third and fourth spaces, usually the largest of the series, give off branches to the mammary gland.

(*g*) The **musculo-phrenic**, or lateral terminal branch of the internal mammary artery, runs downwards and laterally, from the sixth intercostal space to the tenth costal cartilage. In the upper part of its course it lies upon the thoracic surface of the diaphragm, but it pierces the diaphragm about the level of the eighth costal cartilage, and terminates on its abdominal surface. Its branches are:—

(i.) **Muscular**, which supply the diaphragm and anastomose with the superior and inferior phrenic arteries.

(ii.) **Intercostal branches**, two in each of the seventh, eighth, and ninth intercostal spaces; they are distributed in the same manner as the corresponding branches of the internal mammary artery, and terminate by anastomosing with the aortic intercostals and their collateral branches.

(*h*) The **superior epigastric**, or medial terminal branch of the internal mammary artery, descends into the anterior wall of the abdomen. It leaves the thorax, between the sternal and costal origins of the diaphragm, and enters the sheath of the rectus abdominis muscle, lying first behind, and then in the substance of the muscle. It terminates by anastomosing with branches of the inferior epigastric artery. Its branches are:—

(i.) **Muscular**, to the rectus, to the flat muscles of the abdominal wall, and to the diaphragm.

(ii.) **Anterior Cutaneous.**—Small branches which pierce the rectus abdominis muscle and the anterior portion of its sheath. They accompany the anterior terminal branches of the lower thoracic nerves, and terminate in the subcutaneous tissues and skin of the middle portion of the anterior abdominal wall.

(iii.) **Xiphoid**, a small branch which crosses the front of the xiphoid process to anastomose with its fellow of the opposite side. It supplies the adjacent muscles and skin.

(iv.) **Hepatic branches** of small size pass backwards in the falciform ligament to the liver, where they anastomose with branches of the hepatic artery.

(4) The **costo-cervical trunk** (Fig. 735) springs from the posterior aspect of the second part of the subclavian artery on the right side and from the first part

on the left side. It runs upwards and backwards, over the apex of the pleural sac, to the neck of the first rib, where it divides into superior intercostal and deep cervical branches.

Branches.—(*a*) The **deep cervical** branch sometimes arises from the subclavian artery directly; but more commonly it springs from the costo-cervical trunk at the upper border of the neck of the first rib. It runs backwards, to the back of the neck, passing between the first thoracic and last cervical nerves, and between the transverse process of the last cervical vertebra and the neck of the first rib. In the back of the neck it ascends between the semispinalis capitis (O.T. complexus) and the semispinalis cervicis muscles and it terminates by anastomosing with the descending branch of the occipital artery. It anastomoses also with branches of the ascending cervical and vertebral arteries, supplies the adjacent muscles, and sends a spinal branch, through the intervertebral foramen between the last cervical and the first thoracic vertebræ, into the vertebral canal; this branch anastomoses with the spinal branches of the vertebral and intercostal arteries.

(*b*) The **superior intercostal branch** descends, anterior to the neck of the first rib, between the first thoracic nerve laterally and the first thoracic ganglion of the sympathetic trunk medially and, at the lower border of the neck of the rib, it gives off the posterior intercostal artery of the first space; then, after crossing anterior to the neck of the second rib, it becomes the posterior intercostal artery of the second intercostal space. The first two posterior intercostal arteries, which are respectively a branch and the continuation of the superior intercostal artery, run laterally, each in its own space, lying first between the pleura and the posterior intercostal membrane, and then between the internal and external intercostal muscles. Their branches terminate by anastomosing with anterior intercostal branches of the internal mammary artery. Each gives off *muscular* branches to the intercostal muscles, a *nutrient branch* to the rib below which it lies, and a *collateral branch* which runs along the lower border of the corresponding space.

Abnormalities.—The **superior intercostal branch** of the costo-cervical trunk may be absent, and the profunda cervicis branch may arise directly from the subclavian trunk. The superior intercostal is sometimes formed from a postcostal instead of a precostal primitive channel. In such cases it passes between the necks of the ribs and the transverse processes of the vertebræ instead of, as usual, in front of the necks of the ribs.

ARTERIA AXILLARIS.

The **axillary artery**, which lies in the axillary space, is the direct continuation of the subclavian artery, and it becomes the brachial artery.

It commences at the external border of the first rib, at the apex of the axillary space. It passes distally, with a lateral inclination, along the lateral wall of the space, *i.e.* to the medial side of the shoulder-joint and the humerus, to the lower border of the teres major, where it becomes the brachial artery. A line drawn from the middle of the clavicle to the medial border of the prominence of the coracobrachialis muscle, when the arm is abducted until it is at right angles with the side, indicates the position and direction of the artery.

The position and direction, however, and to a certain extent the relations of the axillary artery, are modified by changes in the position of the upper extremity. With the arm hanging by the side the axillary artery describes a curve with the concavity directed downwards and medially, and the vein is to its medial side. When the arm is at right angles with the side, the axillary artery is almost straight; it lies closer to the lateral wall of the axilla, and the vein overlaps it antero-medially. When the arm is raised above the level of the shoulder the axillary artery is curved over the head of the humerus, with the convexity of the curve below, and the vein lies still more in front of it.

For descriptive purposes the artery is divided into three parts: the first part lies above, the second behind, and the third part below the pectoralis minor.

Though it is the usual custom to describe three parts of the axillary artery,—a division which is of practical interest in so far as it emphasises the fact that the axillary artery is surgically accessible above the pectoralis minor,—it is to be noted that the upper border of the pectoralis minor is frequently exactly opposite the external border of the first rib, at the point where the axillary artery begins. In the strict sense, therefore, no part of the artery is above the pectoralis minor.

Relations of the First Part—*Posterior.*—The first part of the artery is enclosed, together with the vein and the cords of the brachial plexus, in a prolongation of the cervical fascia known as the axillary sheath. Posterior to the sheath are the upper serration of the serratus anterior, the contents of the first intercostal space, and the long thoracic nerve, the latter descending vertically between the artery and the serratus anterior; whilst, within the sheath, the medial anterior thoracic nerve and the medial cord of the brachial plexus lie behind the artery. *Anterior.*—It is covered in front by the costo-coracoid membrane. The membrane intervenes between the artery and the cephalic vein, the branches of the lateral anterior thoracic nerve, the branches of the thoraco-acromial artery with their accompanying veins, and the clavicular part of the pectoralis major muscle, superficial to which are the deep fascia, the platysma, the supra-clavicular branches of the cervical plexus, and the superficial fascia and the skin. Posterior to the costo-coracoid membrane the artery is crossed by a loop of communication between the lateral and medial anterior thoracic nerves. *Lateral.*—Above and to the lateral side are the lateral and posterior cords of the brachial plexus and the lateral anterior thoracic nerve. Below and to the medial side is the axillary vein, the medial anterior thoracic nerve intervening.

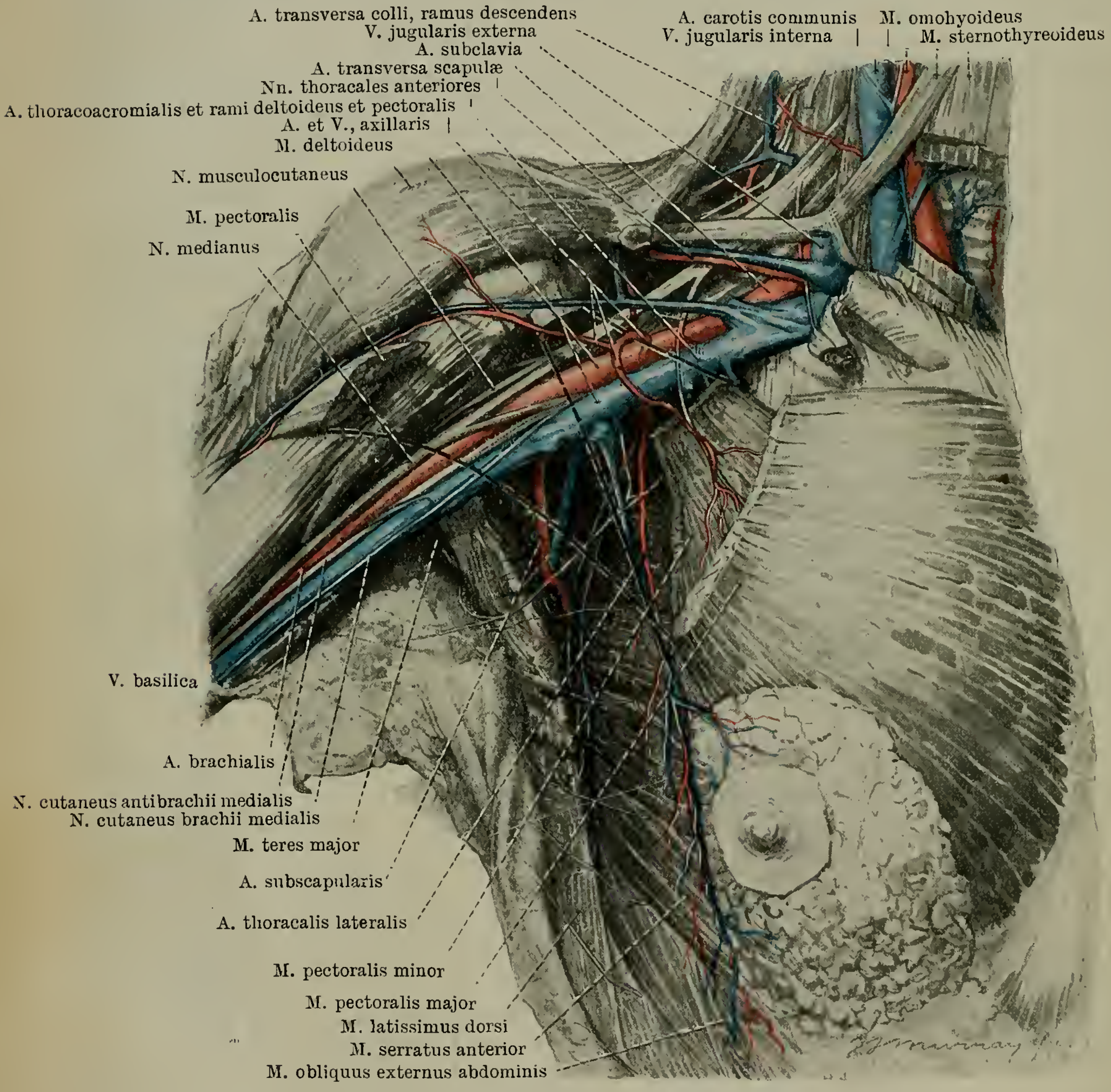

Fig. 741.—The Axillary Artery and its Branches.

Note.—The middle third of the clavicle has been removed; and the arm has been slightly abducted and rotated laterally. Parts of the pectoralis major and minor have been removed; the positions of the lower border of the pectoralis major and the upper and lower borders of the pectoralis minor are indicated by broken black lines.

Relations of the Second Part—*Posterior.*—Behind the second part of the artery are the posterior cord of the brachial plexus and a layer of fascia which separates it from the subscapularis muscle. *Anterior.*—In front is the pectoralis minor, and, more superficially, the pectoralis major, the fasciæ and skin. *Lateral.*—To the lateral side lies the lateral cord of the brachial plexus. *Medial.*—On the medial side the medial cord of the plexus lies in close relation to the artery, and intervenes between it and the axillary vein.

Relations of the Third Part—*Posterior.*—The third part of the artery rests posteriorly upon the lower border of the subscapularis, the latissimus dorsi, and the teres major. It is separated from the fibres of the subscapularis by the axillary (O.T. circumflex) and radial (O.T. musculo-spiral) nerves, and from the latissimus dorsi and teres major by the radial nerve alone. *Anterior.*—It is crossed in front by the medial head of the median nerve. In its upper half it lies under cover of the lower part of the pectoralis major, the fasciæ and skin, whilst its lower part, which is superficial, is covered by skin and fasciæ only. *Lateral.*—To the lateral side lie the median and musculo-cutaneous nerves and the coraco-brachialis muscle. *Medial.*—To the medial side is the axillary vein. The two vessels are, however, separated by two of the chief branches of the medial cord of the brachial plexus, for in the angle between the vein and the artery, and somewhat in front of the latter, lies the medial cutaneous nerve of the forearm (O.T. internal cutaneous nerve); and in the angle behind is the ulnar nerve. The medial cutaneous nerve of the arm (O.T. lesser internal cutaneous) lies medial to the vein, and the venæ comites of the brachial artery ascend along the medial side, to terminate in the axillary vein at the lower border of the subscapularis muscle.

Abnormalities.—The **axillary artery** does not vary much as regards its origin or course. Its relations may be modified by the existence of a muscular or tendinous "axillary arch," which, passing from the latissimus dorsi to the pectoralis major, crosses the distal part of the artery superficially; and a further interesting modification is associated with an anomalous arrangement of its branches. Occasionally the subscapular, circumflex, and profunda and superior ulnar collateral arteries arise from the axillary by a common stem. In those cases the chief branches of the brachial plexus are grouped round the common stem instead of round the main trunk. The arrangement is due to the persistence of a different part of the original vascular plexus.

Sometimes the axillary artery divides into the radial and ulnar arteries, and more rarely the interosseous artery may spring from it.

Obviously there is no brachial artery when the radial and ulnar arteries are formed by the division of the axillary; its place is taken by the two abnormal vessels which, as a rule, are separated by the median nerve as they run through the arm; the radial is usually more superficial than the ulnar, and crosses laterally in front of it at the bend of the elbow.

Branches of the Axillary Artery.

(1) **Arteria Thoracalis Suprema.**—The **highest thoracic artery** is a small branch which arises from the first part of the axillary at the lower border of the subclavius. It runs downwards and medially, across the first intercostal space, pierces the medial part of the costo-coracoid membrane, and supplies branches to the subclavius, the pectoralis major and minor, and to the serratus anterior (O.T. magnus) and the intercostal muscles; it anastomoses with branches of the transverse scapular, the internal mammary, and the thoraco-acromial arteries.

(2) The **thoraco-acromial artery** (Fig. 741) arises near the upper border of the pectoralis minor, from the second part of the axillary artery. It is a very short trunk, of considerable size, which passes forwards, pierces the costo-coracoid membrane, and terminates, deep to the clavicular portion of the pectoralis major, by dividing into four terminal branches—clavicular, pectoral, deltoid, and acromial.

(*a*) The **clavicular branch** is a long slender artery which runs upwards and medially, to the sterno-clavicular joint, anastomosing with the supreme thoracic, with branches of the transverse scapular, and with the first perforating branch of the internal mammary artery. It supplies the adjacent muscles and the sterno-clavicular articulation.

(*b*) The **pectoral** is a large branch which descends between the two pectoral muscles, to both of which it gives branches, and it anastomoses with the intercostal and lateral thoracic arteries.

(*c*) The **deltoid branch** runs distally, in the groove between the pectoralis major and the deltoid, where it lies by the side of the cephalic vein, as far as the insertion of the deltoid. It anastomoses with the acromial branch and with the anterior circumflex artery, and it gives branches to the pectoralis major and deltoid muscles and to the skin.

(*d*) The **acromial branch** runs upwards and laterally, across the tip of the coracoid process, to the acromion; it anastomoses with the deltoid branch, with the acromial branches of the transverse scapular, and with the posterior circumflex arteries. It gives branches to the deltoid.

(3) The **lateral thoracic artery** arises from the second part of the axillary, and descends, along the lower border of the pectoralis minor, to anastomose with the intercostal and subscapular arteries and with the pectoral branch of the thoraco-acromial. It supplies the adjacent muscles, and sends mammary branches to the lateral part of the corresponding mammary gland.

(4) The **subscapular artery** is the largest branch of the axillary artery. It arises from the third part of the artery, opposite the lower border of the subscapularis, along which it descends, giving branches to the muscle and to the medial wall of the axillary space. After a short course it divides into two terminal branches, the circumflexa scapulæ and the thoraco-dorsalis.

(1) The **circumflexa scapulæ** is frequently the larger branch. It arises about 37 mm. (one and a half inches) from the commencement of the subscapular trunk, and passes backwards into the triangular space which lies between the subscapularis above, the teres major below, and the long head of the triceps laterally. Turning round, and usually grooving the axillary border of the scapula, under cover of the teres minor, it enters the infraspinous fossa, where it breaks up into branches which anastomose with branches of the descending branch of the transverse cervical artery and the transverse scapular arteries. Whilst it is in the triangular space the artery gives off an *infrascapular branch* which passes into the subscapular fossa and terminates by anastomosing with the branches of the descending branch of the transverse cervical and the transverse scapular arteries. It gives off, in the same situation, a descending branch also, which runs downwards, to the lower angle of the scapula, between the teres major and minor muscles, and small branches are given to the deltoid and long head of triceps.

(2) The thoraco-dorsal continuation of the subscapular trunk accompanies the thoraco-dorsal nerve (O.T. long subscapular) along the axillary border of the scapula to the wall of the thorax, where it anastomoses with the lateral thoracic artery and with branches of the intercostal arteries.

(5) The **posterior humeral circumflex artery** arises from the third part of the axillary artery and passes backwards, accompanied by the axillary nerve, through an intermuscular cleft, the so-called quadrilateral space, which is bounded by the teres minor and subscapularis above, the teres major below, the long head of the triceps medially, and the humerus laterally. It turns round the surgical neck of the humerus, under cover of the deltoid muscle, and terminates in numerous branches which supply the deltoid. As a rule it is an artery of large size, only slightly smaller than the subscapular.

Branches.—(*a*) **Muscular** to the teres major and minor, the long and lateral heads of the triceps, and the deltoid; (*b*) An **acromial branch,** which ascends to the acromion, where it anastomoses with the acromial branches of the transverse scapular and the thoraco-acromial arteries; (*c*) A **descending branch,** which runs distally, along the lateral head of the triceps, to anastomose with the profunda artery; (*d*) **Articular** to the shoulder-joint; (*e*) **Nutrient** to the head of the humerus; (*f*) **Terminal,** which supply a large portion of the deltoid, and anastomose with the anterior circumflex and thoraco-acromial arteries.

(6) The **anterior humeral circumflex artery** is a small branch; it is given off from the third part of the axillary close to, or in common with, the posterior circumflex. It passes laterally, posterior to the coraco-brachialis and the two heads of the biceps, round the front of the surgical neck of the humerus, and it terminates by anastomosing with the posterior circumflex. At the intertubercular groove it gives a well-marked branch which accompanies the tendon of the long head of the biceps, supplying the sheath of the tendon, and giving branches to the shoulder-joint. It also gives muscular branches to the adjacent muscles, one of which runs distally along the tendon of insertion of the pectoralis major.

ARTERIA BRACHIALIS.

The **brachial artery** is the direct continuation of the axillary. It commences at the lower border of the teres major, and ends, in the cubital fossa, at the level of the neck of the radius, by dividing into the radial and ulnar arteries.

The general course of the brachial artery is distally and laterally, along the *medial* side of the arm, at first on the medial side and then in front of the humerus. Its position and that of the axillary artery may be indicated on the surface, when the arm is abducted, by a line drawn from the middle of the clavicle to the centre of the bend of the elbow.

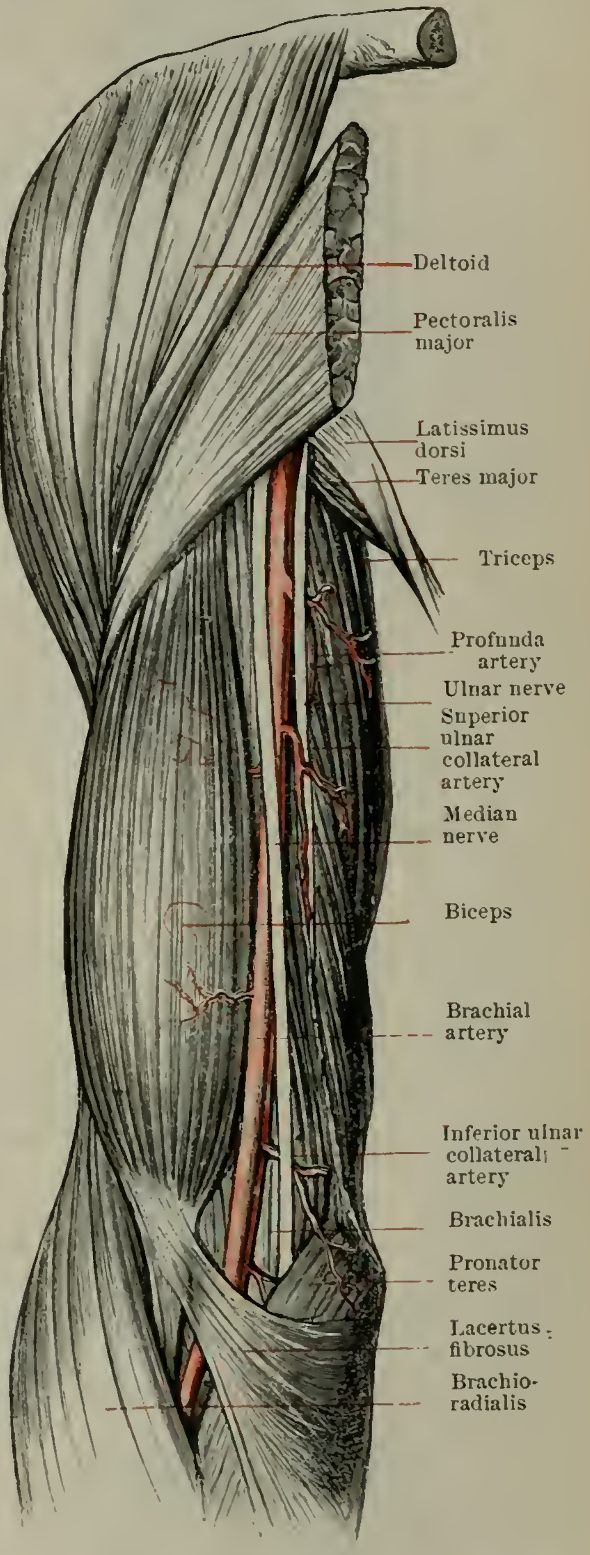

Fig. 742.—The Brachial Artery and its Branches.

Relations—*Posterior.*—It lies, successively, anterior to the long head of the triceps, the radial nerve and the profunda vessels intervening; the medial head of the triceps; the insertion of the coraco-brachialis; and the brachialis. *Anterior.*—It is overlapped *anteriorly* by the medial border of the biceps; it is crossed, at the middle of the arm, by the median nerve, and, in addition, it is covered by deep and superficial fascia and skin. In the cubital fossa a thickened portion of the deep fascia, the lacertus fibrosus (O.T. semilunar or bicipital fascia), separates it from the median basilic vein and the volar branch of the medial cutaneous nerve of the forearm, both of which lie in the superficial fascia. *Lateral.*—To the *lateral side* it is in relation, proximally, with the median nerve, and, distally, with the biceps. *Medial.*—To the *medial side* it is in relation, in the proximal part of its extent, with the basilic vein, the medial cutaneous nerve of the forearm, the medial cutaneous nerve of the arm, and the ulnar nerve, and in the distal part with the median nerve. Two venæ comites, a medial and a lateral, accompany the artery, and communications between these pass across the vessel.

Abnormalities.—The brachial artery is rarely prolonged beyond its usual point of bifurcation; not uncommonly, however, it bifurcates at a more proximal level. Of the two terminal branches of the brachial, one may divide into radial and interosseous, the other forming the ulnar; or one may divide into radial and ulnar, whilst the other is the interosseous artery. Occasionally the brachial artery terminates by dividing into three branches—viz., the radial, the ulnar, and the interosseous. In any case, the branch which gives origin to or becomes the interosseous was, in all probability, the original trunk.

Division of the brachial artery at a more proximal level than usual occurs most commonly in the proximal third of the arm, and least commonly in the distal third; the resulting trunks are often united near the bend of the elbow by a more or less oblique anastomosis.

In cases of proximal division of the brachial artery the radial branch may pierce the deep fascia of the arm near the bend of the elbow, and passes distally in the forearm immediately deep to the skin; in other cases the radial runs deeper, and passes behind the tendon of the biceps. The ulnar branch sometimes runs, on the medial intermuscular septum, towards the medial epicondyle, and then laterally towards the middle of the bend of the elbow, under a band of fascia from which the proximal fibres of the pronator teres arise, or round the supracondylar process of the humerus if it is present. More commonly the ulnar branch runs distally towards the medial epicondyle, and crosses superficial to the flexor muscles or deep to the palmaris longus; and in a few cases it is subcutaneous. In rare cases the ulnar artery accompanies the ulnar nerve behind the medial epicondyle; in those cases it has obviously been formed by enlargement of the ordinary superior ulnar collateral and dorsal ulnar recurrent arteries.

Instead of following its usual course along the brachialis muscle, the brachial artery may accompany the median nerve behind a supracondylar or epicondylic process, or ligament, as in many carnivora; it may pass in front of the median nerve instead of behind it. It may give off a "vas aberrans" or a median artery, and any of its ordinary branches may be absent.

The vas aberrans given off from the brachial artery usually ends in the radial artery, sometimes in the radial recurrent, and rarely in the ulnar artery.

Branches of the Brachial Artery.

(1) The **profunda artery** of the arm is a large branch which arises from the postero-medial aspect of the brachial, soon after its commencement. It runs distally and laterally, with the radial nerve, in the radial sulcus and divides, at the back of the humerus, into two terminal branches, anterior and posterior. Not infrequently the division takes place at a higher level, and the artery appears double. The anterior terminal branch accompanies the radial nerve through the lateral intermuscular septum, and passes distally, between the brachio-radialis and the brachialis, to the front of the lateral epicondyle, where it anastomoses with the radial recurrent artery. The posterior terminal branch continues distally, behind the lateral intermuscular septum, and anastomoses, posterior to the lateral epicondyle, with the interosseous recurrent artery and with the inferior ulnar collateral artery.

Whilst they are posterior to the humerus one of the terminal branches gives off—(*a*) a slender *medial collateral twig*, which descends in the substance of the medial head of the triceps to the back of the elbow, where it anastomoses with the inferior ulnar collateral artery; (*b*) a *nutrient branch*, which enters a foramen on the posterior surface of the humerus; and (*c*) an *ascending branch*, which anastomoses with the descending branch of the posterior circumflex artery.

(2) **Muscular branches** are given to the biceps, coraco-brachialis, brachialis, triceps, and pronator teres.

(3) **Nutrient.**—A small artery which arises from the middle of the brachial and enters the nutrient foramen on the antero-medial surface of the body of the humerus.

(4) The **superior ulnar collateral artery** is smaller than the profunda, with which it sometimes arises by a common trunk; usually, however, it springs from the postero-medial aspect of the middle of the brachial artery. It runs distally and posteriorly, with the ulnar nerve, through the medial intermuscular septum, and then, passing more vertically, reaches the back of the medial epicondyle of the humerus, where it terminates by anastomosing with the dorsal and volar ulnar recurrent and inferior ulnar collateral arteries.

(5) The **inferior ulnar collateral artery** arises from the medial side of the brachial artery about 50 mm. (2 inches) above its termination. It runs medially, posterior to the median nerve and anterior to the brachialis. Then it pierces the medial intermuscular septum, and turns laterally, between the medial head of the triceps and the posterior surface of the bone, to the lateral epicondyle. It supplies the adjacent muscles and anastomoses, anterior to the medial epicondyle, with the volar ulnar recurrent, behind the medial epicondyle with the dorsal ulnar recurrent and the superior ulnar collateral, at the middle of the back of the humerus with the medial collateral branch of the profunda, and posterior to the lateral epicondyle with the posterior terminal branch of the profunda and with the interosseous recurrent artery.

ARTERIA RADIALIS.

The **radial artery** (Figs. 743 and 744) is the smaller of the two terminal branches of the brachial artery, but it is the more direct continuation of the parent trunk. It commences, in the cubital fossa, opposite the neck of the radius, and terminates in the palm of the hand, by anastomosing with the deep branch of the ulnar artery, and thus completing the deep volar arch (O.T. palmar).

The trunk is divisible into **three parts.**

The *first part* lies in the volar part of the forearm. It runs distally and somewhat laterally to the apex of the styloid process of the radius. The *second part* curves round the lateral side of the wrist, and across the back of the os multangulum majus, to reach the proximal end of the first interosseous space. The *third part* passes volarwards, through the first interosseous space, to the palm of the hand, where it joins the deep branch of the ulnar artery.

Relations of the First Part—*Dorsal.*—It passes successively across the volar aspects of the following structures: the tendon of insertion of the biceps, the supinator, the pronator teres, the radial portion of the flexor digitorum sublimis, the flexor pollicis longus, the pronator quadratus, and the volar ligament of the wrist-joint.

Volar.—The artery is covered superficially, in the proximal half, by the volar border of the brachioradialis; in the remainder of its extent it is covered only by skin and fasciæ.

To the *radial side* are the brachioradialis and the superficial branch of the radial nerve. The nerve lies quite near to the middle third of the artery. To the *ulnar side* are the pronator teres, proximally, and the flexor carpi radialis, distally. Two venæ comites, one on each side, accompany the artery.

Branches of the First Part.—(1) The **radial recurrent** arises in the cubital fossa where it springs from the lateral side of the radial, on the volar surface of the supinator. It runs towards the radial border of the forearm, passes between the superficial and deep divisions of the radial (musculo-spiral) nerve, and then runs proximally to the lateral epicondyle of the humerus, where it anastomoses with the anterior terminal branch of the profunda. The radial recurrent supplies numerous muscular branches to the brachio-radialis, the supinator, the extensor carpi radialis longus, and the extensor carpi radialis brevis.

(2) **Muscular branches** to the muscles on the radial side of the volar aspect of the forearm.

(3) The **superficial volar branch** (Fig. 743) is a slender vessel which arises a short distance proximal to the wrist and runs distally across the ball of the thumb. It usually pierces the superficial muscles of the thenar eminence, and terminates either in their substance or by uniting with the ulnar artery and completing the superficial arch of the palm of the hand.

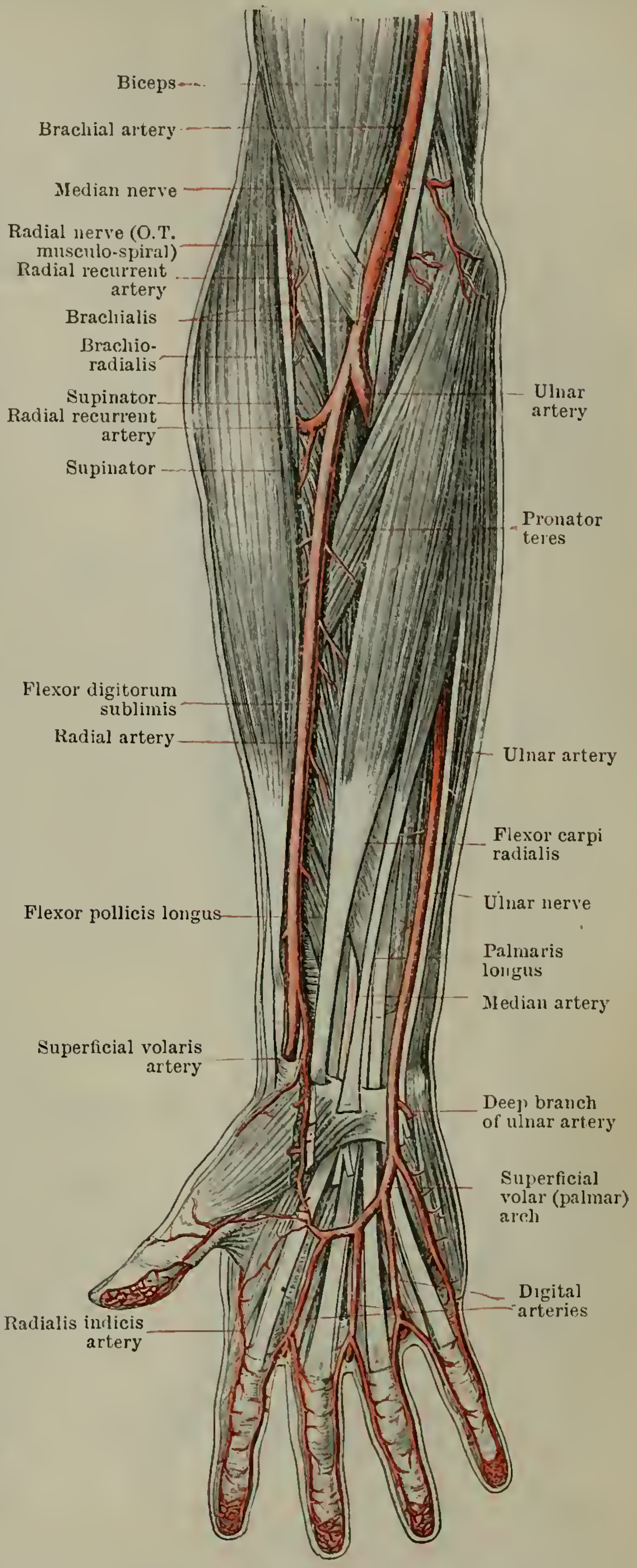

Fig. 743.—Superficial Dissection of the Volar Aspect of the Forearm and Hand, showing the radial and ulnar arteries and the superficial volar arch with its branches.

(4) A **volar carpal branch** passes ulnarwards, between the flexor tendons and their synovial sheaths, and the radial attachments of the volar carpal ligaments. It anasto-

moses with the volar carpal branch of the ulnar artery to form the volar carpal arch. and it receives communications from the volar interosseous artery and from the deep volar arch.

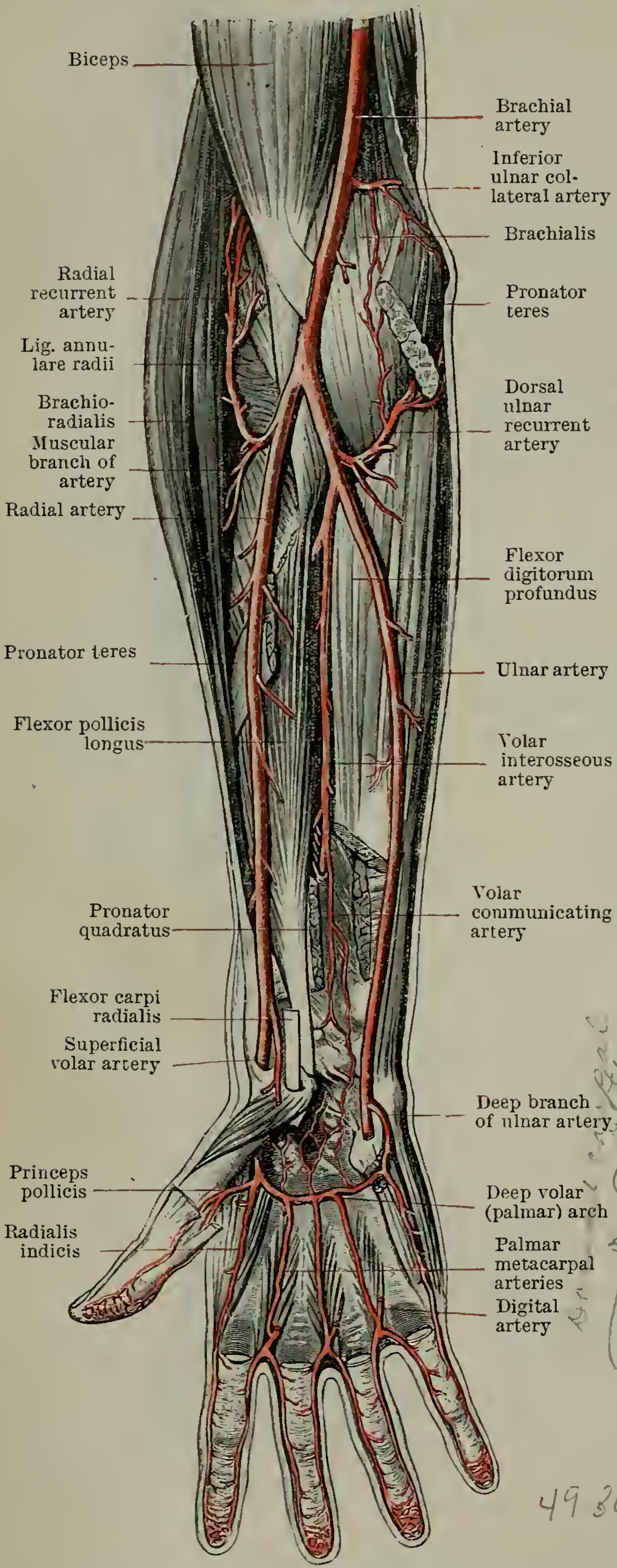

Fig. 744.—Deep Dissection of the Front of the Forearm and Hand, showing the radial and ulnar arteries and their branches and the deep volar arch and its branches.

49 30

Relations of the Second Part.—As it curves round the radial side and the dorsum of the wrist, the radial artery lies upon the radial collateral ligament of the intercarpal joint and upon the back of the os multangulum majus. It is crossed by the abductor pollicis longus, the extensor pollicis brevis, and the extensor pollicis longus; more superficially it is covered by skin, and by fascia, which contains the cephalic vein and some filaments of the superficial branch of the radial nerve.

Branches of the Second Part—(1) **Dorsales Pollicis.**—Two small arteries which run along the borders of the dorsal aspect of the thumb; they supply the skin, tendons, and joints, and anastomose with the volar digital arteries.

(2) **Dorsalis Indicis Radialis.**—A slender artery which runs distally, on the ulnar head of the first dorsal interosseous muscle and along the dorsal aspect of the radial border of the index-finger.

(3) and (4) The **first dorsal metacarpal** and the **dorsal radial carpal** arise by a common trunk which crosses deep to the extensor pollicis longus.

(*a*) The metacarpal branch passes distally, on the dorsal aspect of the second dorsal interosseous muscle, and divides, opposite the heads of the metacarpal bones, into two dorsal digital branches which supply the adjacent sides of the index and middle fingers. (*b*) The dorsal carpal branch runs ulnarwards, on the dorsal carpal ligaments, deep to the extensor tendons, to anastomose with the dorsal carpal branch of the ulnar artery, and to complete the **dorsal carpal arch** which receives the terminations of the volar and dorsal interosseous arteries. The dorsal carpal arch gives off the **second and third dorsal metacarpal arteries**, which run distally, on the dorsal aspects of the third and fourth dorsal interosseous muscles, as far as the heads of the metacarpal bones, where each divides into two dorsal digital branches for the adjacent sides of the third and fourth and the fourth and fifth digits, respectively. Each dorsal metacarpal artery is connected with the deep volar (palmar) arch by a **proximal perforating branch** which passes through the proximal part of the corresponding interosseous space, and with a digital branch from the superficial volar (palmar) arch by a **distal perforating branch** which passes through the distal part of the space.

Relations of the Third Part.—The third part of the radial artery passes volarwards, between the two heads of the first dorsal interosseous muscle, to reach the palm, where it turns ulnarwards, deep to the proximal oblique part of the adductor muscle of the thumb, and, after passing through the proximal fibres of the transverse part of the adductor pollicis, or between the adjacent borders of the oblique and transverse parts of that muscle, it unites with the deep branch of the ulnar artery, completing the deep volar (palmar) arch.

Branches of the Third Part.—(1) The **princeps pollicis** branch is given off as soon as the radial artery enters the palm. It runs distally, on the volar aspect of the first metacarpal bone, between the adductor and the opponens pollicis, and under cover of the long flexor tendon, and divides, near the distal end of the bone, into collateral branches which run along the sides of the thumb and anastomose with the dorsales pollicis arteries.

(2) The **arteria volaris indicis radialis** is a branch which runs distally between the ulnar head of the first dorsal interosseous muscle and the adductor of the thumb and along the radial side of the index-finger to its tip. It supplies the adjacent tissues, and not uncommonly it anastomoses with the superficial volar (palmar) arch.

Abnormalities.—The **radial artery** may be absent, its place being taken by branches of the ulnar or interosseous arteries; it may arise, more proximal than usual, from the axillary, or from the brachial. It may terminate in muscular branches in the volar part of the forearm, or as the superficial volar, or in carpal branches; the distal portion of the artery, in those cases, is usually replaced by branches of the ulnar or interosseous arteries. Occasionally the radial divides some distance proximal to the wrist into two terminal branches, one of which gives off the carpal branches, and becomes the superficial volar, whilst the other crosses superficial to the extensor tendons and passes to the dorsum of the wrist.

The radial artery may run a superficial course, or, and especially when it commences at a more distal level than usual, it may pass deep to the pronator teres and the radial origin of the flexor digitorum sublimis. In some cases it passes to the dorsum of the wrist across the brachioradialis, and in others it lies superficial, instead of deep, to the extensor tendons of the thumb.

Its branches may be diminished or increased in number. The radial recurrent may spring from the brachial or ulnar arteries, or may be represented by several branches from the proximal part of the radial. The dorsal artery of the index digit may be large, and may replace the princeps pollicis and the volaris indicis radialis. On the contrary, the dorsal carpal artery and dorsal digital branches of the radial may be small, or the former may be replaced by branches of the metacarpal arteries, and the latter by the proximal perforating branches of the deep volar arch.

The **princeps pollicis** and **volaris indicis radialis** arteries may be absent, their places being taken either by branches of the superficial volar arch or by the dorsalis indicis radialis artery.

The **superficial volar arch** is sometimes absent; its branches are then given off from the deep arch. On the other hand, it may be larger than normal, and it may be completed on the radial side by the volaris indicis radialis, the princeps pollicis, or the comes nervi mediani arteries.

The **deep volar arch** is much more rarely absent than the superficial arch. When absent its branches are supplied by the superficial arch, the proximal perforating arteries, or the volar carpal arch.

ARTERIA ULNARIS.

The **ulnar artery** (Figs. 743 and 744) is the larger terminal branch, but the less direct continuation of the brachial artery. It commences in the cubital fossa, opposite the neck of the radius, and terminates in the palm of the hand, where it anastomoses with the superficial volar artery to form the superficial volar (palmar) arch.

From its origin it runs obliquely, distally and ulnarwards, deep to the muscles arising from the medial epicondyle, to the junction of the proximal and middle thirds of the forearm, where it comes into relation with the ulnar nerve; it then passes directly distally, on the radial side of the ulnar nerve, to the wrist; crosses anterior to the main part of the transverse carpal ligament, on the radial side of the pisiform bone, and enters the palm of the hand to form the main part of the superficial volar (palmar) arch.

Relations—*Dorsal.*—Proximo-distally it lies volar to the distal part of the brachialis, the flexor digitorum profundus, and the transverse carpal ligament. *Volar.*—On its volar aspect it is crossed, in the oblique part of its course, by the pronator teres, the median nerve, which is separated from the artery by the deep head of the pronator teres, the flexor digitorum sublimis, the flexor carpi radialis, and the palmaris longus. In the middle third of the forearm it is overlapped by the volar border of the flexor carpi ulnaris, and in the distal third it is covered by skin and fasciæ only. A short distance proximal to the wrist the palmar cutaneous branch of the ulnar nerve lies volar to it, and as it crosses the transverse carpal ligament, it is bound down by a fascial expansion from the tendon of the flexor carpi ulnaris. Two venæ comitcs, which frequently communicate with one another, lie one on each side of the artery. On the *radial side* there is also, in its distal two-thirds, the flexor digitorum sublimis. On its *ulnar side* are the flexor carpi ulnaris and the ulnar nerve.

Branches.—(1) The **volar ulnar recurrent** is a small branch which arises in the cubital fossa, frequently in common with the dorsal ulnar recurrent. It passes proximally, to the anterior aspect of the medial epicondyle, under cover of the pronator teres, and anastomoses with branches of the superior and inferior ulnar collateral arteries.

(2) The **dorsal ulnar recurrent branch**, larger than the volar, arises in the cubital fossa, from the ulnar side of the ulnar artery, and ascends, on the brachialis and under cover of the muscles which arise from the medial epicondyle, to the posterior aspect of that prominence, where it passes between the humeral and olecranoid heads of the flexor carpi ulnaris, and anastomoses with the superior and inferior ulnar collateral arteries. It gives branches to the adjacent muscles and to the elbow-joint.

(3) The **common interosseous artery**, a short trunk which springs from the radial and dorsal aspect of the ulnar artery, in the distal part of the cubital fossa. It passes dorsally, towards the proximal border of the interosseous membrane, and divides into volar and dorsal interosseous branches.

(3*a*) The **volar interosseous artery** runs distally, on the volar surface of the interosseous membrane, between the adjacent borders of the flexor pollicis longus and the flexor digitorum profundus, to the proximal border of the pronator quadratus; there it pierces the interosseous membrane, and continues distally, first on the dorsal surface of the membrane, deep to the extensor pollicis longus and extensor indicis proprius, and then on the dorsal surface of the radius, in the groove for the extensor digitorum communis; and it terminates, on the dorsum of the carpus, by joining the dorsal carpal arch. It is accompanied on the volar aspect of the interosseous membrane by the volar interosseous nerve, and, after it has pierced the membrane, by the dorsal interosseous nerve.

Branches.—(*a*) **Nutrient** to the radius and ulna; (*b*) **Muscular** to the adjacent muscles; (*c*) The **volar communicating**, a slender branch which passes distally, deep to the pronator quadratus and on the volar surface of the interosseous membrane, to anastomose with the volar carpal arch; (*d*) Small **anastomotic branches** are given off, on the dorsum of the forearm, to anastomose with the dorsal interosseous artery; (*e*) The **median artery** (**O.T comes nervi mediani**) is a long slender branch which arises from the proximal part of the volar interosseous artery and runs with the median nerve to the palm, where it anastomoses with recurrent branches of the superficial volar arch.

(3*b*) The **dorsal interosseous artery** is usually smaller than the volar interosseous. It passes dorsally between the proximal border of the interosseous membrane and the oblique cord, and then between the supinator and abductor pollicis longus, after which it runs distally, between the superficial and deep muscles on the dorsum of the forearm, to the wrist. At the wrist it anastomoses with the volar interosseous artery and with the dorsal carpal arch. As it crosses the abductor pollicis longus it is accompanied by the dorsal interosseous nerve, but in the remainder of its course it is separated from the nerve by the deep muscles.

Branches.—(*a*) An **interosseous recurrent** branch is given off at the dorsal margin of the distal border of the supinator. It runs proximally, on the dorsal surface of the supinator, under cover of the anconæus, to the back of the lateral epicondyle of the humerus, where it anastomoses with the posterior terminal branch of the profunda and with branches of the inferior ulnar collateral artery. (*b*) **Muscular branches** to both superficial and deep muscles on the dorsum of the forearm. (*c*) **Cutaneous branches** to the skin on the dorsum of the forearm and the wrist.

(4) The **volar carpal** branch of the ulnar artery is a small branch, given off proximal to the transverse carpal ligament; it passes towards the radial side, deep to the flexor tendons and their sheaths, on the volar surface of the proximal attachments of the volar radio-carpal ligament, and anastomoses with the volar carpal branch of the radial to form the volar carpal arch.

(5) The **dorsal carpal branch** of the ulnar artery arises from the ulnar side of the ulnar artery, immediately proximal to the pisiform bone. It passes dorsally, deep to the ulnar flexor and the ulnar extensor of the carpus, to the dorsum of the carpus, where it unites with the dorsal carpal branch of the radial to form the dorsal carpal arch.

(6) **Profunda.**—This branch passes distally between the abductor and flexor brevis digiti quinti, and, turning towards the radial side, deep to the flexor brevis, the opponens digiti quinti, and the long flexor tendons and their sheaths, it joins the termination of the radial artery to complete the deep volar (palmar) arch.

Abnormalities.—The **ulnar artery** may be absent, being replaced by the median artery or the interosseous artery, and it may terminate in the deep instead of in the superficial volar arch.

It rarely arises more distally than usual, and when it arises at a more proximal point it most commonly passes superficial to the muscles which spring from the medial epicondyle. Moreover, in those cases it frequently has no interosseous branch, the latter vessel springing from the radial artery and in all probability variations of this description are produced by the ulnar artery taking origin from the main trunk, which is represented by the radio-interosseous vessel, at a more proximal level than usual. Even when it commences in the usual way the ulnar artery may pass superficial to the muscles arising from the medial epicondyle, and in those cases its interosseous and recurrent branches spring from the radial artery.

The volar and dorsal interosseous arteries may arise separately from the ulnar instead of by a common interosseous trunk. The recurrent branches of the ulnar may spring from the interosseous, and the interosseous itself may be a branch of the radial.

The small median artery, the companion artery of the median nerve, usually a branch of the volar interosseous, may spring from the axillary, brachial, or ulnar arteries; it may be much larger than usual, and it may terminate either by breaking up into digital branches, or by joining one or more digital branches of the superficial volar arch or the arch itself.

THE ARTERIAL ARCHES OF THE WRIST AND HAND.

The Volar Carpal Arch (Figs. 743 and 744).—The volar carpal arch lies on the volar aspect of the volar carpal ligaments, deep to the long flexor tendons and their synovial sheaths. It is formed by the union of the volar carpal branches of the radial and ulnar arteries, and it receives the communicating branch from the volar interosseous artery and recurrent branches from the deep volar arch. The branches of distribution which pass from it supply the ligaments and synovial membrane of the radio-carpal and intercarpal joints.

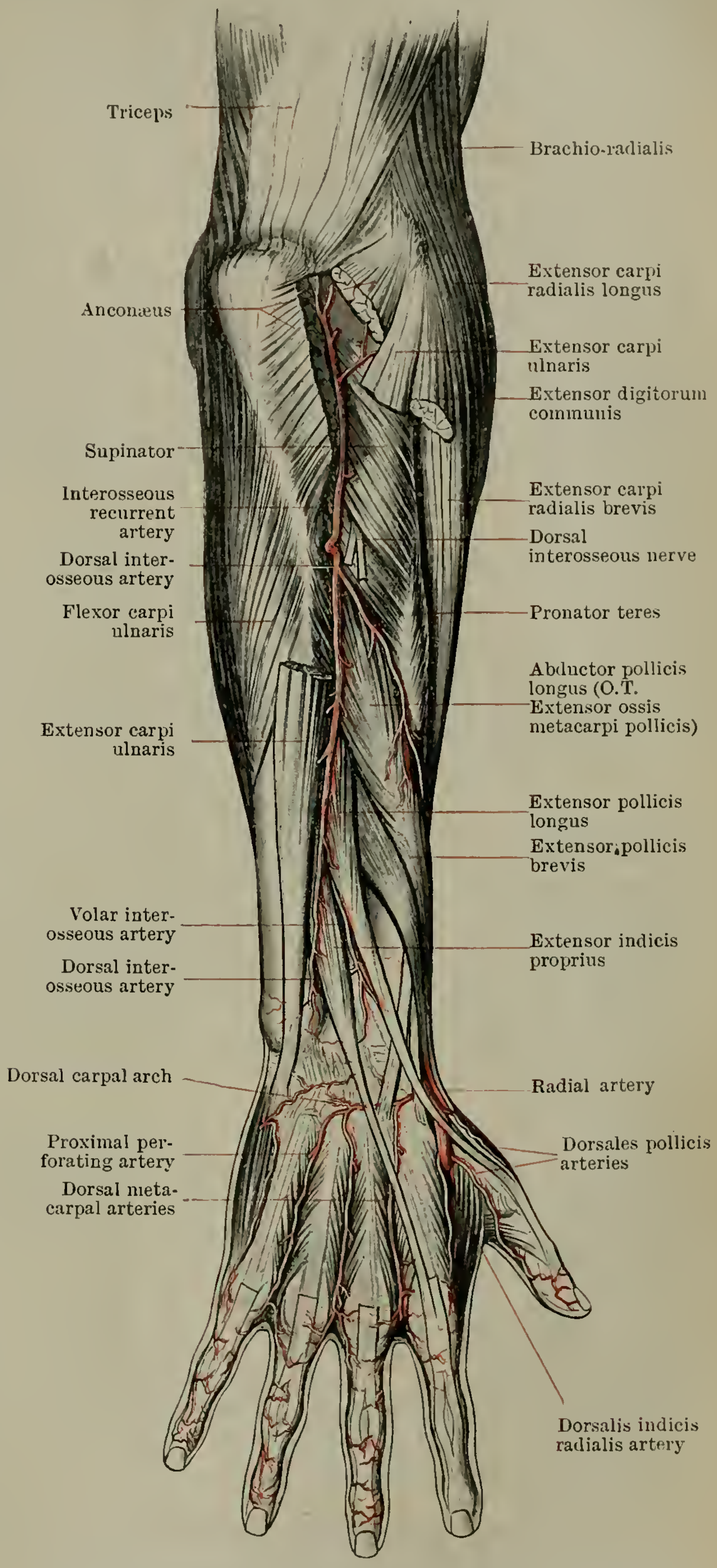
Triceps
Anconæus
Supinator
Interosseous recurrent artery
Dorsal interosseous artery
Flexor carpi ulnaris
Extensor carpi ulnaris
Volar interosseous artery
Dorsal interosseous artery
Dorsal carpal arch
Proximal perforating artery
Dorsal metacarpal arteries
Brachio-radialis
Extensor carpi radialis longus
Extensor carpi ulnaris
Extensor digitorum communis
Extensor carpi radialis brevis
Dorsal interosseous nerve
Pronator teres
Abductor pollicis longus (O.T. Extensor ossis metacarpi pollicis)
Extensor pollicis longus
Extensor pollicis brevis
Extensor indicis proprius
Radial artery
Dorsales pollicis arteries
Dorsalis indicis radialis artery

FIG. 745.—THE DORSAL INTEROSSEOUS ARTERY AND THE SECOND PART OF THE RADIAL ARTERY, WITH THEIR BRANCHES.

The Dorsal Carpal Arch (Fig. 745).—This arch lies on the dorsal carpal ligaments deep to the extensor tendons and their sheaths. It is formed by the union of the dorsal carpal branches of the radial and ulnar arteries, and receives the terminations of the volar and dorsal interosseous arteries.

Branches.—(*a*) **Articular** to the adjacent articulations. (*b*) **Dorsal metacarpal**

two slender branches which run distally, along the third and fourth dorsal interosseous muscles, to the clefts of the fingers, where each divides into dorsal digital branches. They communicate near their origins with the deep volar arch by the proximal perforating arteries, and near their terminations with the volar digital vessels through the distal perforating arteries. Their digital terminal branches run distally, on the dorso-lateral aspects of the fingers which bound the third and fourth interosseous spaces, and they anastomose with the special volar digital branches of the volar digital arteries.

The **superficial volar arch** (O.T. superficial palmar) (Fig. 743) includes the terminal portion of the ulnar artery, and is usually completed on the radial side by the superficial volar, or by the volaris indicis radialis or the princeps pollicis branches of the radial artery. It extends from the ball of the little finger to the ulnar border of the superficial head of the flexor pollicis brevis, and reaches distally to a line drawn across the palm at the level of the distal border of the fully abducted thumb. It is accompanied by venæ comites and it is covered by the integuments and the central portion of the palmar aponeurosis, and, on the ulnar side of the palm, by the palmaris brevis. It is in contact dorsally with the flexor brevis and opponens digiti quinti, and with the common digital branches of the ulnar and median nerves, as well as with the flexor tendons and the lumbrical muscles.

Branches.—Four **volar common digital arteries** arise from the convexity of the arch. The most ulnar of the four passes along the ulnar border of the little finger, accompanied by the common digital branch of the ulnar nerve; the other three pass distally superficial to the common digital nerves, one along the middle of each of the ulnar three interosseous spaces, towards the interdigital clefts, just proximal to which each common digital artery divides into two **special digital arteries** which supply the contiguous sides of the fingers bounding the cleft. As the special digital branches pass along the sides of the fingers they lie superficial to the corresponding special digital nerves, and supply branches to the joints, to the flexor tendons and their sheaths, and to the skin and subcutaneous tissues on the volar surfaces of the fingers; they give off dorsal branches also which anastomose with the dorsal digital arteries and supply the tissues on the dorsal aspects of the second and terminal phalanges. Some of the dorsally directed branches form a plexus in the matrix of the nail. In the pulp of the finger-tips anastomosing twigs join to form arches from which numerous branches are given off to the skin and subcutaneous fat.

Each of the three most radial special digital arteries is joined, immediately proximal to its division, by a volar metacarpal artery from the deep volar arch and a distal perforating artery from a dorsal metacarpal artery. The most ulnar digital artery is joined by a branch which arises either from the most ulnar volar metacarpal artery or from the deep volar arch.

The **deep volar arch** (O.T. deep palmar) (Fig. 744) extends from the base of the metacarpal bone of the little finger to the proximal end of the first interosseous space, and is formed by the terminal part of the radial artery anastomosing with the profunda branch of the ulnar. It is from 12 to 18 mm. (half to three-quarters of an inch) proximal to the level of the superficial volar arch. It lies deeply in the palm, in contact with the proximal ends of the bodies of the metacarpal bones and on the origin of the interossei muscles, and deep to the long flexor tendons and their synovial sheaths.

Branches.—(*a*) The **proximal perforating**: three small arteries which pass dorsally, through the ulnar three interosseous spaces and between the origins of the dorsal interosseous muscles. They anastomose on the dorsum of the hand with the dorsal metacarpal arteries.

(*b*) Small irregular **recurrent branches** pass proximally and unite with the volar carpal arch.

(*c*) The **articular** to the adjacent articulations.

(*d*) The **volar metacarpal arteries** are three vessels which pass distally, on the interosseous muscles of the three ulnar interosseous spaces, deep to the flexor tendons. They terminate by anastomosing with the volar digital arteries just before the latter vessels divide into special volar digital branches.

(*e*) The **communicating**, a small irregular branch which passes ulnarwards between the flexor tendons and the short muscles of the little finger to anastomose with the ulnar volar digital artery.

BRANCHES OF THE DESCENDING THORACIC AORTA.

The branches given off from the thoracic portion of the descending aorta are distributed chiefly to the walls of the thorax and to the thoracic viscera. They contribute also to the supply of the spinal medulla and its membranes, and to that of the vertebral column and of the upper part of the abdominal wall. The branches, which are numerous and for the most part arranged in pairs, are as follows:—

Visceral.	Bronchial. Œsophageal. Pericardial. Mediastinal.	Parietal.	Intercostal. Subcostal. Superior phrenic. The vas aberrans.

Visceral Branches of the Descending Thoracic Aorta.

1. The **bronchial branches** of the thoracic aorta are usually two in number—an upper and a lower—and both pass to the left lung. The *upper left bronchial artery* arises from the front of the aorta opposite the fifth thoracic vertebra; the *inferior left bronchial artery* usually takes origin near the lower border of the left bronchus. Both vessels are directed downwards and laterally to the back of the bronchus which they accompany, and, dividing similarly, they follow its ramifications in the lung. They not only supply the walls of the bronchial tubes and the substance of the lungs, but also give branches to the bronchial glands, the pulmonary vessels, the pericardium, and the œsophagus.

As a rule there is only one *right bronchial artery*. It arises either from the first right aortic intercostal artery or from the upper left bronchial artery. More rarely it springs directly from the aorta. In its course and distribution it corresponds to the bronchial arteries of the left side.

Abnormalities.—The **bronchial arteries** obviously correspond to splanchnic arteries and their continuations to diverticula from the walls of the gut; therefore the usual origin of the right bronchial artery from the first right aortic intercostal artery must result from the persistence of an anastomosis between a splanchnic artery and the first part of a somatic intersegmental artery; the origin of the right from the upper left bronchial artery, which sometimes occurs, is due to the fusion of the roots of two splanchnic arteries. The occasional origin of a bronchial vessel from an internal mammary artery can result only from the persistence and enlargement of an anastomosis between a splanchnic artery and the ventral branch of a somatic segmental artery. The origin of a bronchial branch from a subclavian artery may have the same or a different significance on opposite sides of the body. A bronchial artery arising from the left subclavian artery corresponds with the origin of the right bronchial artery from the first aortic intercostal artery; it is due to the persistence of an anastomosis between a splanchnic artery and the root of a somatic intersegmental artery; and the origin of a bronchial artery from a right subclavian artery may be due to a similar cause. It may, on the other hand, be due to the enlargement of an anastomosis between a splanchnic branch of the descending aorta and a splanchnic branch of the fourth right aortic arch. When, as occasionally happens, the bronchial artery arises from the inferior thyreoid, it is due to the persistence and enlargement of an anastomosis between splanchnic arteries.

2. The **œsophageal branches** are variable; usually four or five small branches spring from the front of the aorta and pass forwards to the œsophagus, in the walls of which they ramify, anastomosing above with branches of the left bronchial and inferior thyreoid arteries, and below with œsophageal branches of the left gastric and the phrenic arteries.

3. The **pericardial branches** are three or four small irregular vessels which are distributed on the surface of the pericardium.

4. Small **mediastinal branches** pass to the areolar tissue and glands in the posterior mediastinum, and to the posterior part of the diaphragm.

Parietal Branches of the Descending Thoracic Aorta.

1. **The Intercostal Arteries.**—There are nine pairs of aortic intercostal arteries which usually arise separately from the back of the aorta, but, not uncommonly, a pair may take origin by a common trunk. They are distributed to the lower nine intercostal spaces, to the vertebral column, to the contents

of the vertebral canal, and to the muscles and skin of the back. The first three on each side give branches to the mammary gland also. The arteries of opposite sides closely correspond, but, since the aorta, in the thoracic region, lies on the left of the vertebral column, the right intercostal arteries cross the front of the column, posterior to the œsophagus, the thoracic duct, and the vena azygos, and are longer than the left arteries. In other respects the courses of all the aortic intercostal arteries are almost identical. As each artery runs postero-laterally, across the side of the vertebral column, to an intercostal space, it passes posterior to the pleura, and is crossed, opposite the head of a rib, by the sympathetic trunk. The lower arteries are crossed by the splanchnic nerves also, and those on the left side are crossed by the hemiazygos or accessory hemiazygos veins.

As each artery passes laterally, between the necks of two adjacent ribs, it gives off a posterior branch. Then it ascends to the upper border of the space to which it belongs, and, passing either behind or in front of the corresponding intercostal nerve, is continued along the space, in the costal groove. In the space, as far as the angle of the rib, it lies between the pleura and the posterior intercostal membrane, and, in that part of its course, it is embedded in the endothoracic fascia. Then it is continued forward between the internal and external intercostal muscles. In the costal groove the artery lies between the corresponding vein above and the intercostal nerve below, and it terminates anteriorly by anastomosing with an anterior intercostal branch of the internal mammary or of the musculo-phrenic artery. The lower two intercostal arteries, on each side, extend beyond their spaces into the abdominal wall, and anastomose with branches of the superior epigastric, subcostal, and lumbar arteries. The first right aortic intercostal artery frequently gives off the right bronchial artery.

Branches.—(*a*) The **posterior branch** passes backwards, accompanied by the posterior branch of a spinal nerve, medial to the anterior superior costo-transverse ligament, between the necks of the ribs which bound the space, and between the adjacent transverse processes, to the vertebral groove, where it divides into a medial and a lateral cutaneous terminal branch. The *medial cutaneous branch* passes backwards and medially, either over or through the multifidus, giving branches to the muscles between which it passes and to the vertebral column. The *lateral branch* runs laterally under cover of the longissimus dorsi to the interval between it and the iliocostalis dorsi. It terminates in the skin of the back, after giving branches to the adjacent muscles. Before it divides, each posterior branch gives off muscular branches, and a *spinal branch* which passes through the corresponding intervertebral foramen, and enters the vertebral canal, to the contents and walls of which it is distributed. The spinal branch divides into three branches—neural, post-central, and pre-laminar. The *neural branch* divides into two branches which run medially, on the roots of the spinal nerve; they pierce the dura mater and arachnoid, and divide into branches some of which pass to the membranes of the spinal medulla, whilst others are continued on to reinforce the posterior and anterior spinal arteries. The *post-central branch* divides into ascending and descending branches which, anastomosing with similar branches above and below, form a series of vertical arches on the backs of the bodies of the vertebræ. The arches of opposite sides are connected by short transverse anastomoses. The *pre-laminar branch* is small, and its ascending and descending branches are distributed in a similar though less regular manner on the posterior wall of the vertebral canal.

(*b*) A **collateral branch** arises near the angle of the rib. It descends and runs forward along the lower border of the intercostal space, to anastomose in front with an anterior intercostal branch of the internal mammary or musculo-phrenic artery. The collateral branches of the lower two intercostal arteries, on each side, are inconstant; when present they are small, and terminate in the abdominal wall.

(*c*) **Muscular branches** to the adjacent muscles are given off both by the main trunk and its collateral branch.

(*d*) A **lateral cutaneous** offset accompanies the lateral cutaneous branch of the intercostal nerve.

In addition to the secondary branches above-named, the trunk of the first aortic intercostal, on each side, anastomoses with the superior intercostal, and may supply the whole or the greater part of the second intercostal space. The upper three or four aortic intercostal arteries, on each side, give branches to the mammary gland which anastomose with branches of the lateral thoracic and internal mammary arteries. Longitudinal anastomoses between adjacent trunks and also between adjacent posterior branches of intercostal arteries sometimes exist near the necks of the ribs, or near the transverse processes. These longitudinal anastomoses are of considerable morphological interest.

2. The **subcostal arteries** are the last pair of parietal branches given off from the thoracic aorta. They are in series with the aortic intercostal arteries, but are situated below the last ribs. Each gives off a posterior branch which behaves in the same manner as the posterior branch of an ordinary aortic intercostal artery. The trunk runs along the lower border of the twelfth rib in company with the last thoracic nerve. It passes below the arcus lumbocostalis lateralis to the abdomen, and there crosses anterior to the quadratus lumborum, and posterior to the kidney and the adjacent part of the colon. It next pierces the aponeurosis of origin of the transversus abdominis, and runs between the transversus and the internal oblique muscles, anastomosing with the lower intercostal arteries, with the lumbar arteries, and with branches of the superior epigastric artery.

Abnormalities.—Variations of the intercostal arteries are not very common, but they are significant and interesting. Corresponding vessels of opposite sides may arise from a common stem which has been formed by the fusion of the roots of two somatic intersegmental arteries after or simultaneously with the fusion of the primitive dorsal aortæ. The number of intercostal arteries may be reduced, one artery supplying two or more intercostal spaces; in these cases the roots of origin of some of the somatic intersegmental arteries in the thoracic region have disappeared, and the precostal anastomoses between their ventral branches have persisted.

Occasionally the number of the aortic intercostal arteries is increased, an additional artery being given to the second intercostal space, which is usually supplied by the superior intercostal artery; this is brought about by the persistence of the root of the tenth somatic intersegmental artery and the disappearance of the precostal anastomosis between the ventral branches of the ninth and tenth somatic intersegmental arteries. Very rarely the first aortic intercostal artery sends a branch upwards between the necks of the ribs and the transverse processes of the upper thoracic region; this branch supplies the upper intercostal spaces, the superior intercostal artery being small or absent, and it terminates by becoming the profunda cervicis artery. It is due to the persistence of the postcostal anastomoses in the upper thoracic region, and is a repetition of a condition regularly present in some carnivores.

There are no very important variations of the œsophageal, pericardial, and mediastinal arteries.

3. **Superior phrenic branches** are given off from the lower part of the thoracic aorta. They are small vessels which ramify on the upper and posterior surfaces of the diaphragm, and anastomose with branches of the pericardiaco-phrenic and musculo-phrenic arteries.

4. The **vas aberrans** is a variable and inconstant branch of the thoracic aorta; it represents the dorsal roots of the fourth and sixth right aortic arches of the embryo. When present it arises from the front and right side of the upper part of the descending aorta near the upper left bronchial artery, and passes upwards and to the right behind the œsophagus; it frequently anastomoses with the right superior intercostal artery, and it may be enlarged and form the first part of the right subclavian artery.

BRANCHES OF THE ABDOMINAL AORTA.

The branches of the abdominal portion of the aorta are distributed almost entirely to the walls and contents of the abdominal cavity, but some supply small branches to the vertebral column, and to the contents of the vertebral canal, and others are prolonged into the pelvis minor. They are divisible into visceral and parietal groups, both of which include paired and single (unpaired) vessels.

- **Visceral.**
  - **Paired.**
    - Suprarenal.
    - Renal.
    - Spermatic or ovarian.
  - **Single.**
    - Cœliac axis.
    - Superior mesenteric.
    - Inferior mesenteric.
- **Parietal.**
  - **Paired.**
    - Inferior phrenic.
    - Lumbar.
    - Common iliac.
  - **Single.** Middle sacral.

The Paired Visceral Branches of the Abdominal Aorta.

1. **Suprarenal Arteries** (Fig. 748).—There are three pairs of **suprarenal arteries**—the superior, middle, and inferior. Of these the middle only arise

directly from the aorta; the superior spring from the inferior phrenic, and the inferior from the renal arteries.

The *middle suprarenal arteries* are two small branches which arise, posterior to the pancreas, from the sides of the aorta, close to the origin of the superior mesenteric artery. They run, one on each side, laterally and upwards, upon the crura of the diaphragm just above the renal arteries, to the suprarenal glands, to which they are distributed. They anastomose with the superior and inferior suprarenal arteries.

2. The **renal arteries** (Fig. 748) arise, one on each side, from the aorta, about 12 mm. (half an inch) below the origin of the superior mesenteric artery and opposite the second lumbar vertebra.

Both arteries are of large size, and the right is frequently slightly lower in position than the left. Each artery runs almost transversely to the hilum of the corresponding kidney. It passes anterior to the crus of the diaphragm and the upper part of the psoas muscle. The left artery lies posterior to the pancreas; the right vessel passes behind the inferior vena cava, the head of the pancreas, and the descending part of the duodenum. The renal vein usually lies below and anterior to the artery, but near the kidney the vein not infrequently occupies a posterior position.

On reaching the hilum of the kidney each artery divides into three branches, two of which pass anterior to the pelvis renalis, and between it and the renal vein, and the third posterior to the pelvis. In the renal sinus these primary branches break up into numerous secondary branches which enter the kidney substance between the pyramids.

Branches.—The following branches are given off by each renal artery, in addition to the terminal branches:—

(*a*) **Inferior suprarenal**, which passes upwards to the lower part of the suprarenal gland.

(*b*) **Ureteral.**—Small branches to the upper part of the ureter, which anastomose with branches of the internal spermatic or ovarian arteries.

(*c*) **Peri-nephric.**—Small branches to the fatty capsule of the kidney, which anastomose with the lumbar arteries.

(*d*) **Glandular offsets**, either from the main trunk or from some of its branches, pass to the lumbar lymph glands.

Abnormalities.—~~The renal~~ **arteries** frequently deviate from the normal arrangement. The arteries of opposite sides may spring from a common stem, or there may be two or more renal arteries on one or both sides. The accessory arteries are more common on the left than on the right side, and an accessory artery arising below the ordinary vessel is more common than one arising above it.

Accessory renal arteries may be derived not only from the aorta, but also from the common iliac or hypogastric arteries; they have been described as arising also from the inferior phrenic, spermatic, lumbar, or middle sacral arteries, and even from the external iliac artery. As the kidney is developed in the region of the first sacral vertebra, and afterwards ascends to its permanent position, it is not surprising that it occasionally receives arteries from the main stem of more than one of the segments of the body through which it has passed, and it is usually found that the lower the position of the kidney in the abdomen the more likely it is to receive its arteries from the lower part of the aorta or from the common iliac arteries. The accessory renal arteries which spring from the inferior phrenic, the spermatic, and lumbar arteries can only be the result of the persistence and enlargement of anastomosing channels between the renal and either another intermediate visceral, or a somatic artery.

3. The **internal spermatic arteries** are present in both sexes; in the male they are called the **testicular arteries** and in the female **ovarian arteries**. In each sex they are long slender vessels which spring from the front of the aorta a short distance below the origins of the renal arteries.

3*a*. **The Testicular Arteries.**—Each testicular artery runs downwards and forwards, on the anterior surface of the psoas major, to the abdominal inguinal ring, where it comes into relation with the ductus deferens. It accompanies the ductus deferens through the inguinal canal to the testis, to which it is distributed.

Relations—*Posterior.*—The right artery passes in front of the inferior vena cava, and as each artery descends, on the anterior surface of the psoas major, it passes in front of the corresponding genito-femoral nerve and the ureter.

Anterior.—Each artery is in relation anteriorly with the peritoneum to which it is attached; but crossing in front of the right artery and intervening between it and the peritoneum are the third or transverse part of the duodenum, the right colic and the ileo-colic arteries, the terminal part of the superior mesenteric artery, and the cæcum. Crossing anterior to the left artery are the left colic and sigmoid branches of the inferior mesenteric artery and the iliac colon.

In the lower part of the abdominal portion of its course each testicular artery is accompanied by two veins, which issue from the pampiniform plexus in the inguinal canal and enter the abdomen through the abdominal inguinal ring, but at a higher level the two veins usually fuse into a single stem.

As it enters the inguinal canal each testicular artery passes in front of the inferior epigastric artery, and the lower end of the external iliac artery; and as it runs downwards and medially, in the canal, it is accompanied by the ductus deferens, and is more or less enclosed in the meshes of the pampiniform venous plexus. At the lower end of the canal it passes through the subcutaneous inguinal ring and descends in the scrotum, lying antero-lateral to the ductus deferens and in close association with the anterior group of testicular veins. At the upper end of the testis it breaks up into branches, some of which are distributed to the testis and others to the epididymis.

Branches.—In the abdominal part of its course each testicular artery gives off:—
(*a*) **Ureteral branches**, to the abdominal part of the ureter.
(*b*) **Peri-nephric twigs**, to the peri-nephric fat.
(*c*) **Peritoneal branches**, which are distributed to the peritoneum.
(*d*) **Glandular branches**, which supply blood to the lumbar lymph glands.
Its terminal branches are the **testicular** and **epididymal** twigs already mentioned.

3*b*. **Ovarian Arteries.**—The course and the relations of each ovarian artery, as far as the level of the brim of the pelvis minor, are the same as the relations of the corresponding testicular artery; but at the level of the upper end of the external iliac artery each ovarian artery turns medially, crosses anterior to the upper end of the corresponding external iliac artery and vein, and enters the upper part of the broad ligament of the uterus. In the broad ligament it runs medially, below the uterine tube, to the level of the ovary. There it turns backwards and passes between the layers of the mesovarium, where it breaks up into terminal branches which enter the ovary through the hilum in its anterior border. As it lies in the broad ligament each ovarian artery is accompanied by the pampiniform plexus of ovarian veins. In the lower portion of the abdominal part of its course it is accompanied by two veins, which issue from the pampiniform plexus at the brim of the pelvis minor, and unite at a higher level into a single trunk.

Branches.—(*a*) In the abdominal part of its course the branches of the ovarian artery are the same as those of the testicular artery.

In the pelvic part of its course it gives off:—
(*a*) **Tubal branches**, to the walls of the uterine tube.
(*b*) **Branches** to the round ligament of the uterus.
(*c*) **Uterine branches**, which pass towards the uterus to anastomose with the branches of the uterine artery.

Abnormalities.—The testicular or ovarian arteries may be double on one or both sides; the arteries of the two sides may spring from a common trunk, or each may arise from the renal, accessory renal, or suprarenal arteries. The right artery may pass behind instead of in front of the inferior vena cava. The spermatic and ovarian arteries arise from the upper lumbar portion of the aorta, because the testes and ovaries are developed in and obtain their arterial supply in that region, and the vessels are elongated as the testes and ovaries descend to their permanent positions. The occurrence of two spermatic arteries on one side is probably an indication that the testis was developed in two segments of the body. The origin of a spermatic artery from a renal or suprarenal artery is due to the obliteration of the root of the original vessel and the enlargement of an anastomosis between the intermediate visceral arteries of adjacent segments.

THE UNPAIRED OR SINGLE VISCERAL BRANCHES OF THE ABDOMINAL AORTA.

1. The **cœliac artery** (Figs. 746 and 748) arises from the front of the abdominal aorta, immediately below the aortic orifice of the diaphragm and between its crura. It is a short but wide vessel which runs almost horizontally forwards, for a distance of about 12 mm. (half an inch), and it terminates by dividing into three branches—the left gastric, the hepatic, and the splenic.

Abnormalities of the Cœliac Artery.—The cœliac artery may be absent, its branches arising separately from the aorta or from some other source. Sometimes it gives off only two branches, usually the left gastric and splenic, and occasionally it gives four branches, the additional branch being either a second left gastric artery or a separate gastro-duodenal artery.

Relations.—As the short trunk lies behind the omental bursa it runs forwards, below the caudate lobe of the liver and above the upper border of the pancreas and the splenic vein. It is surrounded by the cœliac plexus of the sympathetic, and has the right cœliac ganglion to its right side and the left cœliac ganglion to its left side.

Branches.—(*a*) The **left gastric** (O.T. **coronary**) is the smallest branch of the cœliac artery. It runs obliquely upwards and to the left, and reaches the lesser curvature of the stomach close to the œsophagus. It then turns sharply forwards, downwards, and to the right, and runs towards the pyloric end of the stomach to anastomose with the right gastric branch of the hepatic artery. In the first part of its course the artery lies posterior to the omental bursa; it then passes into the left gastro-pancreatic fold, and is continued between the layers of the lesser omentum.

Branches.—(i.) **Œsophageal.**—When the left gastric artery reaches the stomach it gives off an œsophageal branch which passes upwards, on the œsophagus, and breaks up into branches which anastomose with œsophageal branches of the thoracic aorta and with branches of the inferior phrenic. (ii.) **Gastric branches** are distributed to both surfaces of the stomach. They anastomose with the short gastric branches of the splenic, and with branches of the gastro-epiploic arterial arch on the greater curvature of the stomach.

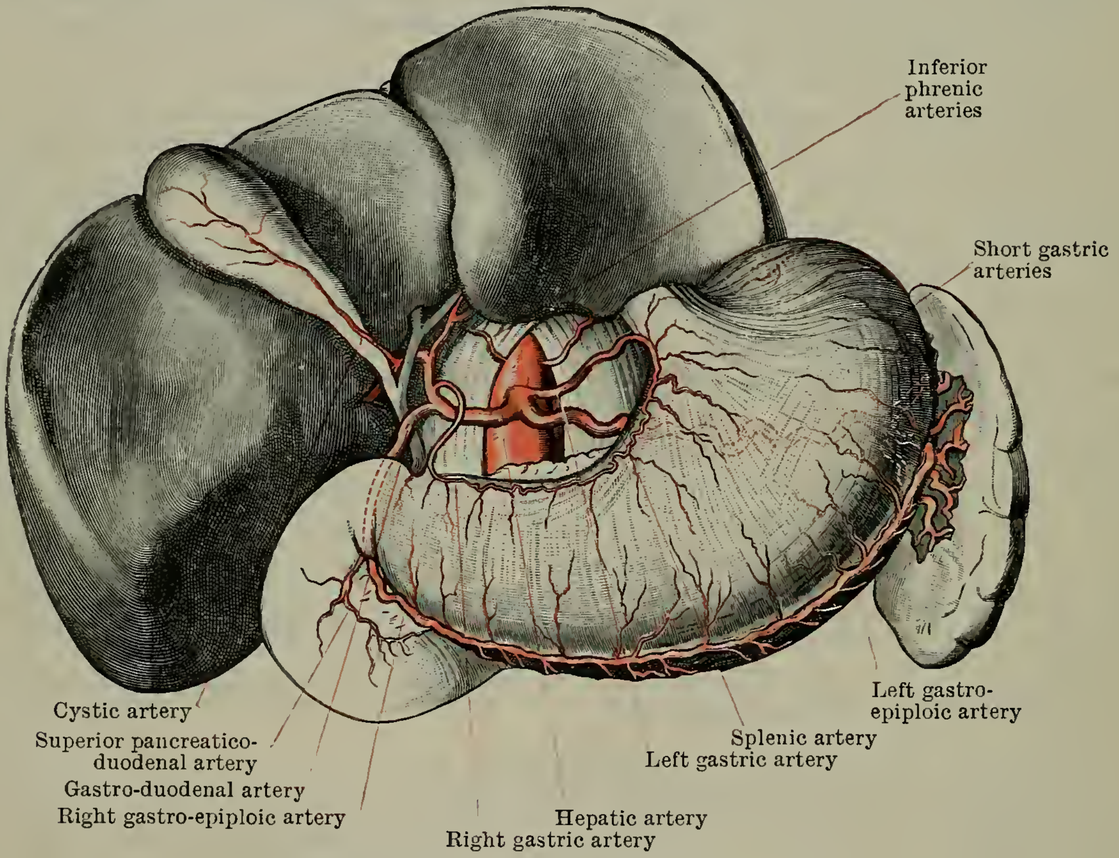

Fig. 746.—The Cœliac Artery and its Branches.

Abnormalities.—The left gastric artery is occasionally double; it may spring directly from the aorta, and it may give off the left hepatic or an accessory hepatic artery.

(*b*) The **splenic artery** (Fig. 746) is the largest branch of the cœliac artery. It runs a tortuous course behind the stomach and the omental bursa, and along the upper border of the pancreas. It lies anterior to the left suprarenal gland and the upper end of the left kidney, and passes forwards between the two layers of the lieno-renal ligament, in which it divides into from five to eight terminal branches which enter the hilum of the spleen and supply the splenic substance. It is accompanied by the splenic vein, which lies below it.

Abnormalities.—The **splenic artery** may arise from the middle colic, from the left hepatic, or from the superior or inferior mesenteric artery.

Branches.—(i.) **Pancreatic.**—Numerous small branches are given off to the pancreas. A larger branch (pancreatica magna), occasionally present, enters the upper border of the pancreas, about the junction of its middle and left thirds, and runs from left to right in the substance of the pancreas, a little above and posterior to the pancreatic duct. Both the small and large arteries supply the substance of the pancreas, and anastomose with one another and with branches of the pancreatico-duodenal arteries.

(ii.) The **short gastric branches**, four or five in number, are given off, either from the terminal part of the splenic artery or, more commonly, from some of its terminal branches. They pass between the layers of the gastro-splenic ligament to the left part of the greater curvature of the stomach, and anastomose with the œsophageal, the left gastric, and the left gastro-epiploic arteries.

(iii.) The **left gastro-epiploic branch** arises from the front of the splenic, close to its termination, and passes forwards, between the layers of the gastro-splenic ligament, to the left end of the lower part of the greater curvature of the stomach, along which it is continued, from left to right, between the layers of the greater omentum. It ends by anastomosing with the right gastro-epiploic artery, and it gives off numerous *gastric* branches to both surfaces of the stomach; they anastomose with the short gastric and with branches of the left and right gastric arteries. Long slender *omental* branches pass to the omentum and anastomose with branches of the colic arteries.

(*c*) The **hepatic artery** (Fig. 746) runs along the upper border of the head of the pancreas to the right gastro-pancreatic fold of peritoneum in which it turns forwards to the upper border of the first part of the duodenum. It then passes upwards, between the layers of the hepato-duodenal ligament, anterior to the portal vein and to the left of the bile duct, and reaches the porta hepatis, where it divides into right and left branches.

Abnormalities.—The **hepatic artery** may spring directly from the aorta or from the superior mesenteric artery, and the left hepatic artery arises occasionally from the left gastric artery. Accessory hepatic arteries are not uncommon, and they originate either from the left gastric, superior mesenteric, renal, or inferior mesenteric artery.

Branches.—(i.) The **right gastric artery** is a small branch which arises opposite the upper border of the first part of the duodenum. It runs to the pylorus, between the layers of the lesser omentum, and then turns to the left along the smaller curvature of the stomach. It gives branches to both surfaces of the stomach, and terminates by anastomosing with the left gastric artery.

(ii.) The **gastro-duodenal artery.**—This branch of the hepatic arises just above the upper border of the first part of the duodenum, descends behind it and terminates opposite its lower border. In its course it lies between the neck of the pancreas and the first part of the duodenum, and anterior to the portal vein. The bile duct is on its right side. The vessel ends by dividing into the right gastro-epiploic and the superior pancreatico-duodenal arteries. The **right gastro-epiploic artery** is the larger of the two terminal branches of the gastro-duodenal; it passes from right to left, along the greater curvature of the stomach, between the layers of the greater omentum, and unites with the left gastro-epiploic branch of the splenic artery. From the arterial arch so formed branches pass upwards on both surfaces of the stomach, to anastomose with branches of the right and left gastric arteries. Other branches pass downwards in the greater omentum, and anastomose with branches of the colic arteries. The **superior pancreatico-duodenal artery** runs a short course to the right, between the duodenum and the head of the pancreas, and divides into anterior and posterior terminal branches, which descend, the former in front of and the latter behind the head of the pancreas, to anastomose with similar branches of the inferior pancreatico-duodenal artery. They supply the head of the pancreas, anastomosing in it with the pancreatic branches of the splenic artery; branches are given also to the second part of the duodenum and to the bile duct.

(iii.) **Terminal Branches.**—The **right hepatic artery** passes, either in front of or behind the hepatic duct and behind the cystic duct, to the right end of the porta hepatis; there it divides into two or more branches which enter the substance of the liver and accompany the branches of the portal vein and the hepatic duct. As it crosses above the junction of the hepatic and cystic ducts, the right hepatic artery gives off a cystic branch. The *cystic artery* runs downwards and anteriorly, along the cystic duct, to the gall-bladder, where it divides into anterior and posterior branches; the anterior passes downwards between the gall-bladder and the visceral surface of the liver, to both of which it gives offsets; the posterior branch is distributed on the posterior surface of the gall-bladder, between it and the peritoneum. The **left hepatic artery** is longer and narrower than the right. It runs to the left end of the porta hepatis, gives one or two branches to the caudate lobe, crosses the fossa of the umbilical vein, and breaks up into branches which terminate in the substance of the left lobe of the liver.

2. The superior mesenteric artery (Figs. 747 and 748) springs from the front of the aorta, about 12 mm. (half an inch) below the origin of the cœliac artery and opposite the first lumbar vertebra.

It passes obliquely downwards and forwards, crossing anterior to the left renal vein, the uncinate process of the head of the pancreas, and the third or transverse part of the duodenum; opposite the latter it enters the root of the mesentery, in which it continues to descend, curving obliquely from above downwards and to the right, to the right iliac fossa, and crossing, in this part of its course, obliquely in front of the aorta, the lower part of the inferior vena cava, the right ureter, and the right psoas major muscle. At its origin it lies posterior to the neck of the pancreas and the splenic vein; where it passes in front of the duodenum it is crossed anteriorly by the transverse colon; and in the lower part of its extent it is behind the coils of small intestine.

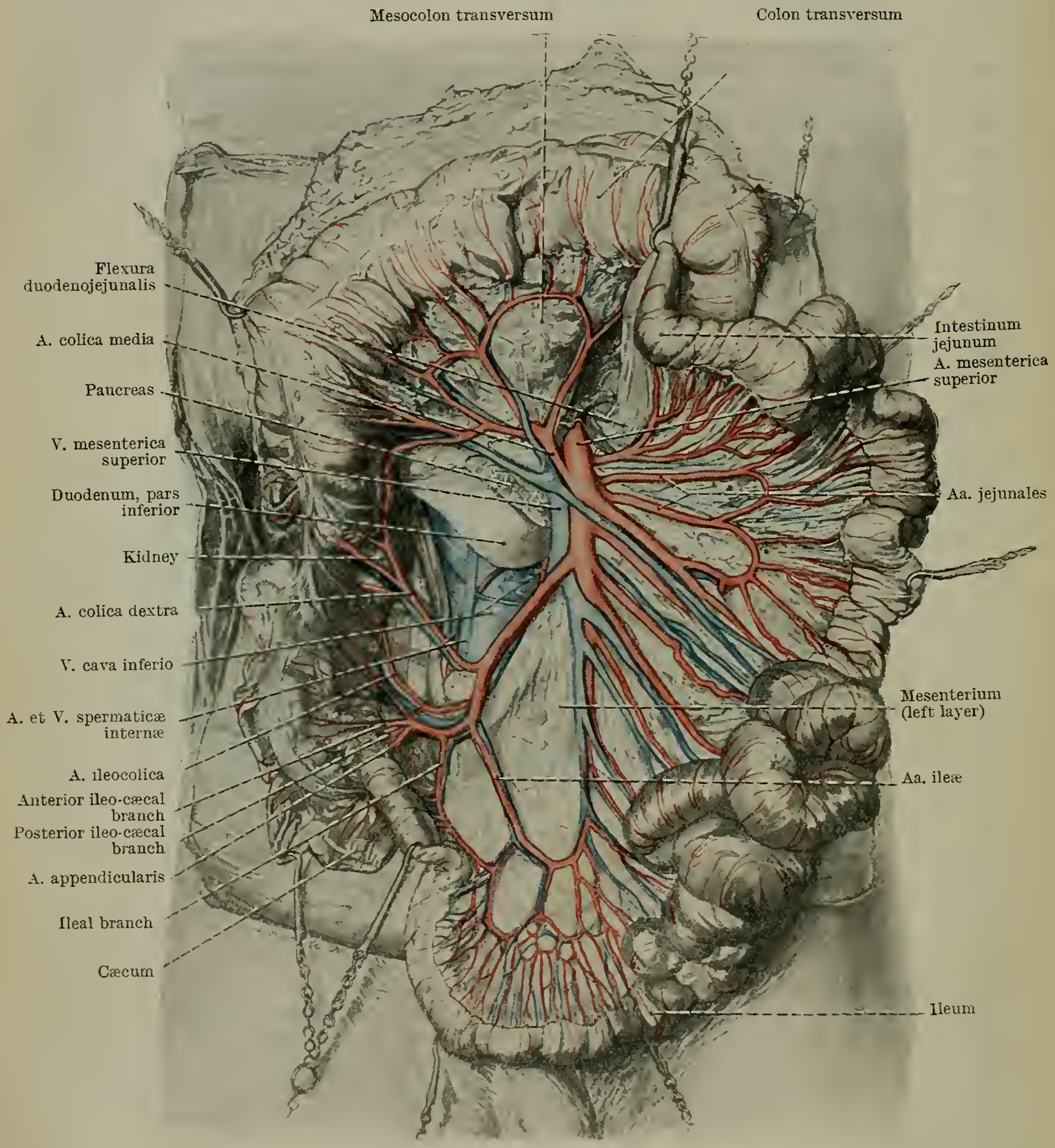

Fig. 747.—The Superior Mesenteric Artery and its Branches.

Note the difference in the number and arrangement of the loops formed by the jejunal branches as contrasted with the ileal branches.

Abnormalities.—The superior mesenteric artery may be double, and it may supply the whole of the alimentary canal from the second part of the duodenum to the end of the rectum, the inferior mesenteric artery being absent. In addition to its ordinary branches it may give off a hepatic, a splenic, a pancreatic, a gastric, a gastro-epiploic or a gastro-duodenal branch. Very rarely it gives off an omphalo-mesenteric branch, which passes to the region of the umbilicus and becomes connected with capillary vessels in the falciform ligament of the liver.

Branches.—It gives off numerous branches which supply the duodenum and the pancreas in part, the whole of the small intestine below the duodenum, and the large intestine nearly as far as the left colic flexure.

The branches are as follows:—

(*a*) The **intestinal** branches to the small intestine, varying from ten to sixteen in number, are separable into two groups, *jejunal* and *ileal*; they spring from the convexity of the superior mesenteric artery, and pass obliquely forwards and downwards, between the layers of the mesentery, each dividing into two branches which anastomose with adjacent branches to form a series of arcades, from which secondary branches are given off. This process of division and union is repeated three or four times in the case of the ileal arteries; thus four or five tiers of arches are formed, from the most distal of which terminal branches are given off to the walls of the jejunum and ileum. Branches from the successive arcades are also given off to the mesenteric lymph glands. The terminal branches anastomose together in the walls of the gut, forming a vascular network, which communicates above with the inferior pancreatico-duodenal artery and below with the terminal branch of the superior mesenteric trunk. The arterial loops and branches are accompanied by corresponding veins, lymphatics, and nerves.

(*b*) The **inferior pancreatico-duodenal artery.** This branch arises either from the trunk of the superior mesenteric, at the upper border of the third part of the duodenum, or from the first jejunal branch. It runs to the right, between the head of the pancreas and the third part of the duodenum, and terminates by dividing into two branches, anterior and posterior, which ascend, the former in front, and the latter behind the head of the pancreas; they supply the head of the pancreas, the descending and inferior parts of the duodenum, and they anastomose with the similar branches of the superior pancreatico-duodenal artery.

(*c*) The **middle colic artery** is a large branch which springs from the front of the superior mesenteric as it enters the root of the mesentery. It runs downwards and forwards, in the transverse mesocolon, and terminates by dividing into two branches, right and left, which anastomose respectively with the right and left colic arteries, forming arcades. Secondary and tertiary loops are sometimes formed and the terminal branches are distributed to the walls of the transverse colon.

(*d*) The **right colic artery** springs from the right or concave side of the superior mesenteric, either alone or in the form of a common trunk which divides into right colic and ileo-colic branches. It runs to the right, posterior to the peritoneum on the posterior wall of the abdomen, and in front of the right psoas major, the ureter, and the internal spermatic vessels, towards the ascending colon, near which it divides into an ascending and a descending branch. The former passes upwards, and anastomoses, in the transverse mesocolon, with the middle colic artery. The latter descends to anastomose with the upper branch of the ileo-colic, and from the loops thus formed branches are distributed to the walls of the ascending colon and the beginning of the transverse colon.

(*e*) The **ileo-colic artery** arises by a common trunk with the right colic, or separately from the right side of the superior mesenteric, and passes downwards and to the right, behind the peritoneum, towards the lower part of the ascending colon, where it terminates by dividing into an ascending branch which anastomoses with the lower branch of the right colic, and a descending branch which communicates with the colic terminal branches of the superior mesenteric trunk.

(*f*) **Terminal.**—The lower end of the superior mesenteric artery divides into five branches—(i.) ileal, (ii.) appendicular, (iii.) anterior ileo-cæcal, (iv.) posterior ileo-cæcal, and (v.) colic.

The **ileal branch** turns upwards and to the left in the lowest part of the mesentery, and anastomoses with the intestinal arteries. The **appendicular branch** passes behind the terminal portion of the ileum, and through the mesentery of the vermiform process to the vermiform process, upon which it ends. The **anterior ileo-cæcal** crosses the front of the ileo-cæcal junction in a fold of peritoneum; the **posterior ileo-cæcal** crosses the ileo-cæcal junction posteriorly, and the **colic** runs upwards to the ascending colon. The ileo-cæcal branches supply the walls of the cæcum, and, like the colic branch, anastomose with branches of the ileo-colic artery. In some cases the majority or all of the above terminal branches spring from the ileo-colic.

3. The **inferior mesenteric artery** (Fig. 748) arises from the front of the aorta towards the left side, 37 mm. above the bifurcation; it passes downwards and slightly to the left, lying posterior to the peritoneum and anterior to the left psoas major muscle, to the upper and left border of the left common iliac artery, where it becomes the superior hæmorrhoidal.

Abnormalities.—The **inferior mesenteric artery** may give hepatic, renal, or middle colic branches; occasionally it is absent, being replaced by branches of the superior mesenteric, and sometimes, as in ruminants and some rodents, its left colic branch does not anastomose with the middle colic artery.

All these variations of the unpaired visceral branches of the abdominal aorta are merely due to modifications of the usual processes by which the vessels are developed.

The hepatic, splenic, and left gastric arteries may arise directly from the aorta, a condition which is due to the retention of a greater number of the splanchnic arteries than usual. A double superior mesenteric artery results from the persistence of both the right and left splanchnic vessels from which the superior mesenteric artery is formed, these remaining separate instead of fusing together. All the other variations are the results of the obliteration of the usual channels, combined with the enlargement of anastomoses which exist both between the splanchnic arteries of adjacent segments and between the splanchnic and intermediate visceral arteries.

Branches.—(*a*) The **left colic artery** arises from the left side of the inferior mesenteric near its origin, and almost immediately divides into an upper and a lower branch. The *upper branch* runs upwards and to the left towards the left colic flexure, and to the lower pole of the left kidney, where it divides into (i.) a branch which enters the transverse mesocolon, and, turning medially, terminates by joining the left branch of the middle colic artery, and (ii.) a descending branch to the upper part of the descending colon. The *lower branch* passes to the left, behind the peritoneum, and divides into upper and lower divisions; the upper anastomoses with the descending division of the upper branch and supplies the lower part of the descending colon. The lower division supplies the iliac colon, and it anastomoses with the branches of the upper division and with the branches of the sigmoid arteries. Both branches of the left colic artery lie immediately behind the peritoneum, and each branch crosses anterior to the ureter and the internal spermatic vessels.

(*b*) The **sigmoid branches**, usually two in number, arise from the convexity of the inferior mesenteric, and pass downwards and to the left to the lower part of the iliac colon and to the pelvic colon. They lie posterior to the peritoneum, and anterior to the psoas major, the ureter, and the upper part of the iliacus. They terminate by dividing into branches which anastomose with the terminal twigs of the lower branch of left colic above and with branches of the superior hæmorrhoidal below, forming a series of arches from which branches are distributed to the lower part of the iliac colon and the pelvic colon.

(*c*) The **superior hæmorrhoidal artery** is the direct continuation of the inferior mesenteric. It enters the mesentery of the pelvic colon, crosses the front of the left common iliac artery, descends into the pelvis minor as far as the third piece of the sacrum, or, in other words, the junction between the pelvic colon and the rectum, and divides into two branches which pass downwards on the sides of the rectum. Half-way down the rectum each of the two terminal branches of the superior hæmorrhoidal artery divides into two or more branches which pass through the muscular coats and terminate in the submucous tissue, where they divide into numerous small branches which pass vertically downwards, anastomosing with one another, with offsets from the middle hæmorrhoidal branches of the internal iliac arteries, the inferior hæmorrhoidal branches of the internal pudic arteries, and with branches from the middle sacral artery.

The superior hæmorrhoidal artery supplies the mucous membrane of the pelvic colon and the rectum and the muscular coats of the pelvic colon.

PARIETAL BRANCHES OF THE ABDOMINAL AORTA.

1. The **inferior phrenic arteries** (Fig. 748), right and left, are of small size; they arise, either separately or by a common trunk, from the aorta, immediately below the diaphragm, to which they are distributed. Diverging from its fellow, each artery runs upwards and laterally, on the corresponding crus of the diaphragm —that on the right side passing posterior to the inferior vena cava, that on the left side posterior to the œsophagus—and just before reaching the central tendon of the diaphragm each divides into medial and lateral terminal branches. The *medial branch* runs forwards, and anastomoses with its fellow of the opposite side, forming an arch, convex forwards, along the anterior border of the central

tendon of the diaphragm. Offsets from this arch anastomose with the pericardiaco-phrenic, musculo-phrenic, and internal mammary arteries. The *lateral branch* passes laterally towards the lower ribs, and anastomoses with the musculo-phrenic and lower intercostal arteries.

In addition to supplying the diaphragm each inferior phrenic artery gives a **superior suprarenal branch**, to the suprarenal gland of its own side, and, occasionally, small hepatic branches which pass through the coronary ligament to the liver. Further, the left artery gives œsophageal branches which anastomose with œsophageal branches of the aorta and of the left gastric artery, whilst from the artery of the right side minute branches pass to the inferior vena cava.

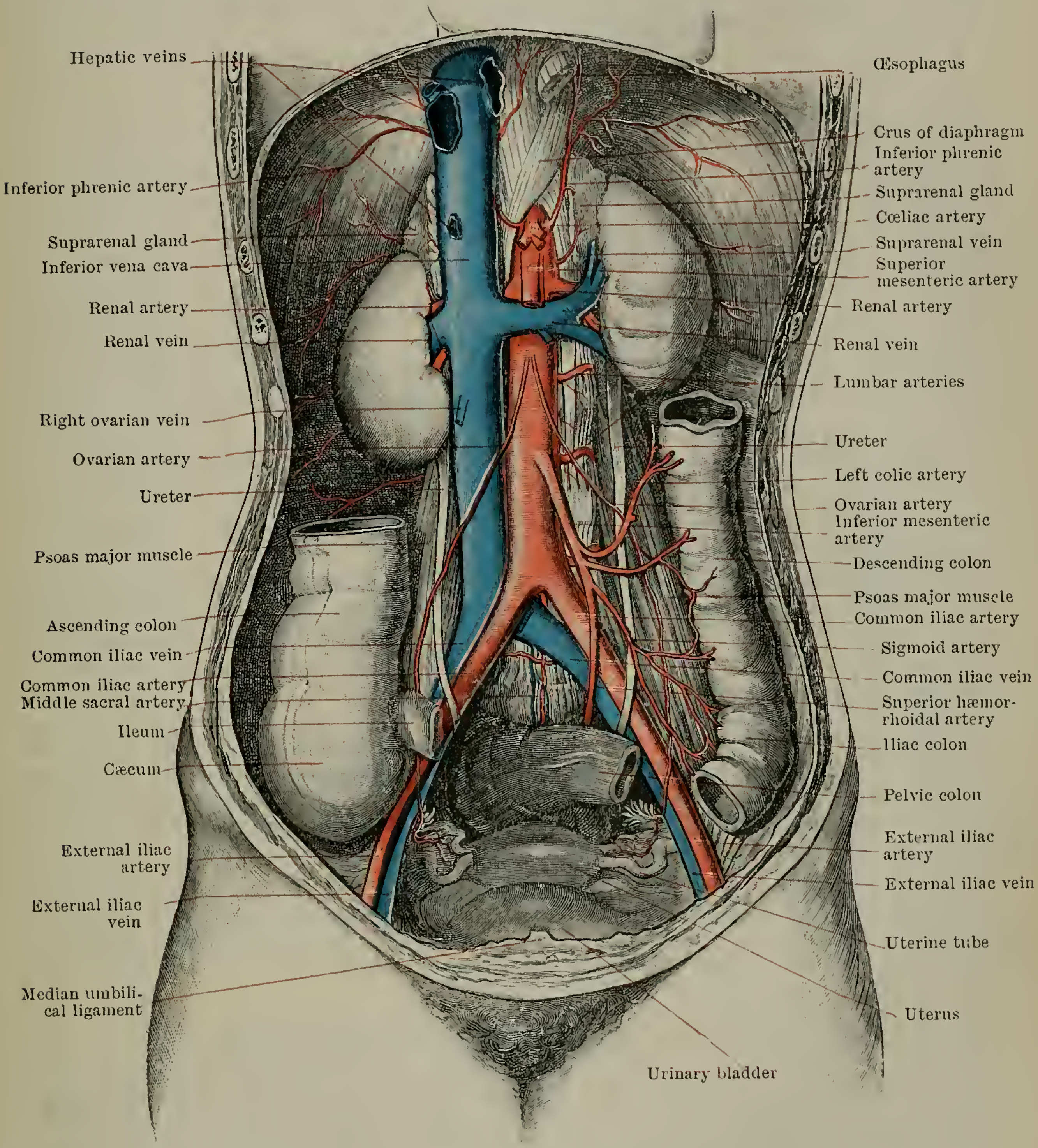

FIG. 748.—THE ABDOMINAL AORTA AND ITS BRANCHES.

Abnormalities.—The **inferior phrenic arteries** are very variable; they may arise by a common trunk either from the cœliac artery or from the aorta; they may arise separately either from the aorta or from the cœliac artery and more commonly from the latter vessel; or again, one may spring from the aorta or cœliac artery, and the other from the coronary, renal, or even from the superior mesenteric artery.

2. The **lumbar arteries** correspond to the intercostal branches of the

thoracic aorta. They are in series with the intercostal arteries; their distribution is very similar; and, like the intercostals, they arise, either separately or by common trunks, from the posterior aspect of the aorta.

There are usually four pairs of lumbar arteries, but occasionally a fifth pair arises from or in common with the middle sacral artery.

From their origins the lumbar arteries pass laterally and posteriorly, across the front and sides of the bodies of the upper four lumbar vertebræ, to the intervals between the adjacent transverse processes, beyond which they are continued into the lateral part of the abdominal wall.

Each artery lies on the body of the corresponding lumbar vertebra. In its backward course, and while still in relation with the vertebral body, it is crossed by the sympathetic trunk, and then, after passing medial to and being protected by the fibrous arches from which the psoas major muscle arises, it runs behind the muscle and the lumbar plexus. The upper two arteries, on each side, also pass posterior to the crura of the diaphragm. Beyond the interval between the transverse processes of the vertebræ each artery turns laterally and crosses the quadratus lumborum—the last usually passing anterior to, and the others posterior to the muscle; it then pierces the aponeurosis of origin of the transversus, and proceeds forwards in the lateral abdominal wall, in the interval between the transversus and internal oblique muscles. The lumbar arteries anastomose with one another, with the lower intercostal and subcostal arteries, and with branches of the superior and inferior epigastric and of the deep circumflex iliac and ilio-lumbar arteries.

Fine twigs also pass from the lumbar arteries to the extra-peritoneal fat; these anastomose with corresponding branches from the inferior phrenic and ilio-lumbar arteries, and with small branches from the hepatic, renal, and colic arteries, to form the *subperitoneal plexus* of Turner.

The abdominal aorta is almost median in position, consequently the right lumbar arteries are scarcely longer than the left. On the right side the arteries pass behind the inferior vena cava, the upper two arteries being separated from that vessel by the right crus of the diaphragm. The upper two right arteries also pass posterior to the cisterna chyli and the lower end of the azygos vein.

Branches—**Dorsal.**—Each lumbar artery gives off, opposite the interval between the vertebral transverse processes, a dorsal branch of considerable size. It is analogous with and is distributed like the posterior branch of an aortic intercostal artery (p. 928). **Muscular branches** are given off, both from the main trunk and its dorsal branch, to the adjacent muscles.

Abnormalities.—Variations of the lumbar arteries are very similar to those of the intercostal arteries, and they are due to similar causes. The lumbar arteries of opposite sides may arise by common stems from the back of the aorta; and the last pair of lumbar arteries may arise in common with the middle sacral artery. Further, a lumbar artery may have its area of distribution extended into the adjacent segment.

3. The **middle sacral artery** (Fig. 748) is a single median vessel. It is commonly regarded as a caudal aorta and as the direct continuation of the abdominal aorta. It is, however, of small size, and almost invariably arises from the back of the aorta, about 12 mm. (half an inch) above its bifurcation. It descends, anterior to the lower two lumbar vertebræ and to the sacrum and coccyx, and ends, opposite the tip of the coccyx, by anastomosing with the lateral sacral arteries to form a loop from which branches pass to the coccygeal glomus. Opposite the fifth lumbar vertebra it is crossed, anteriorly, by the left common iliac vein, below which it is covered by peritoneum and coils of small intestine as far as the third segment of the sacrum, and in the rest of its extent it is posterior to the rectum. It is accompanied below by venæ comites, which, however, unite, above, to form a single middle sacral vein.

As it lies anterior to the last lumbar vertebra it gives off on each side a lumbar branch, the *arteria lumbalis ima*, which is distributed like an ordinary lumbar artery, and as it descends in front of the sacrum it distributes small parietal branches laterally which anastomose with the lateral sacral arteries. The parietal branches usually give off small spinal offsets which enter the anterior sacral foramina. Small and irregular visceral branches pass to the rectum and anastomose with the superior and middle hæmorrhoidal arteries.

Abnormalities.—The **middle sacral artery** usually springs from the back of the aorta above its bifurcation; it may be considerably above, or more rarely it may spring directly from the bifurcation. Not infrequently it arises from the last lumbar artery or from a stem common to the two last lumbar arteries, and occasionally it arises from a common or internal iliac artery. Sometimes it gives off the last pair of lumbar arteries, and, in a few cases, an accessory, renal, or a hæmorrhoidal branch arises from it. The vessel is not always present, it may be double, entirely or in part, and it may bifurcate at its termination.

ARTERIÆ ILIACÆ COMMUNES.

4. The **common iliac arteries** (Figs. 748 and 752) are the terminal branches of the abdominal aorta. They commence opposite the middle of the body of the fourth lumbar vertebra a little to the left of the median plane. Each artery passes downwards and laterally, across the bodies of the fourth and fifth lumbar vertebræ and the intervening intervertebral fibro-cartilage, and it terminates, at the level of the lumbo-sacral articulation and anterior to the corresponding sacro-iliac joint, by dividing into external iliac and hypogastric branches.

The direction of each common iliac is indicated by a line drawn from the bifurcation of the aorta to a point midway between the symphysis pubis and the anterior superior spine of the ilium.

The right artery is a little longer than the left; the former being about 50 mm. (two inches) and the latter 43 mm. (one and three-quarter inches) in length.

Relations—*Anterior.*—Both arteries are covered anteriorly by peritoneum, and are separated by it from coils of the small intestine. Communicating branches between the aortic and hypogastric plexuses of the sympathetic pass in front of the arteries, each of which is often crossed, anteriorly, near its termination by the corresponding ureter.

The left artery is crossed, in addition, by the superior hæmorrhoidal vessels.

Posterior.—Behind the artery, of each side, are the bodies of the fourth and fifth lumbar vertebræ, and the intervening intervertebral fibro-cartilage, the sympathetic trunk, and the psoas major muscle. These relationships, however, are much closer on the left side than on the right. The right common iliac, except at its lower end, where it is in contact with the psoas major, is separated from the structures named by the terminations of the right and left common iliac veins and the commencement of the inferior vena cava. The left common iliac, which is not so separated, lies on the medial border of the psoas major. Somewhat deeply placed, in the areolar tissue between the psoas major and the lumbar vertebræ, are the obturator nerve, the lumbo-sacral trunk, and the ilio-lumbar artery, which form posterior relations to the common iliac artery of the corresponding side.

Lateral.—The lateral relations of each artery are coils of small intestine, and the commencement of the inferior vena cava lies to the lateral side of the upper part of the right artery.

Medial.—On the medial side of the right common iliac artery are the right common iliac vein, below, and the left common iliac vein, above. The last-named vein lies on the medial side of the left common iliac artery.

Branches.—The external iliac and the hypogastric are the only branches.

Abnormalities.—The **common iliac artery** may be longer or shorter than usual, a modification which is determined largely, though not altogether, by the point at which the bifurcation of the aorta takes place. If exceptionally long, it is usually tortuous. In rare cases in man the artery is absent. It occasionally gives off the middle or a lateral sacral artery, and ilio-lumbar, spermatic, or accessory renal branches may arise from it.

ARTERIA HYPOGASTRICA.

The **hypogastric artery** (O.T. **internal iliac**) (Figs. 748, 749, and 752) in the fœtus is the direct continuation of the common iliac trunk. It supplies numerous branches to the pelvis, runs upwards on the anterior abdominal wall to the umbilicus as the umbilical artery, and is prolonged through the umbilical cord to the placenta. One of its pelvic branches—the inferior gluteal (O.T. sciatic)—is at first the main artery of the inferior extremity, but subsequently another branch is given off which becomes the chief arterial trunk of the lower limb. This branch is the external iliac artery; it soon equals and ultimately exceeds the hypogastric in size, and it is into these two vessels that the common iliac appears to bifurcate.

When the placental circulation ceases and the umbilical cord is severed, the umbilical part of the hypogastric trunk which extends from the pelvis minor to the umbilicus atrophies, and is afterwards represented almost entirely by a fibrous cord, known as the obliterated umbilical artery. It is only at its proximal end that the atrophied part remains pervious, and there it forms the commencement of the superior vesical artery. The permanent hypogastric is a comparatively short vessel. Owing to the arrangement of some of its branches it appears to end in an anterior and a posterior division, the former of which is to be regarded as the continuation of the vessel, whilst the latter is simply a common stem of origin for some of the branches.

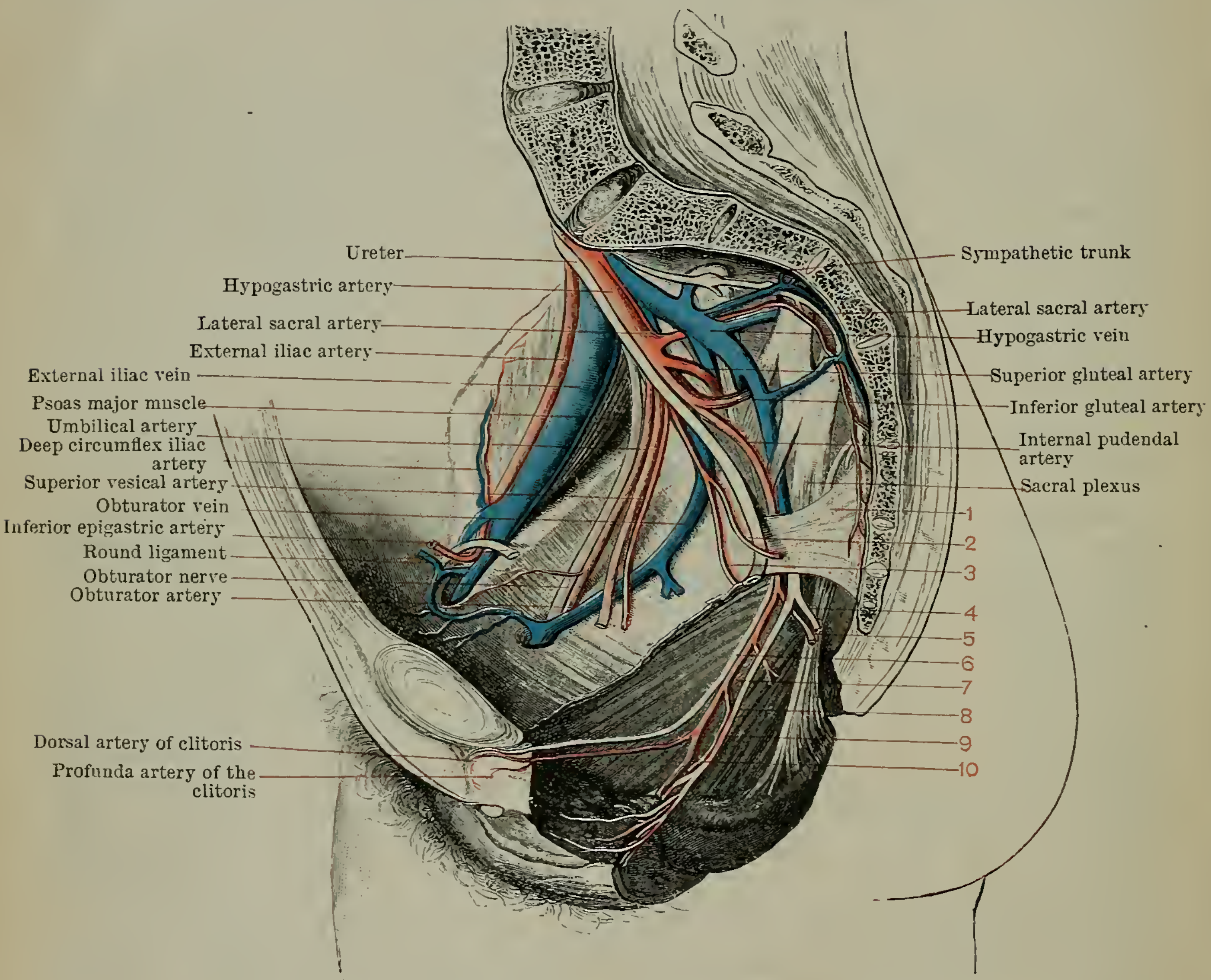

Fig. 749.—Hypogastric Artery and its Branches in the Female.

1. Sacro-spinous ligament.
2. Uterine artery.
3. Vaginal artery.
4. Inferior hæmorrhoidal nerve.
5. Inferior hæmorrhoidal artery.
6. Dorsal nerve of clitoris.
7. Internal pudendal artery.
8. Perineal nerve.
9. Superficial perineal artery.
10. Artery to the bulb of the vestibule.

With this explanation the artery may be described in the usual manner.

It arises from the common iliac opposite the sacro-iliac articulation and at the level of the lumbo-sacral articulation, and descends into the pelvis minor, to terminate, as a rule, opposite the upper border of the greater sciatic notch, in two divisions—anterior and posterior—from each of which branches of distribution are given off. The artery measures about 37 mm. (one and a half inches) in length.

Relations—*Anterior.*—Each hypogastric artery is covered antero-medially by peritoneum, behind which the corresponding ureter descends along the anterior border of the artery. The pelvic colon crosses from the front to the medial side of the left artery, and the terminal part of the ileum bears the same relation to the right artery.

Posterior to it are the hypogastric vein and the commencement of the common iliac vein ; still more posteriorly are the lumbo-sacral trunk and the sacro-iliac joint.

Lateral.—On its lateral side the external iliac vein separates it from the psoas major muscle, above. At a lower level the obturator nerve, embedded in a mass of fat, intervenes between the hypogastric artery and the lateral wall of the pelvis. On its medial side it is crossed by some of the tributaries of the hypogastric vein, and it is covered by peritoneum.

Branches.—The hypogastric artery supplies the greater part of the pelvic wall and contents, and its branches are distributed also to the buttock and thigh and to the external organs of generation.

All the branches may be given off separately from a single undivided parent trunk, but as a rule they arise in two groups corresponding to the two divisions in which the artery, under these circumstances, appears to end.

- Posterior division
  - parietal
    - Ilio-lumbar
    - Lateral sacral
    - Superior gluteal
- Anterior division
  - parietal
    - Obturator
    - Inferior gluteal
    - Internal pudendal
  - visceral
    - Umbilical (Superior vesical)
    - Inferior vesical
    - Middle hæmorrhoidal.

In the female two additional branches are present—a *uterine* and a *vaginal.*

BRANCHES OF THE POSTERIOR DIVISION.

The posterior terminal division gives off the ilio-lumbar and lateral sacral arteries, and is continued as the superior gluteal artery.

1. The **ilio-lumbar artery** runs upwards and laterally, across the upper margin of the pelvis minor, to the iliac fossa. It passes anterior to the sacro-iliac articulation, between the lumbo-sacral trunk and the obturator nerve, and posterior to either the lower part of the common or the upper part of the external iliac vessels, and the psoas and iliacus muscles.

In the iliac fossa it divides into an iliac and a lumbar branch. The **iliac branch** anastomoses with branches of the deep circumflex iliac and obturator arteries, it gives offsets to the iliacus, and supplies a large nutrient branch to the ilium. A **lumbar branch** ascends, behind the psoas major, to the crest of the ilium. It supplies the psoas and quadratus lumborum, and anastomoses with the lumbar and deep circumflex iliac arteries ; it also gives off a *spinal branch,* which enters the intervertebral foramen between the fifth lumbar vertebra and the sacrum, and is distributed like the spinal branches of the lumbar and the aortic intercostal arteries.

2. **Lateral Sacral Arteries.**—There is sometimes only a single **lateral sacral artery** on each side ; more commonly there are two, **superior** and **inferior.**

Both run downwards and medially, on the front of the sacrum. The inferior passes anterior to the piriformis and the sacral nerves, and descends, on the lateral side of the sympathetic trunk, to the coccyx, where it terminates by anastomosing with the middle sacral. The superior branch reaches only as far as the first or the second anterior sacral foramen ; then it enters the sacral canal. It anastomoses with the lower branch and with the middle sacral artery. Branches are given off by the lateral sacral arteries to the piriformis, and to the sacral nerves. Spinal offsets are also given off, which pass through the anterior sacral foramina to the sacral canal ; they supply the membranes of the spinal medulla, the roots of the sacral nerves, and the filum terminale, and anastomose with other spinal arteries. They then pass through the posterior sacral foramina, and anastomose on the back of the sacrum with branches of the superior and inferior gluteal arteries.

3. The Superior Gluteal Artery (Figs. 751 and 755).—After giving off the ilio-lumbar and lateral sacral branches, the posterior division of the hypogastric artery is continued as the **superior gluteal artery.** This is a large vessel which pierces the pelvic fascia, and passes backwards, between the lumbo-sacral trunk and the first sacral nerve. It leaves the pelvis through the upper part of the greater sciatic foramen, above the piriformis muscle, and enters the buttock, where it divides, under cover of the glutæus maximus and between the adjacent borders of the piriformis and glutæus medius muscles, into superficial and deep branches.

(*a*) The **superficial branch** divides at once into numerous rami, some of which supply the glutæus maximus, whilst others pass through it, near its origin, to the overlying skin. The branches freely anastomose with branches of the inferior gluteal, internal pudendal, medial circumflex, deep circumflex iliac, and lateral sacral arteries.

(*b*) The **deep terminal branch,** accompanied by the superior gluteal nerve, runs forwards between the glutæus medius and minimus, and, after giving a nutrient branch to the ilium, subdivides into upper and lower branches. The *upper branch* runs forwards along the origin of the glutæus minimus from the anterior curved line of the ilium, and passes beyond the anterior margins of the glutæus medius and minimus to anastomose, under cover of the tensor fasciæ latæ, with the ascending branch of the lateral circumflex artery. It anastomoses with the deep circumflex iliac artery also, and it supplies muscular branches to the adjacent muscles. The *lower branch* passes more directly forwards, across the glutæus minimus, towards the trochanter major, along with the branch of the superior gluteal nerve which supplies the tensor fasciæ latæ. It supplies the gluteal muscles, and anastomoses with the ascending branch of the lateral circumflex artery.

Before leaving the pelvis the gluteal artery gives **muscular branches** to the pelvic diaphragm and the obturator internus, small **neural branches** to the roots of the sacral plexus, and **nutrient branches** to the hip-bone.

BRANCHES OF THE ANTERIOR DIVISION.

The anterior division gives off both parietal and visceral branches, and is continued as the umbilical artery. The parietal branches are the obturator, the internal pudendal, and the inferior gluteal. The visceral branches include the superior and inferior vesical, and the middle hæmorrhoidal arteries in the male. In the female the anterior division of the hypogastric artery gives off similar visceral branches, and, in addition, a uterine and a vaginal branch.

VISCERAL BRANCHES.

1. The **superior vesical artery** arises from the incompletely obliterated posterior part of the umbilical artery, as it lies at the side of the bladder. It passes medially to the upper part of the urinary bladder and divides into numerous branches which anastomose with the other vesical arteries, and it also gives small branches to the urachus, and often to the lower part of the ureter. It may in addition give off a middle vesical branch, and not infrequently the long slender *artery to the ductus deferens* arises from it.

2. The Umbilical Artery.—Atrophy of that portion of the **umbilical artery** which extends from the anterior division of the hypogastric to the umbilicus has already been referred to. The atrophy is complete between the umbilicus and the origin of the superior vesical artery, but between that origin and the apparent ending of the hypogastric in its two divisions it is incomplete, and the lumen of the vessel, though greatly diminished in size, remains patent. It is from the incompletely obliterated portion that the superior vesical artery arises. The completely obliterated part of the umbilical artery is reduced to a fibrous cord which runs along the side of the bladder to its apex, and then ascends, on the posterior surface of the anterior abdominal wall, to the umbilicus. In the latter part of its course it is known as the **ligamentum umbilicale laterale.** As it passes along the wall of the pelvis it is external to the peritoneum, and it is crossed by the ductus deferens in the male, and by the round ligament in the female.

3. The **inferior vesical artery** runs medially, upon the upper surface of the levator ani, to the base of the bladder. It also gives branches to the seminal vesicles, the ductus deferens, the lower part of the ureter and the prostate, and it anastomoses with its fellow of the opposite side, with the other vesical arteries, and with the middle hæmorrhoidal artery.

4. Arteria Deferentialis.—The **artery to the ductus deferens** may arise from either the superior vesical or the inferior. It is a long slender vessel which accompanies the ductus deferens to the testis, where it anastomoses with the testicular artery. It also anastomoses with the external spermatic branch of the inferior epigastric artery.

5. The **middle hæmorrhoidal artery** is an irregular branch which arises either directly from the anterior division of the internal iliac or from the inferior vesical branch; more rarely it springs from the internal pudendal artery. It runs medially, and is distributed to the muscular coats of the rectum; it also gives branches to the prostate, the seminal vesicle, and the ductus deferens, and it anastomoses with its fellow of the opposite side, with the inferior vesical, and with the superior and inferior hæmorrhoidal arteries.

6. The **vaginal artery** may arise either directly from the anterior division of the hypogastric or from a stem common to it and the uterine artery, and it may be represented by several branches.

It runs downwards and medially, on the floor of the pelvis, to the side of the vagina, and divides into numerous branches which ramify on the anterior and posterior walls of the passage. The corresponding branches of opposite sides anastomose and form anterior and posterior longitudinal vessels, the so-called *azygos arteries.* They also anastomose above with the cervical branches of the uterine artery, and below with the perineal branches of the internal pudendal. In addition to supplying the vagina, small branches are given to the bulb of the vestibule, to the base of the bladder, and to the rectum.

7. The **uterine artery** arises from the anterior division of the internal iliac, either separately or in common with the vaginal or middle hæmorrhoidal arteries. It runs medially and slightly forwards, upon the upper surface of the levator ani, to the lower border of the broad ligament, between the two layers of which it passes medially, and arches above the ureter about three-quarters of an inch from the uterus. It passes above the lateral fornix of the vagina to the side of the neck of the uterus, and then ascends towards the fundus, but at the level of the uterine tube it turns laterally, below the tube and between the layers of the broad ligament, and anastomoses with the ovarian artery. It supplies the uterus, the upper part of the vagina, the medial part of the uterine tube, and gives branches to the round ligament of the uterus. It anastomoses with its fellow of the opposite side, and with the vaginal, the ovarian, and the inferior epigastric arteries, along the round ligament of the uterus.

PARIETAL BRANCHES OF THE ANTERIOR DIVISION.

1. The **obturator artery** (Figs. 749 and 752) runs anteriorly and downwards along the lateral wall of the pelvis minor, just below its upper margin, to the obturator foramen, through the upper part of which it passes. It terminates, immediately on entering the thigh, by dividing into anterior and posterior terminal branches, which skirt round the margin of the obturator foramen deep to the obturator externus muscle. It is accompanied, in the whole of its course, by the obturator nerve and vein, the nerve being above the artery and the vein below it.

To its lateral side is the pelvic fascia, which intervenes between it and the upper part of the obturator internus muscle, whilst on its medial side it is covered by peritoneum. The ureter intervenes between the posterior part of the artery and the peritoneum. When the bladder is distended it also comes into close relation with the lower and anterior part of the artery. In the female the ovarian vessels and the broad ligament form the medial relations of the obturator artery.

Branches.—All the branches except the terminal are given off before the artery leaves the pelvis. They include:—(*a*) **Muscular branches** to the obturator internus, levator ani and ilio-psoas muscles. (*b*) A **nutrient branch** to the ilium, which passes deep to the ilio-psoas muscle, supplies the bone, and anastomoses with the ilio-lumbar artery. (*c*) A **vesical branch** or branches pass medially to the bladder beneath the lateral false ligament. (*d*) A **pubic branch** ascends on the posterior surface of the pubis, and anastomoses with its fellow of the opposite side and with the pubic branch of the inferior epigastric. It is given off just before the artery leaves the pelvis, and, in its upward course, it may pass either on the lateral or medial side of the external iliac vein, whilst not infrequently it runs on the medial side of the femoral ring. In the latter case it is important in relation to femoral hernia; this importance is emphasised when, as sometimes happens, the obturator artery arises as an enlarged pubic branch of the inferior epigastric artery instead of from the hypogastric. (*e*) **Terminal.**—The *anterior terminal branch* runs forwards, and the *posterior* backwards around the margin of the obturator foramen. They lie on the obturator membrane, under cover of the obturator externus, and they anastomose together at the lower margin of the foramen. Both give off offsets which anastomose with the medial circumflex artery, and twigs of supply to the adjacent muscles. The posterior branch also gives an acetabular branch to the hip-joint, which passes upwards, through the acetabular notch on the medial side of the transverse ligament, to supply the ligamentum teres and the head of the femur.

2. The **internal pudendal artery** (Figs. 749 and 750) arises from the anterior division of the hypogastric, close to the origin of the inferior gluteal artery, which slightly exceeds it in size. It runs downwards and backwards, to the lower part of the greater sciatic foramen, lying anterior to the piriformis muscle and the sacral plexus, from both of which it is separated by the pelvic fascia. At the lower border of the piriformis it pierces the pelvic fascia, passes between the piriformis and coccygeus muscles, and leaves the pelvis to enter the buttock. It is accompanied by venæ comites, the inferior gluteal vessels and nerves, the pudendal nerve, and the nerve to the obturator internus. In the buttock it lies on the spine of the ischium, under cover of the glutæus maximus, and between the pudendal nerve and the nerve to the obturator internus, the former being medial to it. It next passes through the lesser sciatic foramen and enters the perineum, in the anterior part of which it terminates by dividing into the profunda artery of the penis and the dorsal artery of the penis.

In the first part of its course *in the perineum* the artery lies in the lateral fascial wall of the ischio-rectal fossa, where it is enclosed in a canal in the fascia (Alcock's canal). This canal, which is situated about one and a half inches above the lower margin of the tuberosity of the ischium, contains also the pudendal veins and the terminal parts of the pudendal nerve, viz., the dorsal nerve of the penis, which lies above the artery, and the perineal division, which lies below the vessel. From the ischio-rectal fossa the internal pudendal artery is continued forwards between the two layers of the fascia of the urogenital diaphragm (O.T. triangular ligament of the urethra), and close to the ramus of the pubis. About half-an-inch below the arcuate ligament it turns somewhat abruptly forwards, pierces the inferior fascia of the urogenital diaphragm, and immediately divides into its terminal branches, viz., the profunda artery and the dorsal artery of the penis. The division sometimes takes place whilst the artery is still between the layers of the urogenital diaphragm.

Branches.—*In the pelvis* it gives small branches to the neighbouring muscles and to the roots of the sacral plexus.

In the buttock.—(*a*) **Muscular branches** are distributed to the adjacent muscles. (*b*) **Anastomotic branches** unite with branches of the superior and inferior gluteal, and medial circumflex arteries.

In the ischio-rectal fossa.—(*c*) The **inferior hæmorrhoidal artery** pierces the wall of the fascial canal, and runs obliquely forwards and medially. It soon divides into two or three main branches, which may arise separately from the pudendal; they pass across the space to the anal passage. The artery anastomoses in the walls of the anal passage with its fellow of the opposite side, and with the middle and superior hæmorrhoidal arteries; it anastomoses with the transverse perineal arteries also; and it supplies cutaneous twigs to the region of the anus, and others, which turn round the lower border of the glutæus maximus, to supply the lower part of the buttock.

(*d*) The **perineal artery** arises in the anterior part of the ischio-rectal fossa, pierces the base of the fascia of the urogenital diaphragm, and divides into long slender *posterior scrotal branches* in the male, and *posterior labial branches* in the female. Those branches are continued forwards, in the urethral triangle, to the scrotum or labium, deep to the superficial perineal fascia. They anastomose with their fellows of the opposite side, with the transverse perineal and the external pudendal arteries, and supply the muscles and subcutaneous structures of the urethral triangle.

(*e*) The **transverse perineal artery** is a small branch which arises either directly from the internal pudendal or from its perineal branch. It runs medially along the base of the fascia of the urogenital diaphragm (O.T. triangular lig.) to the central point of the perineum, where it anastomoses with its fellow of the opposite side, with the perineal artery, and with the inferior hæmorrhoidal arteries. It supplies the sphincter ani, the bulbo-cavernosus or sphincter vaginæ, and the anterior fibres of the levator ani.

In the urethral triangle.—(*f*) The **artery to the bulb**, a branch which is usually of relatively large size, is given off between the fascial layers of the urogenital diaphragm. It runs transversely along the posterior border of the sphincter of the membranous urethræ, and then, turning forwards a short distance from the side of the urethra, it pierces the inferior fascia of the urogenital diaphragm and enters the substance of the bulb. It passes onwards in the corpus cavernosum urethræ to the glans, where it anastomoses with its fellow and with the dorsal arteries of the penis.

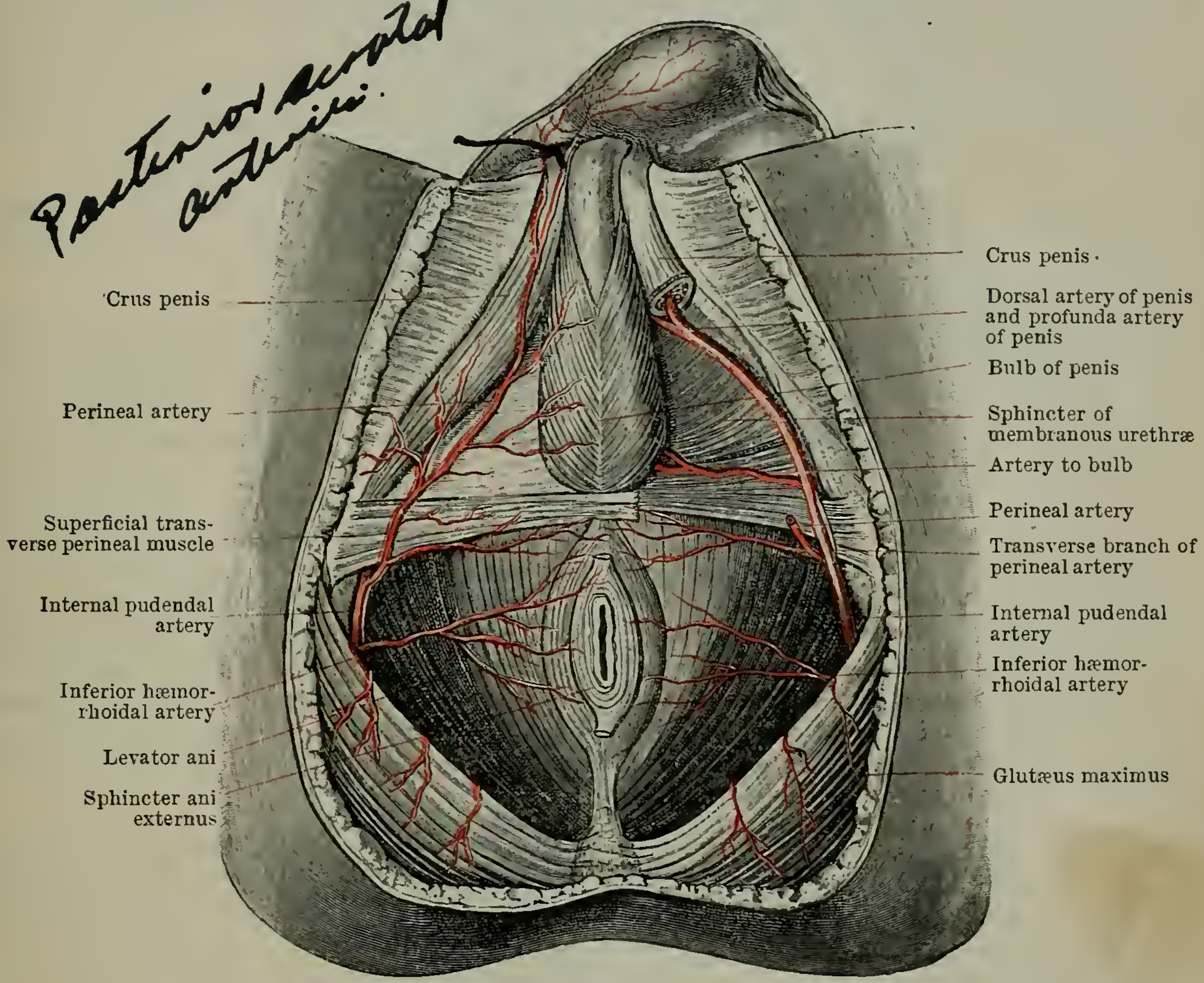
Posterior scrotal arteries.
Crus penis
Perineal artery
Superficial transverse perineal muscle
Internal pudendal artery
Inferior hæmorrhoidal artery
Levator ani
Sphincter ani externus
Crus penis
Dorsal artery of penis and profunda artery of penis
Bulb of penis
Sphincter of membranous urethræ
Artery to bulb
Perineal artery
Transverse branch of perineal artery
Internal pudendal artery
Inferior hæmorrhoidal artery
Glutæus maximus

FIG. 750.—THE PERINEAL DISTRIBUTION OF THE INTERNAL PUDENDAL ARTERY IN THE MALE.

It supplies the sphincter of the membranous urethræ, bulbo-urethral gland (Cowper), the corpus cavernosum urethræ, and the penile part of the urethra. In the female this artery supplies the bulb of the vestibule.

(*g*) The **profunda artery of the penis** (O.T. **artery of the corpus cavernosum**) in the male, and **of the clitoris** in the female, is usually the larger of the two terminal branches. Immediately after its origin it enters the crus penis, and runs forwards in the corpus cavernosum penis, which it supplies.

(*h*) The **dorsal artery of the penis** in the male, and **of the clitoris** in the female, passes forwards between the layers of the suspensory ligament, and runs along the dorsal surface of the penis, with the dorsal nerve immediately to its lateral side, whilst it is separated from its fellow of the opposite side by the deep dorsal vein, which lies in the median plane. It supplies the superficial tissues on the dorsal aspect of the penis, sends branches into the corpus cavernosum penis to anastomose with the profunda artery of the penis, and its terminal branches enter the glans penis, where they anastomose with the arteries to the bulb. It anastomoses also with the external pudendal branches of the femoral.

3. The **inferior gluteal artery** (O.T. **sciatic**) (Figs. 751 and 755) arises from the hypogastric artery, either separately or by a common trunk with the internal pudendal artery. It descends a little postero-lateral to the internal pudendal vessels, pierces the pelvic fascia, runs backwards between the first and second, or second and third sacral nerves, and, passing between the piriformis and coccygeus muscles, leaves the pelvis through the lower part of the greater sciatic foramen, and enters the buttock just below the piriformis. In the buttock it descends posterior and to the medial side of the sciatic nerve deep to the glutæus maximus, and posterior to the obturator internus, the two gemelli, the quadratus femoris, and upper part of the adductor magnus muscles, to the proximal part of the thigh. Below the lower border of the glutæus maximus the artery is comparatively superficial, and having given off its largest branches, it runs distally, as a long slender vessel, with the posterior femoral cutaneous nerve.

Branches—*In the pelvis.*—Small and irregular branches supply the adjacent viscera and muscles and the sacral nerves; they anastomose with branches of the internal pudendal and lateral sacral arteries.

In the buttock.—(*a*) **Muscular branches** are given off to the muscles of the buttock and to the proximal parts of the hamstring muscles. They anastomose with the internal pudendal, medial circumflex, and obturator arteries. (*b*) The **coccygeal branch** arises immediately after the artery leaves the pelvis. It runs medially, pierces the sacro-tuberous ligament and the glutæus maximus, and ends in the soft tissues over the posterior aspect of the lower part of the sacrum and of the coccyx. It gives several branches to the glutæus maximus, and anastomoses with branches of the gluteal and lateral sacral arteries. (*c*) An **anastomotic branch** passes laterally, superficial or deep to the sciatic nerve, towards the greater trochanter of the femur. It anastomoses with branches of the gluteal, internal pudendal, medial and lateral circumflex, and the first perforating arteries, taking part in the formation of the so-called "crucial anastomosis." (*d*) **Cutaneous branches**, accompanying twigs of the posterior cutaneous nerve of the thigh, pass round the lower border of the glutæus maximus muscle to the integument. (*e*) The **a. comitans n. ischiadici** is a long slender branch which runs distally on the surface, or in the substance of the sciatic nerve. It supplies the nerve, and anastomoses with the perforating arteries and with the termination of the profunda femoris artery.

Abnormalities.—The **hypogastric artery** varies as regards length. It is usually longer, and arises at a higher level when the common iliac is short. In rare cases it has been found to arise from the aorta without the intervention of a common iliac. Frequently it does not, even in appearance, end in anterior and posterior divisions, but obviously forms a single trunk, as in the fœtus, from which the several branches are given off.

The visceral branches vary much in number and size, and the middle hæmorrhoidal may not be present, its place being taken by branches from the vesical arteries. A renal branch sometimes arises from the hypogastric artery.

The ilio-lumbar branch may arise from the common iliac instead of from the hypogastric artery; the superior gluteal and inferior gluteal arteries may arise by a common stem, or the superior gluteal may be absent, and its place taken by a branch from the femoral artery; the inferior gluteal artery may, as in the fœtus, constitute the main artery of the lower limb, and run distally to become continuous with the popliteal artery. Probably the arteria comitans nervi ischiadici represents the original continuity of the two vessels. Occasionally the lateral sacral arteries do not arise from the hypogastric trunks.

In some instances the **obturator artery** arises from the inferior epigastric artery instead of from the hypogastric. The condition is apparently due to obliteration of the usual origin of the obturator artery and to the subsequent enlargement of the anastomosing pubic branches of the obturator and inferior epigastric arteries. The course of the abnormal obturator artery is of importance. From its origin it descends into the pelvis minor, on the medial side of the external iliac vein, and in the majority of cases on the lateral side of the crural ring, but in three-tenths of the cases, and more frequently in males than in females, it descends on the medial side of the ring.

The obturator artery sometimes gives off an accessory pudendal branch which passes along the side of the prostate, pierces the urogenital diaphragm, and terminates by dividing into the profunda artery of the penis and the dorsal artery of the penis. When this occurs the internal pudendal artery is small, and it terminates in the artery to the bulb. Occasionally the accessory pudendal arises from the internal pudendal artery in the pelvis, or from one of the vesical arteries.

ARTERIES OF THE INFERIOR EXTREMITY.

The main artery of each lower limb is continued from the corresponding common iliac artery. It descends as a single trunk as far as the lower border of the popliteus, and ends there by dividing into the anterior and posterior tibial arteries. Distinctive names are, however, applied to different parts of the artery, corresponding to the several regions through which it passes. Thus in the abdomen it is

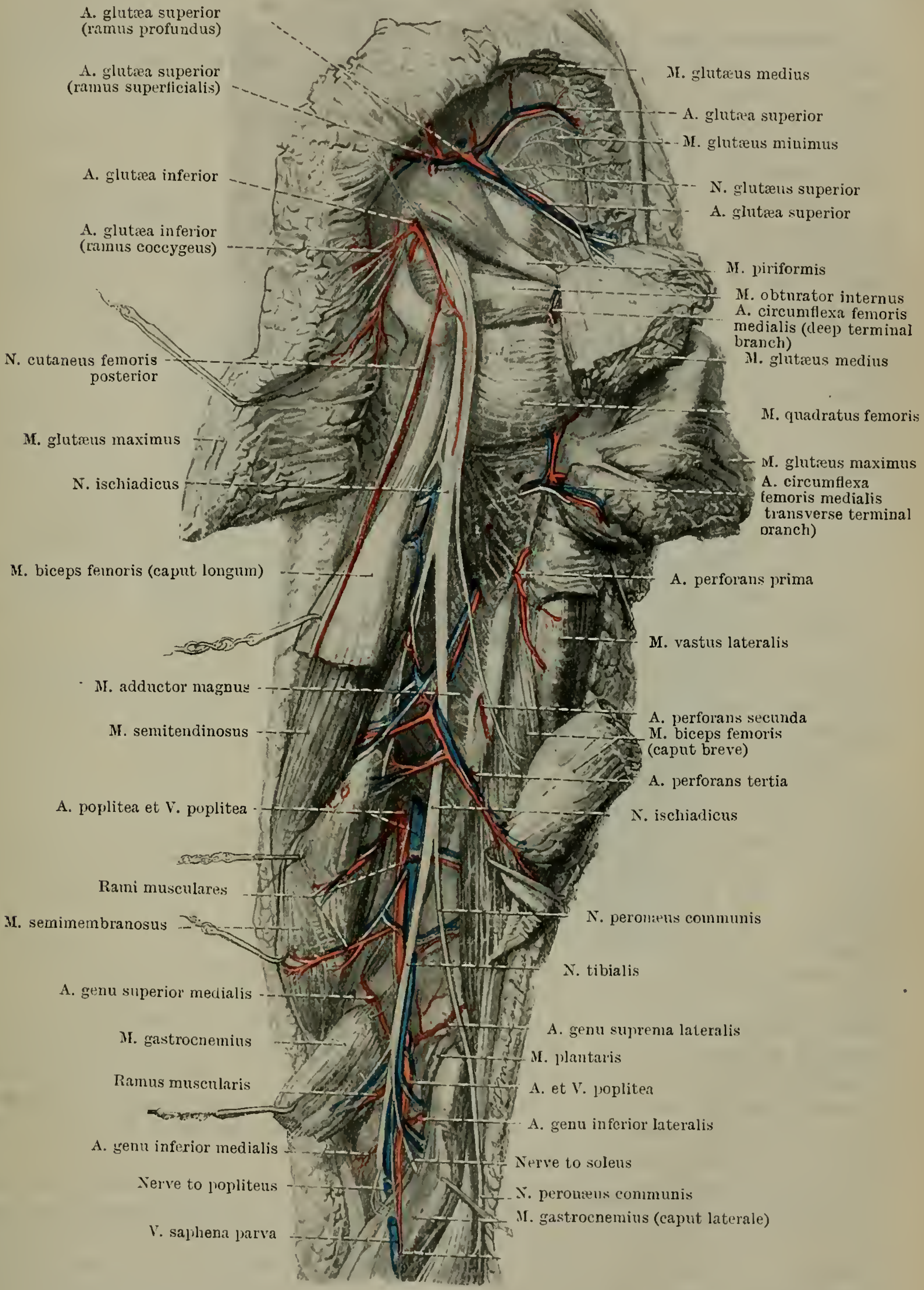

FIG. 751.—THE ARTERIES OF THE BUTTOCK AND THE POSTERIOR ASPECT OF THE THIGH AND KNEE.
NOTE.—In the specimen there was no anastomotic branch of the inferior gluteal artery, and the transverse terminal branch of the medial femoral circumflex artery pierced the upper part of the adductor magnus.

called the **external iliac artery**, in the proximal two-thirds of the thigh it receives the name of the **femoral artery**, whilst its distal part, which is situated on the flexor aspect of the knee, is termed the **popliteal artery**.

ARTERIA ILIACA EXTERNA.

The **external iliac artery** (Figs. 748, 752) extends from a point opposite the sacro-iliac joint, at the level of the lumbo-sacral articulation, to a point below the inguinal ligament (Poupart's), midway between the anterior superior spine of the ilium and the symphysis pubis, where it becomes the femoral artery. Its length is about 87 to 100 mm. (three and a half to four inches), and in the adult it is usually somewhat larger than the hypogastric artery.

It runs downwards, forwards, and laterally, along the superior aperture of the pelvis minor, resting upon the fascia iliaca, which separates it, above, from the medial border, and, below, from the anterior surface of the psoas major muscle; and it is enclosed, with its accompanying vein, in a thin fascial sheath.

Relations—*Anterior.*—It is covered in front by peritoneum, which separates it on the left side from the iliac colon, and coils of small intestine, and on the right side from the terminal portion of the ileum, and sometimes from the vermiform process. The ureter, descending behind the peritoneum, sometimes crosses the front of the artery near its origin, and in the female the ovarian vessels cross the upper part of the artery. Near its lower end the artery is crossed anteriorly by the external spermatic branch of the genito-femoral nerve and by the deep circumflex iliac vein. In the male this part of the artery is crossed also by the ductus deferens, and in the female by the round ligament of the uterus. Several iliac lymph glands lie in front and at the sides of the external iliac artery, and almost invariably one of these is directly anterior to its termination.

Posterior.—The fascia iliaca and psoas major muscle lie behind the artery. Near its upper end the obturator nerve and the external iliac vein are posterior to the vessel.

Lateral.—On its lateral side is the genito-femoral nerve. *Medial.*—To the medial side of its lower part is the external iliac vein.

Branches.—In addition to small branches to the psoas major muscle and to the lymph glands, two named branches of considerable size spring from the external iliac artery, viz., the inferior epigastric and the deep circumflex iliac.

(1) The **inferior epigastric artery** (Figs. 749 and 752) arises, immediately above the inguinal ligament, from the front of the external iliac. It lies in the extra-peritoneal fat, it curves forwards from its origin, turns round the lower border of the peritoneal sac, and runs upwards and medially, along the medial side of the abdominal inguinal ring and along the lateral border of the medial inguinal fossa; it then pierces the transversalis fascia, passes over the semicircular fold (Douglas) and enters the sheath of the rectus abdominis muscle. For a short distance it ascends posterior to the rectus, but it soon penetrates the substance of the muscle, and breaks up into branches which anastomose with terminal offsets of the superior epigastric branch of the internal mammary artery and with the lower intercostal arteries. At the abdominal inguinal ring, in the male, the ductus deferens, the testicular vessels, and the external spermatic branch of the genito-femoral nerve hook round the front and lateral side of the artery, the ductus deferens turning medially behind it; whilst in the female the round ligament of the uterus and the external spermatic branch of the genito-femoral nerve occupy the corresponding positions.

Branches.—(*a*) **Muscular branches** supply the rectus, the pyramidalis, the transversus, and the oblique muscles of the abdominal wall, and anastomose with branches of the deep circumflex iliac, the lumbar, and the lower intercostal arteries. (*b*) **Cutaneous branches**, which pass from the front of the inferior epigastric, pierce the rectus abdominis and the anterior part of its sheath, and terminate in the subcutaneous tissues of the anterior abdominal wall, where they anastomose with corresponding branches of the opposite side and with branches of the superficial epigastric artery. (*c*) The **external spermatic** in the male (**artery of the round ligament of the uterus** in the female) is small. It descends through the inguinal canal and anastomoses with the external pudendal and the scrotal branches of the perineal artery, and in the male with the internal spermatic artery also. In the male it accompanies the spermatic funiculus, supplying its coverings, including the cremaster. In the female it runs with the round ligament. (*d*) The **pubic branch** descends, either on the lateral or the medial side of the femoral ring, to anastomose with the pubic branch of the obturator artery; it anastomoses also with its fellow of the opposite side. Sometimes, when the obturator branch of the hypogastric artery is absent, the pubic branch of the inferior epigastric artery enlarges and becomes the obturator artery, which descends to the obturator foramen either on the lateral or the medial side of the femoral ring. In the latter case the artery may be injured in the operation for the relief of a strangulated femoral hernia.

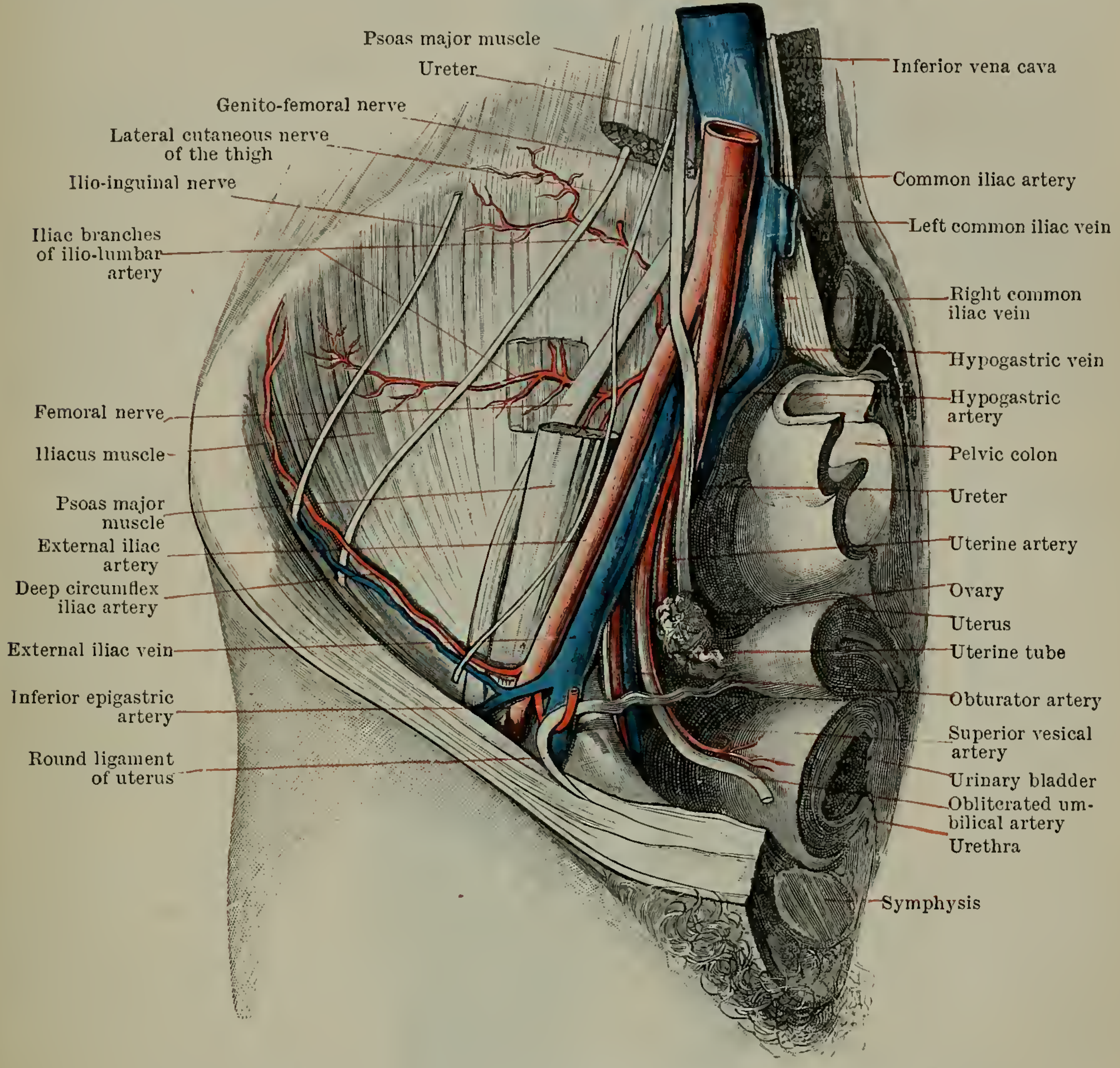

FIG. 752.—THE ILIAC AND HYPOGASTRIC ARTERIES AND VEINS IN THE FEMALE.

(2) The **deep circumflex iliac artery** (Figs. 752 and 753) springs from the lateral side of the external iliac artery, usually a little below the inferior epigastric, and immediately above the inguinal ligament. It runs laterally and upwards to the anterior superior spine of the ilium. In that part of its course it lies just above the lower border of the inguinal ligament, and is enclosed in a fibrous canal formed by the union of the transversalis and iliac fasciæ. A little beyond the anterior superior spine it pierces the transversus abdominis, and is continued between the transversus and the internal oblique, to terminate by anastomosing with branches of the ilio-lumbar artery.

Branches.—(*a*) **Muscular** to the upper parts of the sartorius and the tensor fasciæ latæ, and to the muscles of the abdominal wall. One of the latter branches is frequently of considerable size; it pierces the transversus muscle a short distance anterior to the anterior superior spine of the ilium, and ascends vertically, between the transversus and the internal oblique, anastomosing with the lumbar and the epigastric arteries. (*b*) **Cutaneous branches** pierce the muscles. They terminate in the skin over the crest of the ilium, and they anastomose with the superior gluteal, the superficial circumflex iliac, and the ilio-lumbar arteries.

Abnormalities.—The **external iliac artery** may be much smaller than usual, especially if the inferior gluteal artery persists as the main vessel of the lower limb. It may give off two deep circumflex iliac branches, a dorsal artery of the penis, a medial circumflex artery of the thigh, or a vas aberrans, and its deep circumflex iliac and inferior epigastric branches may arise at higher or lower levels than usual.

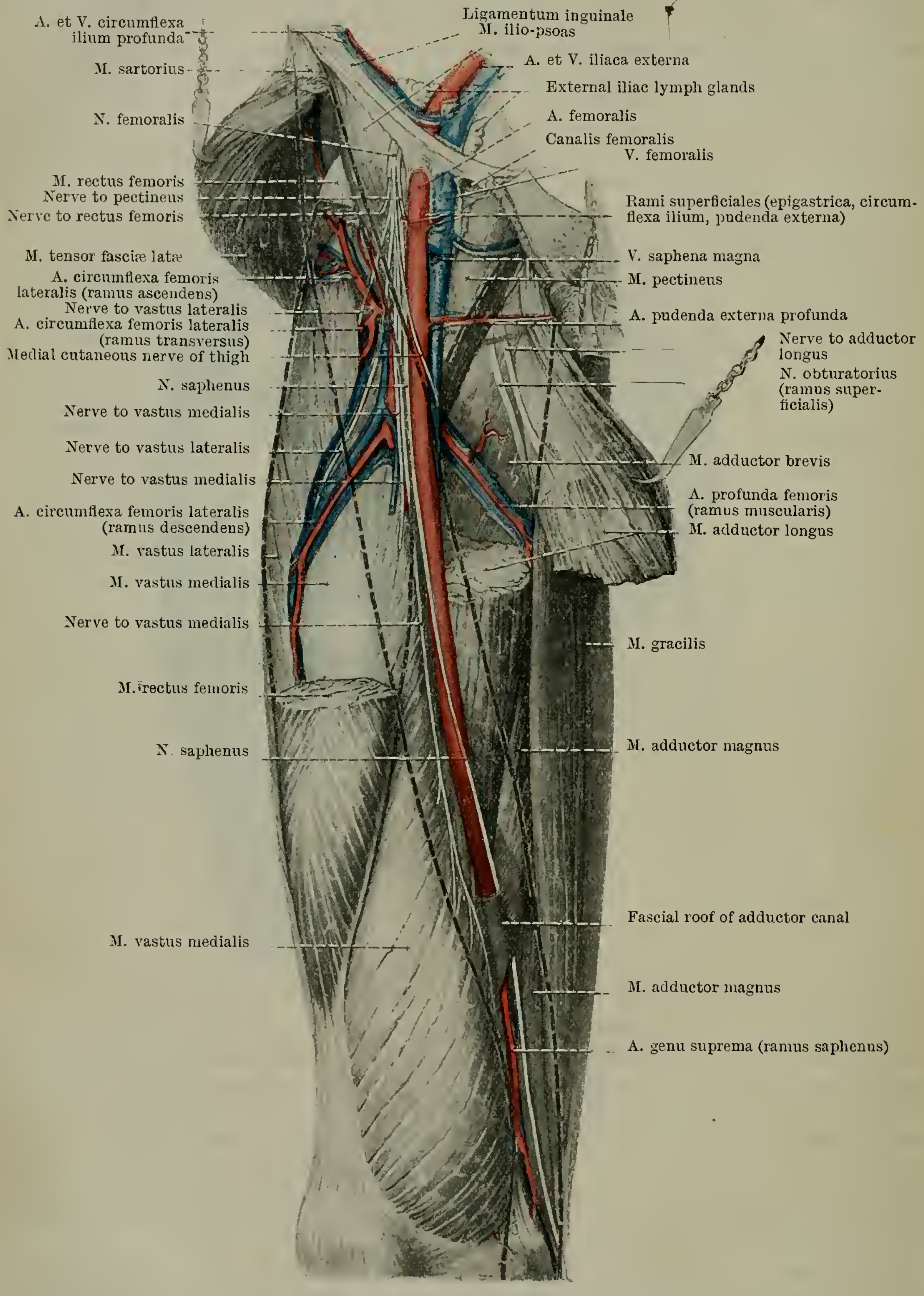
A. et V. circumflexa ilium profunda
M. sartorius
N. femoralis
M. rectus femoris
Nerve to pectineus
Nerve to rectus femoris
M. tensor fasciæ latæ
A. circumflexa femoris lateralis (ramus ascendens)
Nerve to vastus lateralis
A. circumflexa femoris lateralis (ramus transversus)
Medial cutaneous nerve of thigh
N. saphenus
Nerve to vastus medialis
Nerve to vastus lateralis
Nerve to vastus medialis
A. circumflexa femoris lateralis (ramus descendens)
M. vastus lateralis
M. vastus medialis
Nerve to vastus medialis
M. rectus femoris
N. saphenus
M. vastus medialis
Ligamentum inguinale
M. ilio-psoas
A. et V. iliaca externa
External iliac lymph glands
A. femoralis
Canalis femoralis
V. femoralis
Rami superficiales (epigastrica, circumflexa ilium, pudenda externa)
V. saphena magna
M. pectineus
A. pudenda externa profunda
Nerve to adductor longus
N. obturatorius (ramus superficialis)
M. adductor brevis
A. profunda femoris (ramus muscularis)
M. adductor longus
M. gracilis
M. adductor magnus
Fascial roof of adductor canal
M. adductor magnus
A. genu suprema (ramus saphenus)

FIG. 753.—THE FEMORAL ARTERY AND ITS BRANCHES.
NOTE.—The outlines of the sartorius, the upper part of the rectus femoris, and the adductor longus are indicated by broken black lines.

ARTERIA FEMORALIS.

The **femoral artery** (Figs. 753 and 754) is the continuation of the external iliac into the thigh. It commences at the lower border of the inguinal ligament

(O.T. Poupart's), passes through the proximal two-thirds of the thigh, and terminates at the opening in the adductor magnus. At one time it was customary to speak of the first one and a half inches, as far as the origin of the profunda branch, as the common femoral, and to say that it divided into the superficial and deep femoral branches, of which the former was the direct continuation of the common trunk. The morphology and development of the vessel give no support for such terminology.

Course.—Its general direction is indicated by a line drawn from the point of origin, midway between the anterior superior spine of the ilium and the symphysis pubis, to the adductor tubercle, the thigh being flexed, abducted, and rotated laterally.

In its proximal half the femoral artery lies in the femoral trigone (Scarpa), and is comparatively superficial; at the apex of the trigone it passes deep to the sartorius, enters the adductor canal (Hunter's), and is thus more deeply placed.

At their entry into the femoral trigone both the artery and its vein are enclosed, for a distance of 31 mm. (one and a quarter inches), in a funnel-shaped fascial sheath formed of the fascia transversalis anteriorly and the fascia iliaca posteriorly. This is called the **femoral sheath**; it is divided, by antero-posterior septa, into three compartments, of which the lateral is occupied by the femoral artery and lumbo-inguinal branch of the genito-femoral nerve; the intermediate compartment contains the femoral vein; and the medial compartment constitutes the femoral canal.

Relations—*Anterior.*—In the femoral trigone the femoral artery is covered superficially by skin and fasciæ, by superficial sub-inguinal lymph glands and small superficial vessels. The anterior part of the femoral sheath and the fascia cribrosa are in front of the proximal part of the artery, and the fascia lata is in front of the distal part. Near the apex of the triangle the artery is crossed by the medial cutaneous nerve, and not infrequently by a tributary of the great saphenous vein. *Posterior.*—It is in relation, posteriorly, proximo-distally, with the posterior part of the femoral sheath, the pubic or pectineal portion of the fascia lata and the psoas major, the pectineus, and the proximal part of the adductor longus muscles. The nerve to the pectineus passes between the artery and the psoas major; the femoral vein and the profunda artery and vein intervene between it and the pectineus, and the femoral vein also separates it from the adductor longus.

The femoral vein, which lies on a plane posterior to the artery in the lower part of the femoral trigone, passes to its medial side above, where it is separated from the artery by the lateral septum of the femoral sheath. On the lateral side of the artery is the femoral nerve (O.T. anterior crural) proximally; more distally the saphenous nerve and the nerve to the vastus medialis are continued on the lateral side. The lumbo-inguinal branch of the genito-femoral nerve is anterior and to the lateral side, proximally, as it runs for a short distance in the femoral sheath.

In the *adductor canal* the artery has posterior to it the adductor longus and the adductor magnus, whilst anterior and to the lateral side is the vastus medialis. The femoral vein is also posterior to the artery, but lies to its lateral side distally and to its medial side proximally. Anterior to the artery is the fascial roof of the canal, with the obturator or sub-sartorial plexus of nerves and the sartorius muscle. The saphenous nerve enters the adductor canal with the artery, and runs first on its lateral side, then anterior, and lastly on its medial side.

Branches.—The femoral artery gives off the following branches :—

(1) Superficial branches.
    (*a*) The superficial circumflex iliac.
    (*b*) The superficial epigastric.
    (*c*) The superficial external pudendal.
(2) Muscular.
(3) The deep external pudendal.
(4) The profunda.
(5) The arteria genu suprema.

(*a*) The **superficial circumflex** iliac **artery** springs from the front of the femoral artery, just below the inguinal ligament. It pierces the femoral sheath and the fascia lata, lateral to the fossa ovalis, and runs, in the superficial fascia, as far as the anterior superior spine of the ilium. It supplies the lateral set of sub-inguinal glands and the skin of the groin, and it sends branches, through the fascia lata, which anastomose with branches of the deep circumflex iliac artery, and supply the upper parts of the sartorius and tensor fasciæ latæ muscles.

(*b*) The **superficial epigastric artery** arises near the preceding. It pierces the femoral sheath and the fascia cribrosa, and passes upwards and medially between the superficial and deep layers of the superficial fascia of the abdominal wall, towards the umbilicus. It supplies the sub-inguinal glands and the integument, and anastomoses with its fellow of the opposite side, with the inferior epigastric, and with the superficial circumflex iliac and superficial external pudendal arteries.

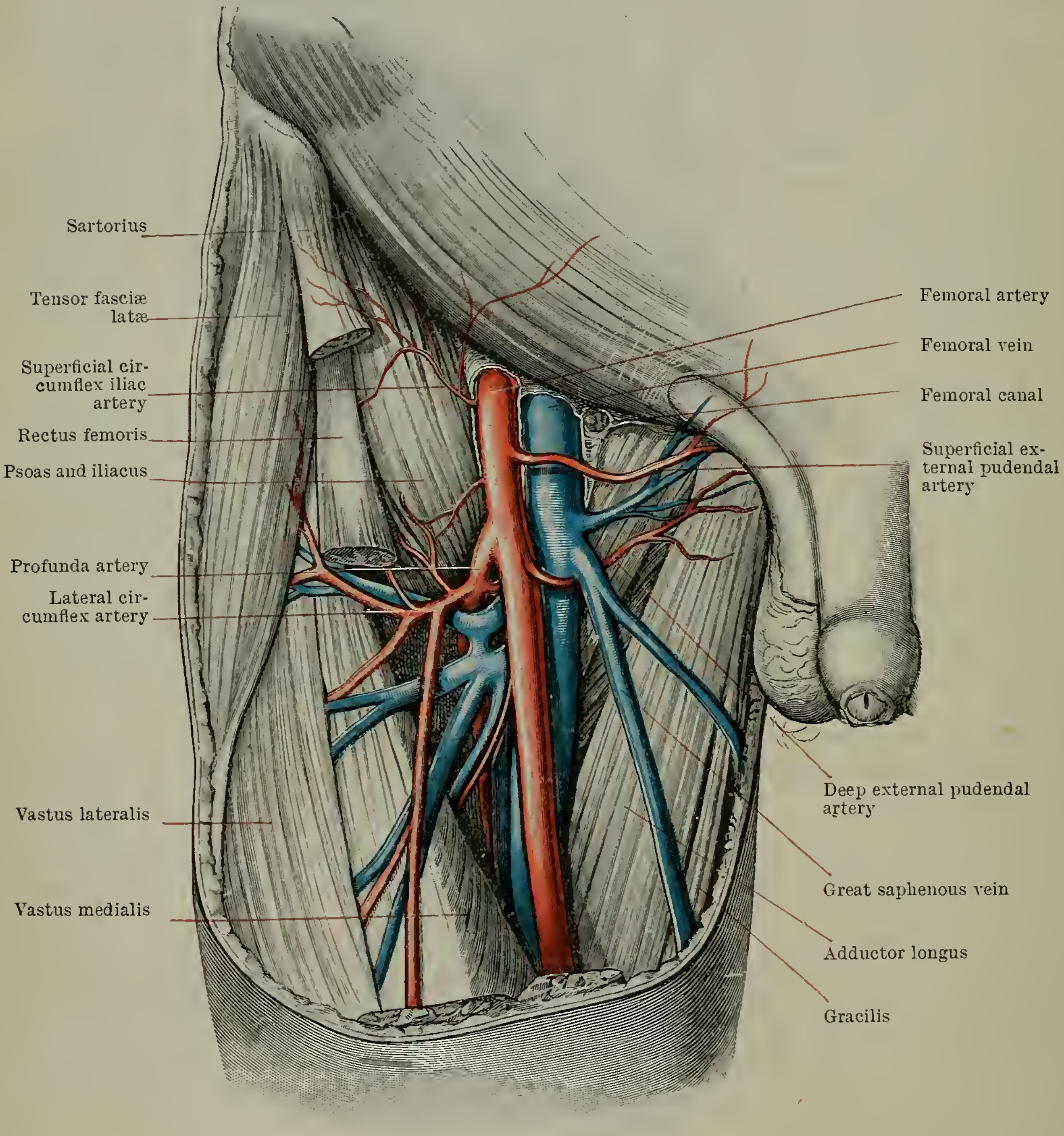

FIG. 754.—THE FEMORAL VESSELS IN FEMORAL TRIGONE.

(*c*) The **superficial external pudendal artery** also springs from the front of the femoral artery, and, after piercing the femoral sheath and the fascia cribrosa, runs upwards and medially towards the pubic tubercle, where it crosses superficial to the spermatic cord and divides into terminal *anterior scrotal* or *labial branches* according to the sex. It supplies the integument of the lower part of the abdominal wall, the root of the dorsum of the penis in the male, and the region of the mons Veneris in the female, and it anastomoses with its fellow of the opposite side, with the deep external pudendal, with the dorsal artery of the penis, and with the superficial epigastric artery.

(2) The **muscular branches** are distributed to the pectineus and the adductor muscles on the medial side, and to the sartorius and the vastus medialis on the lateral side.

(3) The **deep external pudendal artery** arises from the medial side of the femoral. It runs medially, anterior to the pectineus, and either anterior or posterior to the adductor longus, to the medial side of the thigh; it then pierces the deep fascia, and terminates in the scrotum, where it anastomoses with the posterior scrotal branches of the perineal and the anterior scrotal branches of the superficial external pudendal arteries, and with the external spermatic branch of the inferior epigastric artery. In the female it terminates in the labium majus.

(4) The **profunda artery** (Fig. 754) is the largest branch of the femoral artery. It arises about 37 mm. (an inch and a half) distal to the inguinal ligament, from the lateral side of the femoral artery. It curves backwards and medially, passes posterior to the femoral artery, and runs distally, close to the medial aspect of the femur, to the distal third of the thigh, where it perforates the adductor magnus and passes to the back of the thigh. Its termination is known as the *fourth perforating artery.* As the profunda descends it lies anterior to the iliacus, the pectineus, the adductor brevis, and the adductor magnus. It is separated from the femoral artery by its own vein, by the femoral vein, and by the adductor longus muscle.

Branches.—(*a*) **Muscular branches** are given off from the profunda, both in the femoral trigone and whilst it lies between the adductor muscles; many of them terminate in the adductors, others pass through the adductor magnus, and terminate in the hamstrings, where they anastomose with the transverse branch of the medial circumflex and with the proximal muscular branches of the popliteal artery.

(*b*) The **lateral circumflex artery** (Figs. 753 and 754) springs from the lateral side of the profunda, or occasionally from the femoral artery proximal to the origin of the profunda. It runs laterally, anterior to the iliacus and between the superficial and deep branches of the femoral nerve, to the lateral border of the femoral trigone; then, passing posterior to the sartorius and the rectus femoris, it terminates by dividing into three terminal branches —the ascending, the transverse, and the descending. Before its termination it supplies branches to the muscles mentioned and to the proximal part of the vastus intermedius.

(i.) The **ascending terminal branch** runs proximally and laterally, posterior to the rectus femoris and the tensor fasciæ latæ, along the linea intertrochanterica, to the anterior borders of the glutæi, medius and minimus, between which it passes to anastomose with the deep branches of the superior gluteal artery. It supplies twigs to the neighbouring muscles, anastomoses with the gluteal, the deep circumflex iliac, and the transverse branch of the lateral circumflex arteries, and, as it ascends along the linea intertrochanterica, it gives off a branch which passes, between the two limbs of the ilio-femoral ligament, into the hip-joint. (ii.) The **transverse terminal branch** is small; it runs laterally, between the vastus intermedius and the rectus femoris, passes into the substance of the vastus lateralis, winds round the femur, and anastomoses with the ascending and descending branches, with the perforating branches of the profunda, and with the inferior gluteal and medial circumflex arteries. (iii.) The **descending terminal branch** runs distally, posterior to the rectus and along the anterior border of the vastus lateralis, accompanied by the nerve to the latter muscle. It anastomoses with the transverse branch, with twigs of the inferior perforating arteries, with the arteria genu suprema of the femoral, and with the superior lateral genicular branch of the popliteal artery.

(*c*) The **medial circumflex artery** springs from the medial and posterior part of the profunda, at the same level as the lateral circumflex, and runs backwards, through the floor of the femoral trigone, passing between the psoas major and the pectineus; then it crosses the upper border of the adductor brevis, and continuing backwards, below the neck of the femur, it passes between the adjacent borders of the obturator externus and the adductor brevis to the upper border of the adductor magnus, where it divides into two terminal branches, a transverse and a profunda branch.

Branches.—(i.) An **acetabular branch** is given off as the artery passes below the neck of the femur. It ascends to the acetabular notch where it anastomoses with twigs from the posterior branch of the obturator artery, and it sends branches into the acetabular fossa and along the ligamentum teres to the head of the femur. (ii.) A **superficial branch**, which passes medially, anterior to the pectineus and between the adductors brevis and longus. (iii.) **Muscular branches** are given off to the neighbouring muscles. The largest of these branches usually arises immediately before the termination of the artery; it runs distally, on the anterior aspect of the adductor magnus, and anastomoses with the muscular branches of the profunda artery. (iv.) The **profunda terminal branch** (ascending) passes upwards and laterally, between the obturator externus and the quadratus femoris to the trochanteric fossa of the femur, where it anastomoses with branches of the superior and inferior gluteal arteries. (v.) The **transverse terminal branch** runs backwards to the hamstring muscles, usually between the lower border of the quadratus femoris and the upper border of the adductor magnus, but it may pierce the upper part of the adductor magnus. It anastomoses, in front of the distal part of the glutæus maximus, with the inferior gluteal and first perforating arteries and with the transverse branch of the lateral circumflex, and, in the substance of the hamstrings, with the muscular branches of the profunda.

(*d*) The **perforating arteries** (Fig. 755), including the terminal branch of the profunda, are four in number. They curve postero-laterally, round the posterior aspect of the femur, lying close to the bone and anterior to the well-marked tendinous arches which interrupt the continuity of muscular attachments; their terminal branches enter the vastus lateralis and anastomose, in its substance, with one another, with the descending branch of the lateral circumflex, with the arteria genu suprema, and with the superior lateral genicular branch of the popliteal.

The **first perforating artery** pierces the insertions of the adductors brevis and magnus, and some of its branches anastomose, anterior to the gluteus maximus, with the inferior glutæal, with the transverse branch of the medial circumflex, and with the transverse branch of the lateral circumflex, forming what is known as the crucial anastomosis.

The **second perforating artery** pierces the adductors brevis and magnus, and then passes between the glutæus maximus and the short head of the biceps femoris into the vastus lateralis. It anastomoses with its proximal and distal fellows, and with the medial circumflex and the proximal muscular branches of the popliteal artery.

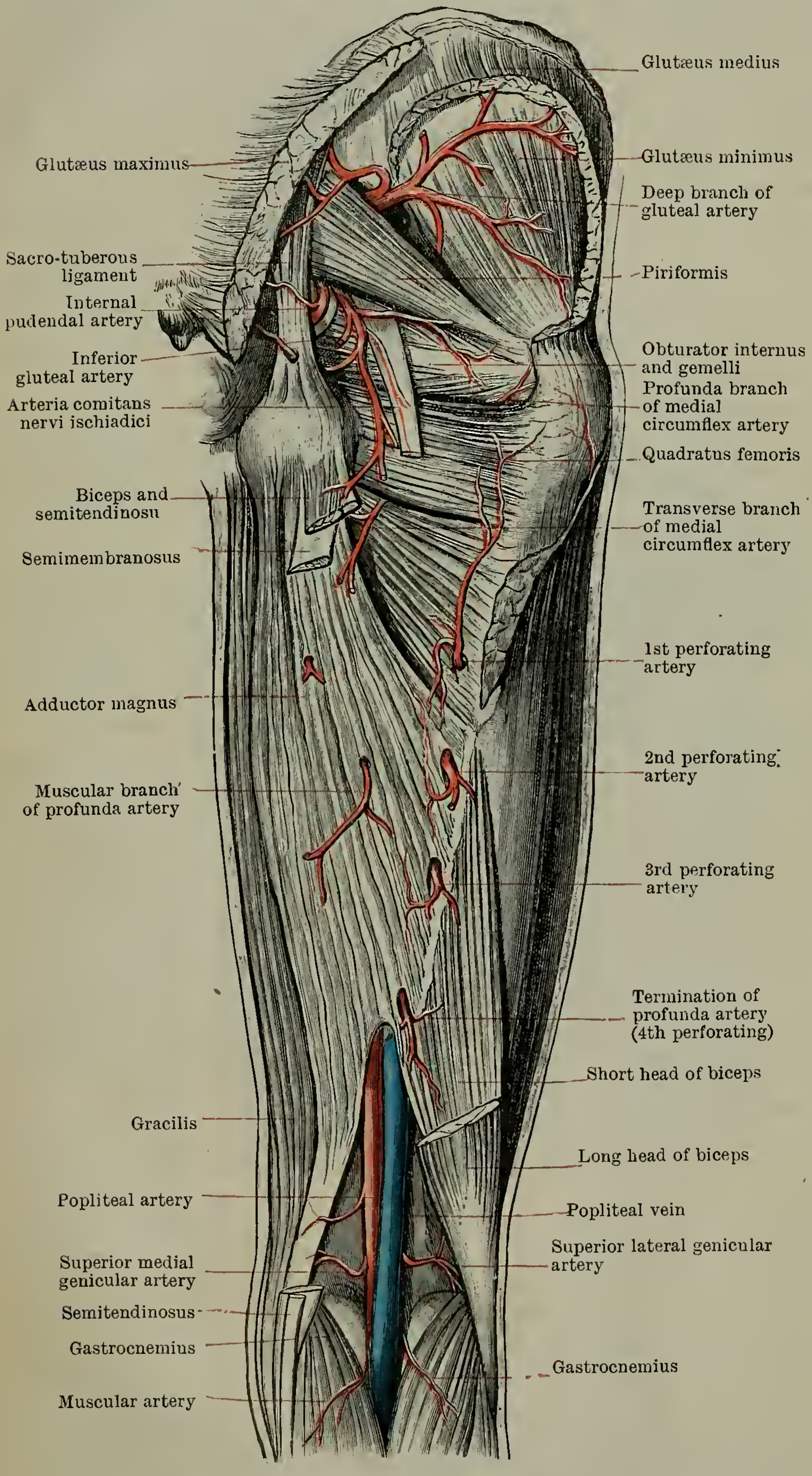

Fig. 755.—The Arteries of the Buttock and the Posterior Aspect of the Thigh and Knee.

The **third** and **fourth perforating arteries** pass through the adductor magnus and the short head of the biceps femoris into the vastus lateralis. Their anastomoses are similar to those of the second perforating.

A **nutrient branch** to the femur is given off either from the second or third perforating artery, usually the former; an additional nutrient branch may also be supplied by the first or fourth perforating arteries.

(5) The **arteria genu suprema** arises near the termination of the femoral artery, in the distal part of the adductor canal, and divides, almost immediately, into a superficial, saphenous, and a deep (musculo-articular) branch; indeed, very frequently the two branches arise separately from the femoral trunk.

(*a*) The **saphenous branch** passes through the distal end of the adductor canal with the saphenous nerve, and appears superficially, on the medial side of the knee, between the gracilis and the sartorius. It gives twigs to the integument of the proximal and medial part of the leg, and it anastomoses with the inferior medial genicular artery. (*b*) The **musculo-articular branch** runs towards the knee, in the substance of the vastus medialis, along the anterior aspect of the tendon of the adductor magnus. It anastomoses with the superior medial genicular artery, and it sends branches laterally, one on the surface of the femur and another along the proximal border of the patella, to anastomose with the descending branch of the lateral circumflex, the fourth perforating artery, the superior lateral genicular, and the anterior tibial recurrent.

Abnormalities.—The **femoral artery** is small, and ends in the profunda and circumflex branches, when the inferior gluteal artery forms the principal vessel of the lower limb. The profunda branch, which arises usually from the lateral side of the femoral trunk, about 37 mm. (1½ in.) distal to the inguinal ligament, may commence at a more proximal or a more distal level, and from the back or the medial side of the femoral trunk. In rare cases when the profunda arises at a more proximal level than usual it may cross anterior to the femoral vein, above the entrance of the great saphenous vein, after which it passes distally and laterally posterior to the femoral vessels (Johnston, *Anat. Anz.*, Bd., 42, 1912). Absence of the profunda has been noted, and in those cases the branches usually given off by it spring directly from the femoral artery.

The femoral artery may be double for a portion of its extent, or it may be joined by a vas aberrans given off from the external iliac artery. In addition to its ordinary branches, it may furnish one or both of the circumflex arteries of the thigh, and sometimes it gives off, near the origin of the profunda, a great saphenous artery, such as exists normally in many mammals. This vessel runs distally through femoral trigone and the adductor canal, and accompanies the saphenous nerve to the medial side of the foot.

The deep circumflex iliac, the obturator, and the inferior epigastric arteries are occasionally given off from the femoral.

ARTERIA POPLITEA.

The **popliteal artery** is the direct continuation of the femoral. It commences at the medial and proximal side of the popliteal fossa, under cover of the semimembranosus, and terminates at the distal border of the popliteus muscle, and on a level with the distal part of the tuberosity of the tibia, by dividing into the anterior and the posterior tibial arteries.

From its origin the artery passes distally, with a lateral inclination, to the interspace between the condyles of the femur, whence it is continued vertically to its termination.

Relations—*Anterior.*—It is in contact in front and proximo-distally with the popliteal surface of the femur, the posterior part of the capsule of the knee-joint, and the fascia covering the posterior surface of the popliteus.

Posterior.—The artery is overlapped behind, in the proximal part of its extent, by the lateral border of the semimembranosus; it is crossed, about its middle, by the popliteal vein and the tibial (O.T. internal popliteal) nerve, the vein intervening between the artery and the nerve; whilst, in the distal part of its extent, it is overlapped by the adjacent borders of the two heads of the gastrocnemius, and is crossed by the nerves to the soleus and popliteus and by the plantaris muscle.

Lateral.—On its lateral side it is in relation, proximally, with the tibial nerve and the popliteal vein, then with the lateral condyle of the femur, and, distally, with the lateral head of the gastrocnemius and the plantaris.

Medial.—On the medial side it is in relation, proximally, with the semimembranosus, in the middle with the medial condyle of the femur, and, distally, with the tibial nerve, the popliteal vein, and the medial head of the gastrocnemius. Popliteal lymph glands are arranged irregularly around the artery.

Branches.—(1) **Muscular branches** are given off in two sets, proximal and distal. The *proximal muscular branches* are distributed to the distal parts of the hamstring muscles, in which they anastomose with branches of the profunda artery.

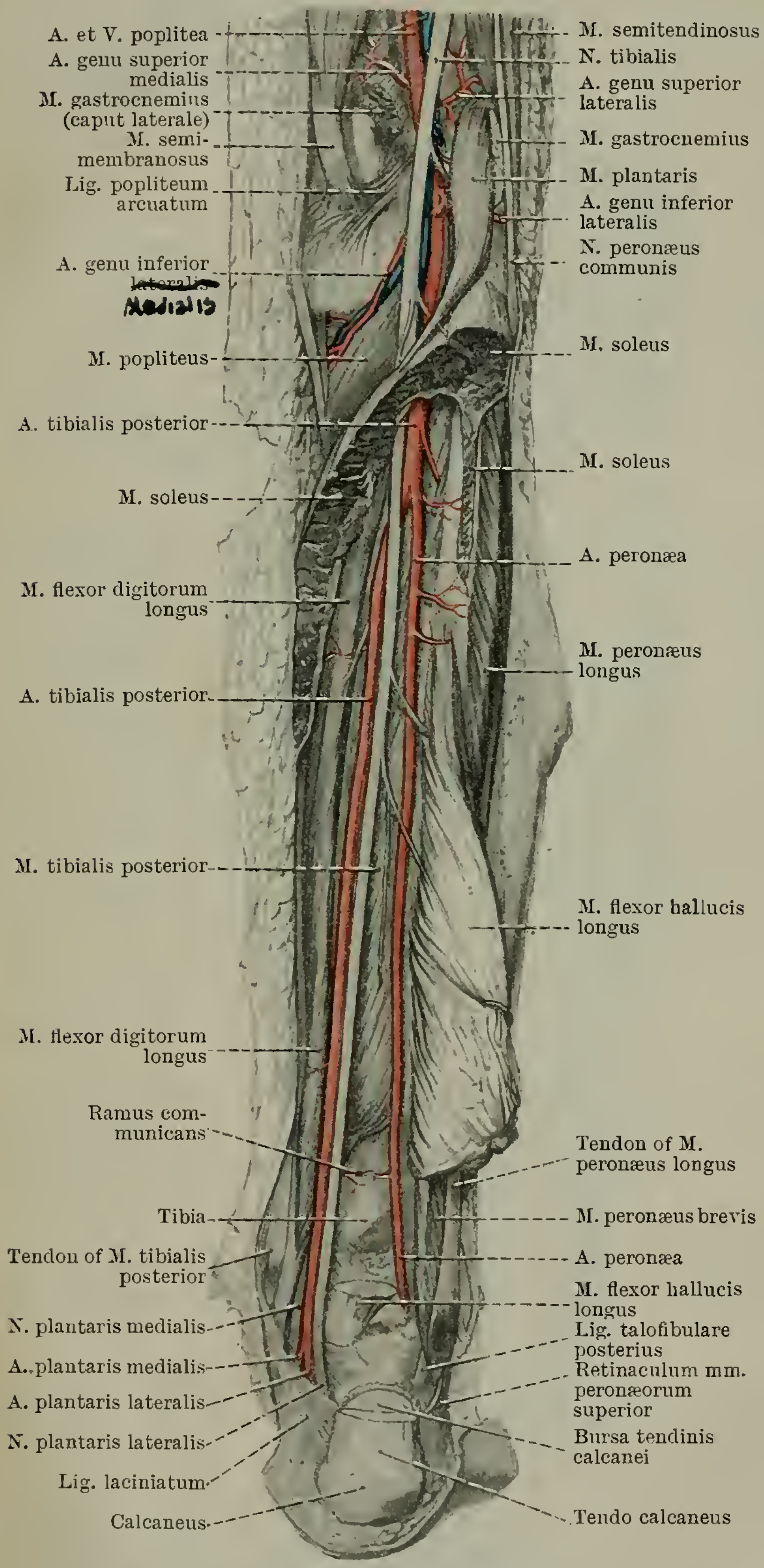

Fig. 756.—The Popliteal and Posterior Tibial Arteries and their Branches.

The distal muscular, or *sural*, arteries enter the proximal parts of the gastrocnemius, the plantaris, the soleus, and the popliteus muscles, and they anastomose with branches of the posterior tibial artery and the lower genicular arteries.

(2) The **genicular branches** are five in number—viz., superior and inferior lateral, superior and inferior medial, and a middle branch.

(*a*) The **superior lateral genicular artery** passes laterally, proximal to the lateral condyle, behind the femur and in front of the biceps tendon, into the vastus lateralis, where it anastomoses with the arteria genu suprema, the descending branch of the lateral circumflex, and the fourth perforating artery; it also sends branches distally to anastomose with the inferior lateral genicular and with the anterior tibial recurrent.

(*b*) The **superior medial genicular artery** passes medially, proximal to the medial condyle, behind the femur, and anterior to the tendon of the adductor magnus, into the vastus medialis. It anastomoses with branches of the arteria genu suprema and of the superior lateral genicular artery.

(*c*) The **inferior lateral genicular artery** runs laterally, across the popliteus muscle and anterior to the plantaris and the lateral head of the gastrocnemius; then, turning forwards, it is joined by the inferior lateral genicular nerve, and passes to the medial side of the fibular collateral ligament. It terminates by anastomosing with its fellow of the opposite side and with the superior lateral genicular and anterior tibial recurrent arteries.

(*d*) The **inferior medial genicular artery** passes medially, distal to the medial condyle of the tibia, along the proximal border of the popliteus and in front of the medial head of the gastrocnemius, to the medial side of the knee, where it turns forwards, between the bone and the tibial collateral ligament, and terminates anteriorly by anastomosing with its fellow of the opposite side, with the recurrent branch of the anterior tibial artery, and with the superior medial genicular artery.

(*e*) The **arteria genu media** passes directly forwards from the front of the popliteal artery, pierces the central part of the posterior surface of the capsule of the knee-joint, and enters the intercondylar fossa. It supplies branches to the crucial ligaments and to the synovial membrane, and is accompanied by the medial genicular branch of the tibial nerve, and sometimes by the genicular branch of the obturator nerve.

(3) **Cutaneous branches** are distributed to the skin over the popliteal fossa. One of these, the *superficial sural artery*, runs along the middle of the back of the calf with the vena saphena parva.

Abnormalities.—The popliteal artery may exceptionally form the direct continuation of the inferior gluteal artery. It sometimes divides at a more proximal or more distal level than usual, and the division may be into either two or three branches; if three terminal branches are present, they are the anterior and posterior tibial and the peroneal arteries, and if only two, either the anterior and posterior tibial, or the anterior tibial and the peroneal arteries.

Occasionally the artery is double for a short portion of its course, and it has been found to cross, first posterior to the medial head of the gastrocnemius to the medial side of the knee, and then anterior to the medial head of the gastrocnemius to regain the popliteal fossa. The number of its branches may be reduced, or they may be increased by the addition of a vas aberrans which connects it with the posterior tibial artery. Its superficial sural branch may enlarge to form a well-marked small saphenous artery.

Arteria Tibialis Posterior.

The **posterior tibial artery**, the larger of the two terminal branches of the popliteal, commences at the distal border of the popliteus and terminates midway between the tip of the medial malleolus and the most prominent part of the heel, at the distal border of the laciniate ligament (O.T. internal annular). It ends by dividing into the medial and the lateral plantar arteries, which pass onwards to the sole of the foot.

The posterior tibial artery runs distally and medially, in the posterior part of the leg, between the superficial and deep layers of muscles and covered, posteriorly, by the deep intermuscular fascia which intervenes between them.

Relations—*Anterior.*—It is in contact anteriorly, and proximo-distally, with the tibialis posterior, the flexor digitorum longus, the posterior surface of the tibia, and the posterior ligament of the ankle-joint.

Posterior.—The artery is crossed about 37 mm. (an inch and a half) distal to its origin by the tibial nerve. Elsewhere it is in contact with the intermuscular fascia which binds down the deep layer of muscles. More superficially the proximal half of the artery is covered by the fleshy parts of the soleus and gastrocnemius muscles, between which is the plantaris; the distal half of the artery is much nearer the surface, and is covered only by skin and fasciæ, except at its termination, where it lies deep to the laciniate ligament.

Lateral and Medial.—The artery is accompanied by two venæ comites, one on each side. The tibial nerve lies at first on the medial side of the vessel, then crosses posterior to it, and is continued distally on its lateral side. In the most distal part of its course the artery is separated from the medial malleolus by the tendons of the tibialis posterior and the flexor digitorum longus, whilst the tendon of the flexor hallucis longus lies postero-lateral to it.

Branches.—The posterior tibial gives off numerous branches, the largest of which, the peroneal, forms one of the chief arteries of the leg. The branches include—

(1) Large **muscular branches** which are distributed to the soleus, the tibialis posterior, the flexor digitorum longus, and the flexor hallucis longus. They anastomose with the deep sural branches of the popliteal artery and the lower medial genicular artery.

(2) A **fibular branch** passes laterally, to the neck of the fibula, where it anastomoses with the inferior lateral genicular and the deep sural arteries, and supplies the adjacent muscles.

(3) The **peroneal artery** (Fig. 756) is the largest branch of the posterior tibial. It arises about 25 mm. (an inch) below the distal border of the popliteus, curves laterally across the proximal part of the tibialis posterior to the medial crest of the fibula, along which it passes to the distal part of the interosseous space. About 25 mm. (an inch) proximal to the ankle-joint it gives off a perforating branch and then passes, posterior to the tibio-fibular syndesmosis and lateral malleolus, to the lateral side of the heel and the foot. It supplies the ankle, the tibio-fibular syndesmosis, and the talo-calcanean joint, and anastomoses with the medial calcanean branch of the lateral plantar artery, and with the tarsal and arcuate branches of the dorsalis pedis.

As the peroneal artery passes laterally from its origin it lies posterior to the tibialis posterior, and is covered posteriorly by the deep intermuscular fascia and by the soleus.

As it descends along the medial crest of the fibula it lies in a fibrous canal between the tibialis posterior in front and the flexor hallucis longus behind. The peroneal artery is accompanied by two venæ comites, and is crossed anteriorly and posteriorly by communicating branches between them.

Branches.—(*a*) **Muscular branches** are distributed to the soleus, tibialis posterior, flexor hallucis longus, and the peroneal muscles. Some pass through the interosseous membrane and supply the anterior muscles of the leg.

(*b*) A **nutrient branch** enters the nutrient foramen of the fibula.

(*c*) A **communicating branch** passes across the back of the distal end of the shaft of the tibia, about 25 mm. (an inch) above the tibio-fibular syndesmosis, to anastomose with the posterior tibial artery.

(*d*) The **perforating branch** passes forwards at the junction of the distal border of the interosseous membrane and the interosseous tibio-fibular ligament, and runs, in front of the ankle, to the dorsum of the foot, where it anastomoses with the lateral malleolar branch of the anterior tibial artery and with the tarsal branch of the dorsalis pedis; it also supplies branches to the tibio-fibular syndesmosis, to the ankle-joint, and to the peronæus tertius.

(4) The **nutrient branch**, the largest of the nutrient group of arteries to long bones, springs from the proximal part of the posterior tibial, pierces the tibialis posterior, and enters the nutrient foramen on the posterior surface of the tibia. In the interior of the bone it divides into proximal and distal branches, the former passing towards the proximal extremity of the bone, and the latter towards the distal extremity. Before entering the tibia the nutrient artery gives small muscular branches.

(5) A **communicating branch** unites the posterior tibial to the peroneal artery about 25 mm. (an inch) above the tibio-fibular syndesmosis. It passes posterior to the shaft of the tibia and anterior to the flexor hallucis longus.

(6) **Cutaneous branches** are distributed to the skin of the medial and posterior part of the leg.

(7) A **posterior medial malleolar branch** is distributed to the medial surface of the medial malleolus, anastomosing with a corresponding branch of the anterior tibial artery.

Abnormalities.—The **posterior tibial artery** may be small or altogether absent, its place being taken by branches of the peroneal artery; again, it may be longer or shorter than usual, in conformity with the more proximal or more distal division of the popliteal trunk. The peroneal artery is large, if either the anterior or the posterior tibial artery is small. The perforating branch of the peroneal is almost invariably large when the anterior tibial artery is small; in some cases, indeed, it replaces the whole of the dorsalis pedis continuation of the latter vessel; in others, however, only the lateral tarsal and arcuate branches are so replaced. The peroneal sometimes arises from a stem common to it and the anterior tibial artery.

PLANTAR ARTERIES.

(8) The **medial** and **lateral plantar arteries** are the terminal branches of the posterior tibial artery. They arise, under cover of the origin of the ligamentum laciniatum, midway between the tip of the medial malleolus and the most prominent part of the medial side of the os calcis (Figs. 756, 757).

The **medial plantar artery** is the smaller of the two terminal branches of the posterior tibial artery. It passes forwards, along the medial side of the foot in the interval between the abductor hallucis and the flexor digitorum brevis, to the head of the first metatarsal bone, where it terminates by uniting with the plantar digital branch of the dorsalis pedis, which is distributed to the medial side of the great toe. In its course forwards it gives off a *superficial branch*, which ramifies on the superficial surface of the abductor hallucis; branches to the adjacent muscles and articulations, and to the subjacent skin; it also gives three *digital branches* which anastomose, at the roots of the three medial interdigital clefts, with the medial plantar metatarsal arteries. Some of the cutaneous branches of the medial plantar artery anastomose, round the medial border of the foot, with the medial cutaneous branches of the dorsalis pedis artery.

The **lateral plantar artery** is the larger of the two terminal branches of the posterior tibial artery. It runs forwards and laterally, first between the flexor digitorum brevis superficially and the quadratus plantæ deeply, and then, in the interval between the flexor digitorum brevis and the abductor digiti quinti, to the medial side of the base of the fifth metatarsal bone, where it turns abruptly medially and, gaining a deeper plane, passes across the bases of the metatarsal bones and the origins of the interossei, and above the oblique head of the adductor of the great toe, to the lateral side of the base of the first metatarsal bone, where it terminates by anastomosing with the dorsalis pedis artery. The last part of the artery is convex forwards and forms the *plantar arch,* which is completed by the profunda branch of the dorsalis pedis.

Branches.—Between its origin and the base of the fifth metatarsal the lateral plantar artery gives off (*a*) the **medial calcanean branch,** which is distributed to the skin and the subcutaneous tissue of the heel.

(*b*) **Muscular branches** to the abductor hallucis, flexor digitorum brevis, quadratus plantæ, and abductor digiti quinti.

(*c*) **Cutaneous branches** to the skin of the lateral side of the foot.

Between the base of the fifth metatarsal bone and the first interosseous space it forms the **plantar arch,** and gives off (*d*) four **plantar metatarsal branches**; (*e*) three **posterior perforating arteries** to the dorsal metatarsal arteries; and (*f*) **articular branches** to the tarsal joints.

The **fifth** or most lateral **metatarsal branch** runs along the lateral side of the little toe, supplying the skin, joints, and the flexor tendons with their synovial sheaths. The three medial **plantar metatarsal branches, second, third,** and **fourth,** run forwards on the plantar surfaces of the interossei, the medial two lying dorsal to the oblique head of the adductor of the great toe, and all three passing dorsal to the transverse head of the adductor. At the bases of the interdigital clefts the second, third, and fourth plantar metatarsal arteries divide into plantar digital arteries which run along the plantar aspects of adjacent toes, and supply skin, joints, and the flexor tendons and sheaths. Opposite the last phalanx of each toe the digital arteries of opposite sides of the toe anastomose together.

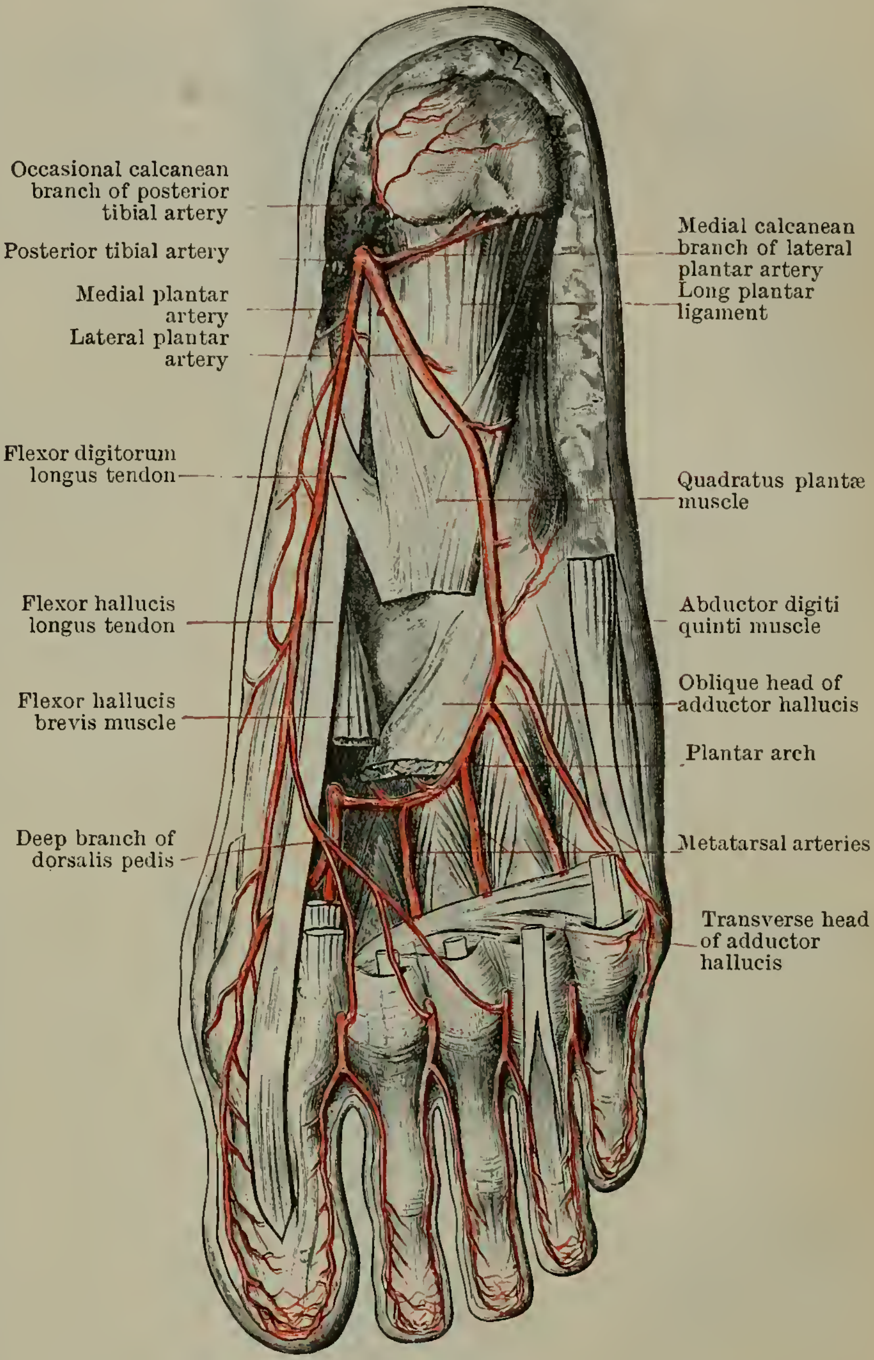
Occasional calcanean branch of posterior tibial artery
Posterior tibial artery
Medial plantar artery
Lateral plantar artery
Flexor digitorum longus tendon
Flexor hallucis longus tendon
Flexor hallucis brevis muscle
Deep branch of dorsalis pedis
Medial calcanean branch of lateral plantar artery
Long plantar ligament
Quadratus plantæ muscle
Abductor digiti quinti muscle
Oblique head of adductor hallucis
Plantar arch
Metatarsal arteries
Transverse head of adductor hallucis

Fig. 757.—The Plantar Arteries and their Branches.

The **posterior perforating arteries** are three in number; they pass dorsalwards through the three lateral inter-metatarsal spaces, between the heads of the dorsal interosseous muscles, and terminate by uniting with the corresponding dorsal metatarsal arteries. **Anterior perforating branches** which communicate with the dorsal metatarsal arteries are given off from two or three of the plantar metatarsal arteries just before they divide.

The **articular branches** are numerous and irregular; they supply the joints and ligaments of the tarsus on its plantar aspect.

Abnormalities.—The **medial plantar artery** is sometimes very small, and it may be absent; its place is taken by branches of the dorsalis pedis or lateral plantar arteries. The lateral plantar artery also may be small or absent, the plantar arch being formed entirely by the dorsalis pedis.

ARTERIA TIBIALIS ANTERIOR.

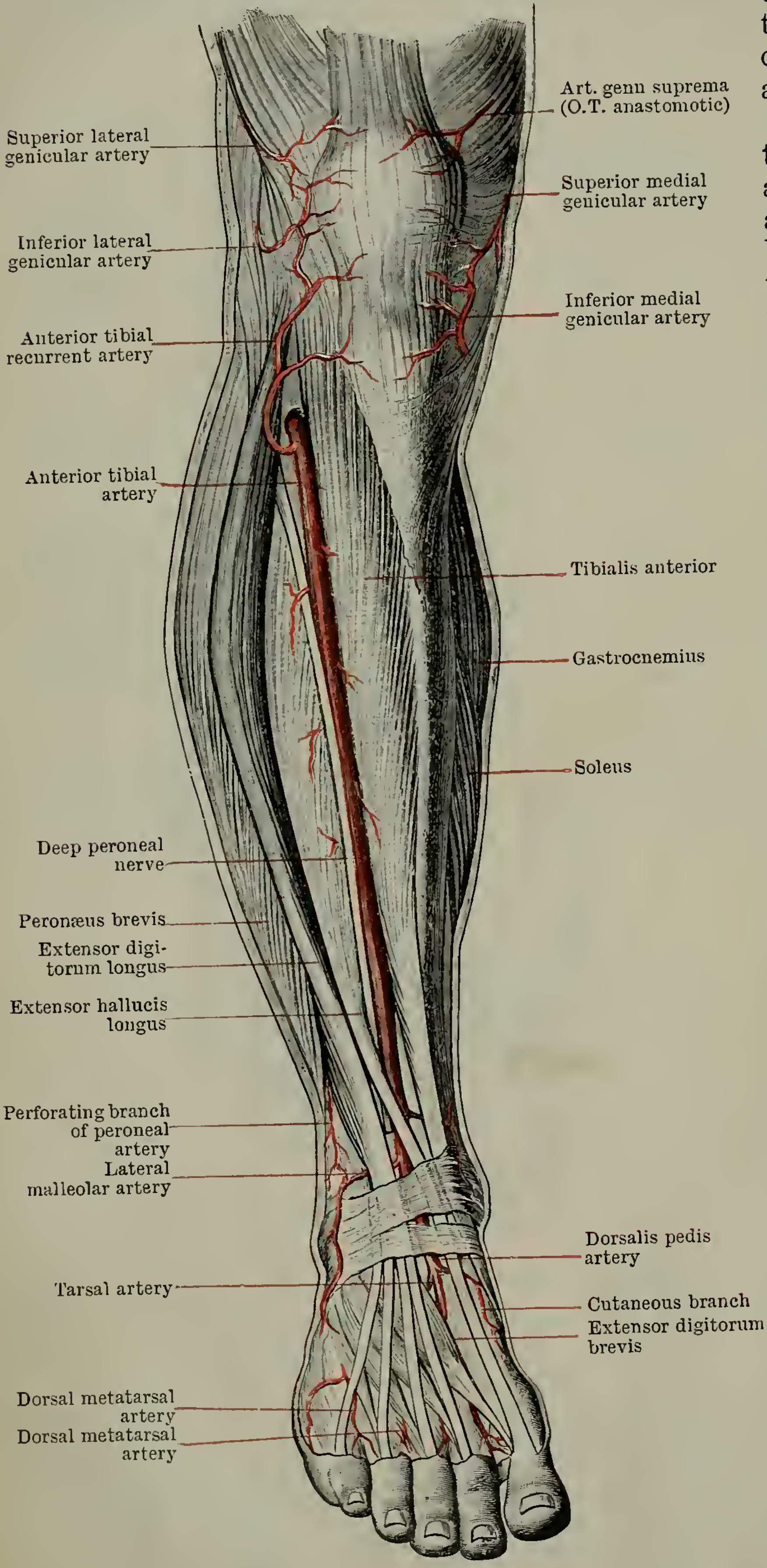
Superior lateral genicular artery
Inferior lateral genicular artery
Anterior tibial recurrent artery
Anterior tibial artery
Deep peroneal nerve
Peronæus brevis
Extensor digitorum longus
Extensor hallucis longus
Perforating branch of peroneal artery
Lateral malleolar artery
Tarsal artery
Dorsal metatarsal artery
Dorsal metatarsal artery
Art. genu suprema (O.T. anastomotic)
Superior medial genicular artery
Inferior medial genicular artery
Tibialis anterior
Gastrocnemius
Soleus
Dorsalis pedis artery
Cutaneous branch
Extensor digitorum brevis

FIG. 758.—THE ANTERIOR TIBIAL ARTERY AND ITS BRANCHES.

The **anterior tibial artery**, the smaller of the two terminal divisions of the popliteal, commences opposite the distal border of the popliteus muscle, and terminates in front of the ankle, where it is continued into the dorsal artery of the foot.

Course and Relations.—From its origin, at the back of the leg, the artery passes anteriorly, between the two slips of the proximal part of the tibialis posterior and above the proximal border of the interosseous membrane. It then runs distally, resting, in the proximal two-thirds of its course, against the anterior surface of the interosseous membrane and, subsequently, on the distal part of the tibia and the anterior ligament of the ankle-joint. In the proximal third of the anterior compartment of the leg it lies between the extensor digitorum longus laterally and the tibialis anterior medially; in the middle third it is between the extensor hallucis longus and the tibialis anterior; in the distal third the extensor hallucis longus crosses in front of the artery and reaches its medial side, and the most distal part of the vessel lies between the tendon of the extensor hallucis longus on the medial side and the most medial tendon of the extensor digitorum longus on the lateral side.

The deep peroneal nerve is at first well to the lateral side of the artery, but it soon passes in front of the vessel, and it lies in front of the middle third of the artery; more distally the nerve is usually found on the lateral side again, and at the ankle it intervenes between the artery and the most medial tendon of the extensor digitorum longus.

Two venæ comites, with numerous intercommunications, accompany the artery.

Obviously the anterior tibial artery is, at least in its proximal part, deeply placed; moreover, its lateral muscular boundaries overlap it. In the distal two-thirds of its extent it is, however, easily accessible from the surface; and beyond being covered by the nerve and crossed by the tendon, as already described, is only covered, in addition, by skin, fascia, and the transverse crural ligament.

Branches.—Close to its origin the artery gives off fibular and posterior tibial recurrent branches; after it reaches the front of the leg it gives off anterior tibial recurrent, muscular, cutaneous, medial malleolar, and lateral malleolar branches.

(1) The **fibular branch** is a small vessel which may arise separately from the anterior tibial artery, or by a common stem with the posterior tibial recurrent; occasionally it springs from the lower end of the popliteal artery, or from the posterior tibial. It runs upwards and laterally, behind the neck of the fibula and through the fibres of the soleus, and it terminates in branches which supply the soleus, the peronæus longus, and the skin of the proximal and lateral part of the leg. It anastomoses with the inferior lateral genicular artery.

(2) The **posterior tibial recurrent branch**, also small, and not always present, runs upwards, anterior to the popliteus muscle, to the back of the knee-joint. It anastomoses with the inferior genicular branches of the popliteal, and gives branches to the popliteus muscle and the proximal tibio-fibular articulation.

(3) The **anterior tibial recurrent branch** arises from the anterior tibial artery in front of the interosseous membrane. It runs proximally and medially, between the proximal part of the tibialis anterior and the lateral condyle of the tibia, accompanied by the recurrent articular branch of the common peroneal nerve, and, after supplying the tibialis anterior and the proximal tibio-fibular articulation, it pierces the deep fascia of the leg; it is connected with the anastomoses round the knee-joint, formed by the genicular branches of the popliteal artery, the descending branch of the lateral circumflex artery, and the arteria genu suprema.

(4) The **muscular branches** are distributed to the muscles of the front of the leg, and a few small branches also pass backwards to the deep surface of the tibialis posterior muscle.

(5) The **cutaneous branches** supply the skin of the front of the leg.

(6) The **medial anterior malleolar branch** arises from the lower part of the anterior tibial artery, and is smaller than its companion on the lateral side. It runs medially, posterior to the tibialis anterior tendon, ramifies over the medial malleolus, anastomosing with branches of the posterior tibial artery, and is distributed to the skin and to the ankle-joint.

(7) The **lateral anterior malleolar branch**, more constant and larger than the medial, passes laterally, posterior to the extensor digitorum longus and peronæus tertius, towards the lateral malleolus. It anastomoses with the perforating branch of the peroneal artery and with the tarsal artery, and supplies the ankle-joint and the adjacent articulations.

Dorsalis Pedis Artery.—The **dorsal artery of the foot** is the direct continuation of the anterior tibial; it commences opposite the front of the ankle-joint, and extends to the posterior extremity of the first interosseous space, where it divides into the first dorsal metatarsal and the profunda branch.

It is covered superficially by skin and fascia, including the cruciate ligament, and it is crossed, just before it reaches the first interosseous space, by the tendon of the extensor hallucis brevis. It rests upon the anterior ligament of the ankle, the head of the talus, the talo-navicular ligament, the dorsum of the navicular bone, and the dorsal naviculo-cuneiform and the inter-cuneiform ligaments between the first and second cuneiform bones. On its lateral side is the medial terminal branch of the deep peroneal nerve, which intervenes between it and the extensor digitorum brevis and the most medial tendon of the extensor digitorum longus. On its medial side it is in relation with the tendon of the extensor hallucis longus. Two venæ comites, one on each side, accompany the artery.

Branches.—On the dorsum of the foot the dorsalis pedis artery gives off cutaneous branches, lateral and medial tarsal branches, the arcuate branch, and the first dorsal metatarsal and the profunda branch.

(1) **Cutaneous branches**, two or three in number, are distributed to the skin on the

dorsum and medial side of the foot; they anastomose with branches of the medial plantar artery.

(2) **The tarsal branches, medial and lateral.**—The medial tarsal branches are small vessels given off from the medial side of the artery. They pass to the medial border of the foot and anastomose with branches of the medial plantar artery. The lateral tarsal branch is given off opposite the head of the talus; it runs laterally, deep to the extensor hallucis brevis and the extensor digitorum brevis, supplying those muscles and the tarsal joints, and it anastomoses with the perforating branch of the peroneal, the arcuate, and lateral plantar arteries, and with the lateral malleolar artery.

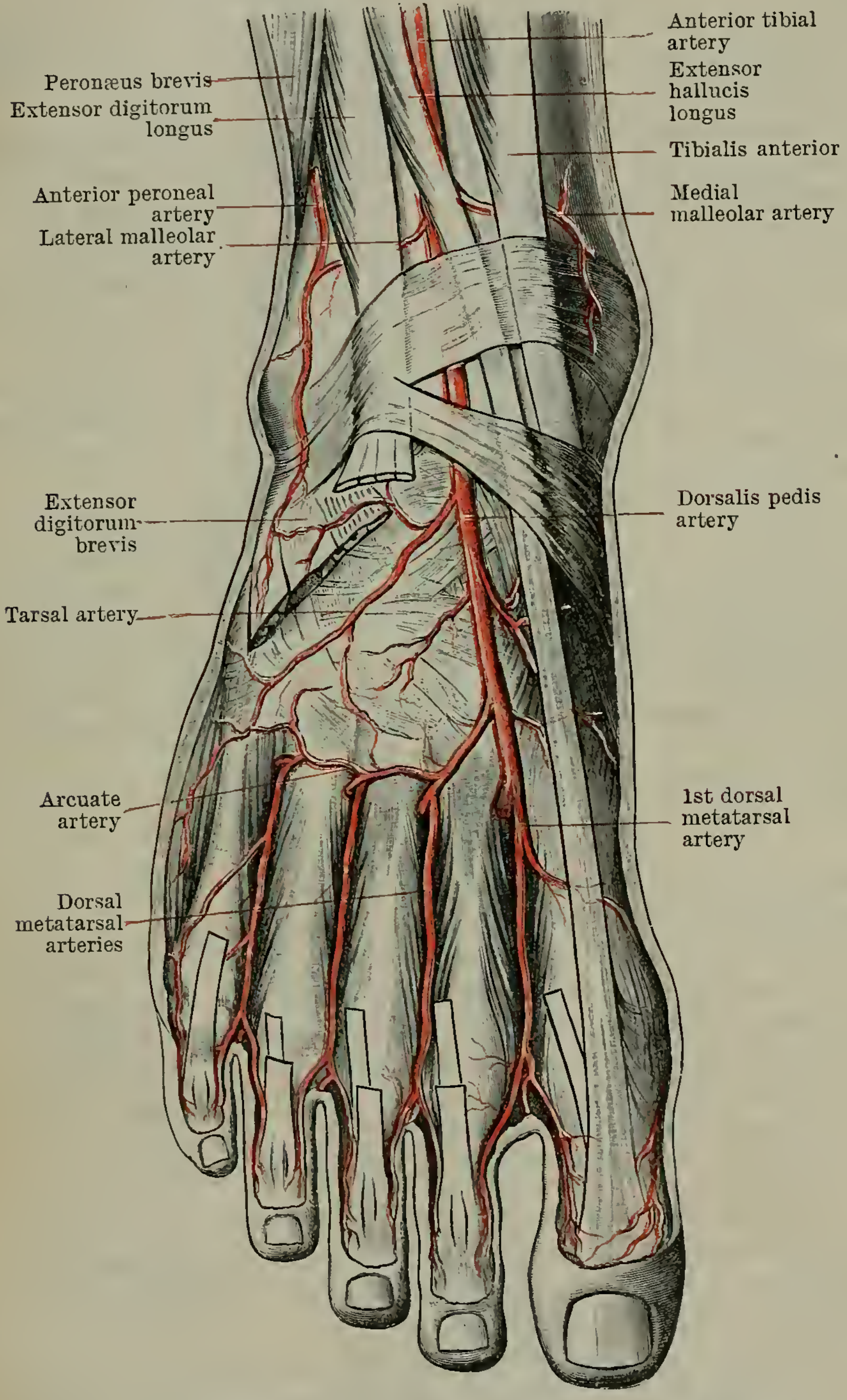

Fig. 759.—The Dorsalis Pedis Artery and its Branches.

(3) The **arcuate artery** arises opposite the first cuneiform bone. It runs laterally, on the bases of the metatarsal bones, deep to the long and short extensor tendons, supplies the extensor hallucis brevis and the extensor digitorum brevis, and anastomoses with branches of the lateral tarsal and lateral plantar arteries. It gives off three **dorsal metatarsal arteries**, second, third, and fourth, which run forwards on the muscles which occupy the three lateral interosseous spaces to the clefts of the toes, where each divides into two *dorsal digital branches* for the adjacent sides of the toes bounding the cleft to which it goes. The lateral side of the little toe receives a branch from the most lateral dorsal metatarsal artery. Each dorsal metatarsal artery gives off a *posterior perforating branch*, which passes through the posterior part of the intermetatarsal space, between the heads of the dorsal interosseous muscle, to anastomose with the plantar arch, and an *anterior perforating branch*, which passes through the anterior part of the space to anastomose with the corresponding plantar metatarsal artery.

(4) The **first dorsal metatarsal artery** is continued forwards from the dorsal artery of the foot, and runs on the dorsal surface of the first dorsal interosseous muscle. It ends by dividing into dorsal digital branches for the adjacent sides of the first and second toes. Before it divides it usually gives off a *dorsal digital branch* which passes, deep to the tendon of the extensor hallucis, to the medial side of the great toe.

(5) The **profunda branch** passes through the posterior end of the first intermetatarsal space, between the two heads of the first dorsal interosseous muscle, to the plantar aspect of the foot, where it unites with the lateral plantar artery and completes the plantar arch. As it unites with the lateral plantar artery it gives off the first plantar metatarsal artery (O.T. arteria magna hallucis), which passes forwards, along the first intermetatarsal space, to the base of the first interdigital cleft, where it divides into plantar digital arteries

for the adjacent sides of the great and second toes; before it divides it gives off a *plantar digital artery* to the medial side of the great toe.

Abnormalities.—The anterior tibial artery may be absent, its place being taken by branches of the posterior tibial and peroneal arteries. It is longer than normal when the popliteal artery divides at a more proximal level than usual, and in those cases it may pass either posterior or anterior to the popliteus muscle. Occasionally the anterior tibial artery and its dorsalis pedis continuation are larger than normal, and the terminal part of the dorsalis pedis takes the place, more or less completely, of the lateral plantar artery.

VENÆ.

Veins commence at the terminations of the capillaries. They converge towards the heart, and unite with one another to form larger and still larger vessels, until, finally, seven large trunks are formed which open into the atria of the heart. Three of the trunks, the **superior vena cava**, the **inferior vena cava**, and the **coronary sinus**, belong to the *systemic circulation*; they contain venous blood, and open into the right atrium. The remaining four, the **pulmonary veins**, belong to the *pulmonary circulation*; they return oxygenated blood from the lungs, and open into the left atrium.

In addition to the systemic and pulmonary veins, there is also a third group of veins, constituting the **portal system**, in which blood from the abdominal part of the alimentary canal, and from the spleen and pancreas, is conveyed to the liver. The portal system is further peculiar in that it both begins and ends in capillaries. From its terminal capillaries in the liver the *hepatic veins* arise, and as these open into the inferior vena cava the blood of the portal system is finally poured into the general systemic circulation. The hepatic veins also receive blood supplied to the liver by the hepatic arteries.

VENÆ PULMONALES.

The terminal **pulmonary veins** (Figs. 721 and 727), two on each side, open into the left atrium of the heart. Their tributaries arise in capillary plexuses in the walls of the pulmonary alveoli. By the union of the smaller veins larger vessels are formed which run along the anterior aspects of the bronchial tubes, and, uniting together, ultimately form a single efferent vessel in each lobe, which passes into the root of the lung. Thus there are five main pulmonary veins, but, immediately after entering the root of the lung, the vessels from the upper and middle lobes of the right lung join together, and so only four terminal pulmonary veins open into the left atrium of the heart. Neither the main stems nor their tributaries possess valves.

Relations.—In the root of the lung the upper pulmonary vein, on each side, lies below and in front of the pulmonary artery. The lower pulmonary vein, on each side, is in the lowest part of the root, and it is in a plane posterior to that in which the upper vein lies.

On the right side the upper pulmonary vein passes behind to the superior vena cava, and the lower passes behind the right atrium. They both terminate in the upper and posterior part of the left atrium close to the interatrial septum.

On the left side both upper and lower pulmonary veins cross anterior to the descending aorta, and they terminate in the upper and posterior part of the left atrium near its left border.

All four pulmonary veins perforate the fibrous layer of the pericardium, and receive partial coverings of the serous layer before they enter the atrium.

SYSTEMIC VEINS.

The **systemic veins** return blood to the right atrium of the heart through the superior vena cava, the inferior vena cava, and the coronary sinus. The two first-named receive blood from the veins of the body and limbs and from most of the abdominal and pelvic viscera. The coronary sinus receives blood from the veins of the walls of the heart alone.

General Arrangement.—The veins of the body wall and limbs form two groups —(1) the superficial veins; (2) the deep veins.

The **superficial veins** lie in the superficial fascia; they commence in the capillaries of the skin and subcutaneous tissues, and are very numerous. They frequently anastomose with one another, and they also communicate with the deep veins, in which, after piercing the deep fascia, they terminate. They may or may not accompany superficial arteries.

The **deep veins** accompany arteries, and are known as *venæ comites.* The large arteries have only one accompanying vein, but with the medium-sized and small arteries there are usually two venæ comites, which anastomose freely with each other by short transverse branches of communication.

Visceral veins usually accompany the arteries which supply viscera in the head, neck, thorax, and abdomen. As a rule there is only one vein with each visceral artery, and, with the exception of those which enter into the formation of the portal system, they terminate in the deep systemic veins.

SINUS CORONARIUS ET VENÆ CORDIS.

The **coronary sinus** (Fig. 721) is a short, but relatively wide, venous trunk which receives the majority of the veins of the heart. It lies in the inferior portion of the coronary sulcus, between the left atrium and the left ventricle, and it is covered superficially by some of the muscular fibres of the atrium.

It terminates in the lower and posterior part of the right atrium, between the orifice of the inferior vena cava on the right, and the right atrio-ventricular orifice anteriorly; an imperfect valve, consisting of one cusp, called the **valve of the coronary sinus (Thebesius)**, is situated at the right margin of the opening of the sinus into the atrium.

The apertures of the tributaries of the coronary sinus, except those of the great and small cardiac veins, are not provided with valves, and the valves of the two veins mentioned are often incompetent.

Tributaries.—(1) The **great cardiac vein** (Fig. 722) commences at the apex of the heart. It ascends, in the anterior interventricular sulcus, to the coronary sulcus; it then turns to the left, and, passing round the left margin of the heart, into the inferior part of the coronary sulcus, terminates in the left extremity of the coronary sinus. It receives tributaries from the walls of both ventricles and from the wall of the left atrium. It receives also the *left marginal vein*; that vein commences at the lower extremity of the left margin of the heart, along which it ascends to its termination.

(2) The **small cardiac vein** is very variable; as a rule it commences at the inferior margin of the heart and passes to the right to the coronary sulcus in which it turns to the left, on the inferior surface of the heart, and terminates in the right extremity of the coronary sinus. It receives tributaries from the walls of the right atrium and the right ventricle.

(3) The **oblique vein of the left atrium (Marshall)** (Fig. 721) is a small venous channel which descends obliquely, on the posterior wall of the left atrium, and terminates in the coronary sinus. Its orifice is not provided with a valve. It is of special interest, inasmuch as it represents the left superior vena cava of some other mammals, and is developed from the left duct of Cuvier.

(4) The **inferior cardiac vein of the left ventricle** runs along the inferior surface of the left ventricle and ends in the coronary sinus.

(5) The **middle cardiac vein** commences at the apex of the heart, and, passing posteriorly, in the inferior interventricular sulcus, terminates in the coronary sinus near its right extremity. It receives tributaries from the inferior parts of the walls of both ventricles.

Veins of the Heart which do not end in the Coronary Sinus.—(*a*) The **anterior cardiac veins** are two or three small vessels which ascend on the anterior wall of the right ventricle to the coronary sulcus, where they either end in the right atrium or terminate in the small cardiac vein. (*b*) The **venæ minimæ cordis.**—A number of small veins, which commence in the substance of the walls of the heart and terminate directly in its cavities, principally in the atria; some few, however, open into the ventricles.

VENA CAVA SUPERIOR AND ITS TRIBUTARIES.

The **superior vena cava** (Figs. 727 and 760) returns the blood from the head and neck, the upper extremities, the thoracic wall, and a portion of the upper part of the wall of the abdomen. It is formed, at the lower border of the first right costal cartilage, by the union of the two innominate veins, and it descends, with a slight convexity to the right, to the level of the third right costal cartilage, where it opens into the upper and posterior part of the right atrium. It is about 75 mm. (three inches) long; in the lower half of its extent it is enclosed within the fibrous layer of the pericardium, and it is covered in front and on each side by the serous layer.

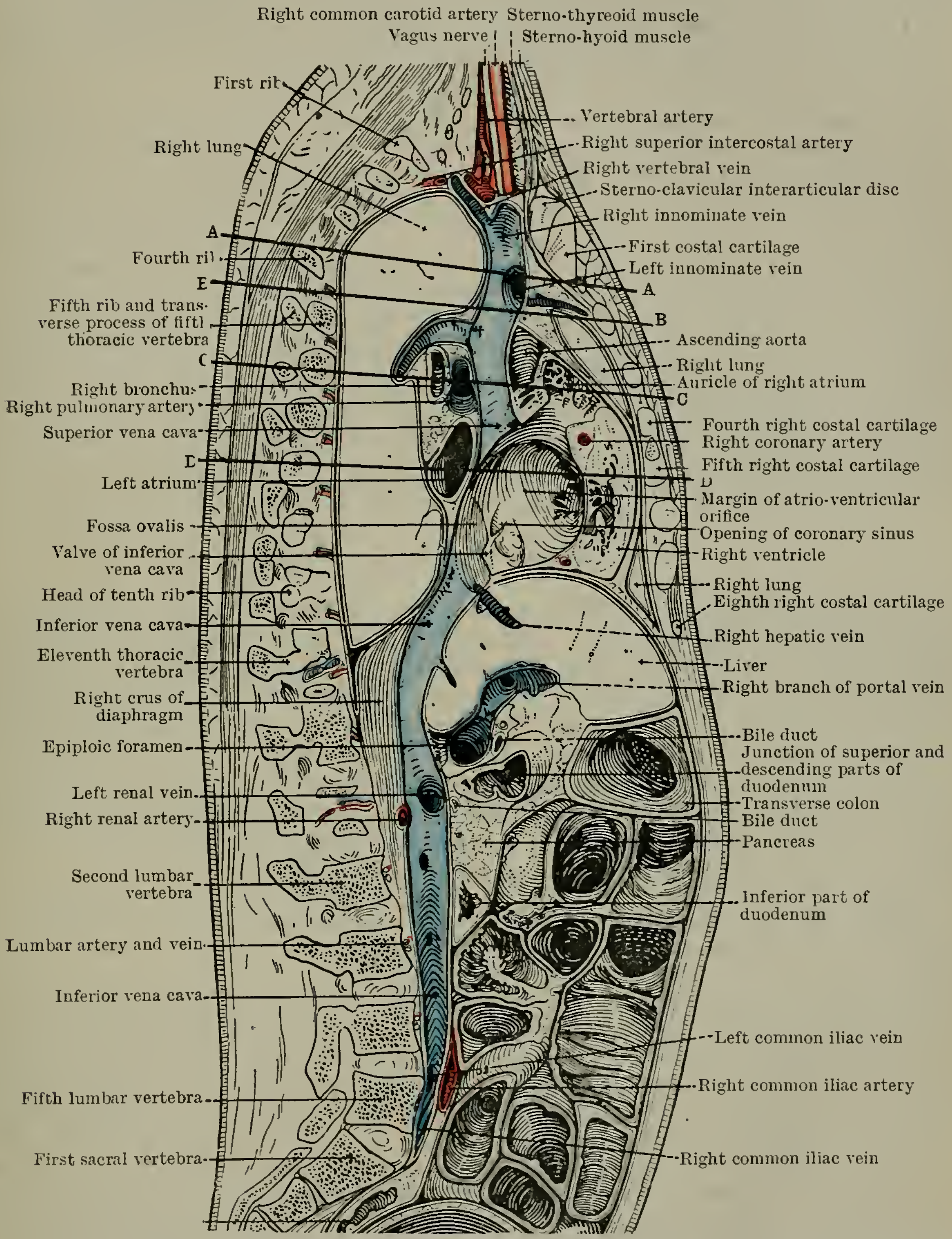

FIG. 760.—A SAGITTAL LATERAL SECTION OF THE BODY OF A YOUNG MALE ALONG THE LINES OF THE SUPERIOR AND THE INFERIOR VENÆ CAVÆ.

Relations.—It is overlapped *anteriorly* by the margins of the right lung and pleural sac and by the ascending aorta. The lung and pleura intervene between it and the second and third costal cartilages, the internal intercostal muscles in the first and second intercostal spaces, and the internal mammary vessels. It is in relation *posteriorly* with the right margin of the trachea, the right vagus nerve, the vena azygos, which opens into it at right angles, the right bronchus, the right pulmonary artery, and the upper right pulmonary vein. On its *left side* are the ascending portion of the aorta, and the commencement of the innominate artery, whilst on the *right side* it is in close relation with the right pleura, the phrenic nerve and the pericardiaco-phrenic vessels intervening.

Tributaries.—In addition to the two innominate veins, by the union of which it is formed, the superior vena cava receives only one large tributary, viz., the vena azygos; but several small pericardial and mediastinal veins open into it.

Abnormalities.—The superior vena cava may develop on the left side instead of on the right. This peculiarity is due to the persistence of the left duct of Cuvier instead of that on the right side, and it is associated with absence of the coronary sinus, which is replaced by the lower part of the left superior vena cava. An exceptional case is recorded in which the opening of the coronary sinus into the heart was obliterated, and the cardiac veins terminated in a trunk which passed upwards to the left innominate vein. This trunk was obviously formed by enlargement of the left duct of Cuvier and the lower part of the left precardinal vein. Not very uncommonly, as the result of the persistence of both ducts of Cuvier, there are two superior venæ cavæ, the transverse anastomosis which usually forms the left innominate vein being small or entirely absent. In such cases the left innominate vein descends in the left part of the superior mediastinum, crosses the aortic arch, is joined by the left superior intercostal vein, and becomes the left superior vena cava; which descends anterior to the root of the left lung, and terminates in the lower and back part of the right atrium. It receives the great cardiac vein, and, turning to the back of the heart, replaces the coronary sinus. This arrangement is normal in many mammals. Occasionally in man the left superior vena cava terminates in the left atrium, and the coronary sinus, which represents a part of the sinus venosus, has been seen to have a similar ending; both these abnormal endings must be the result of malposition of the interatrial septum.

VENA AZYGOS AND ITS TRIBUTARIES.

The **vena azygos** (Fig. 775) commences either from the posterior aspect of the inferior vena cava, at the level of the right renal vein, or as the direct upward continuation of an anastomosing channel which connects together the lumbar veins of the right side, and which is known as the *right ascending lumbar vein.* It ascends through the aortic orifice of the diaphragm, and is continued upwards through the posterior mediastinum. In the upper part of its course, it first passes posterior to the root of the right lung, and then arches anteriorly, above the root, to its termination in the posterior part of the superior vena cava, immediately before the latter vessel pierces the pericardium and at the level of the second costal cartilage. It frequently possesses imperfect valves.

Relations.—*In the abdomen* it lies on the anterior surfaces of the bodies of the upper lumbar vertebræ, posterior to the right crus of the diaphragm and the inferior vena cava, and to the right side of the cisterna chyli.

In the thorax it lies on the anterior surfaces of the bodies of the lower eight thoracic vertebræ, the intervening fibro-cartilages, and the anterior longitudinal ligament; and anterior to the right aortic intercostal arteries. In the lower part of the posterior mediastinum the right pleura and lung lie anterior to it; at a higher level it is overlapped by the right margin of the œsophagus, and immediately before its termination it is crossed by the root of the right lung.

On its left side it is in relation, in the greater part of its extent, with the thoracic duct and, as it arches anteriorly over the root of the lung, with the right vagus nerve and the trachea. About the level of the eighth thoracic vertebra it receives the accessory hemiazygos vein, whilst at the level of the ninth thoracic vertebra the hemiazygos vein opens into it.

In addition to the two veins last mentioned it receives the right posterior intercostal veins, except that from the first space but including the right superior intercostal vein, the right subcostal vein, and, through the ascending lumbar vein, the upper right lumbar veins. It also receives the right bronchial veins and some small œsophageal, pericardial, and mediastinal tributaries.

Tributaries.—(1) The **vena hemiazygos accessoria** is formed by the union of the fourth, fifth, sixth, seventh, and eighth left posterior intercostal veins. It lies on the left sides of the bodies of the fifth, sixth, and seventh thoracic vertebræ, and the corresponding intercostal arteries. It crosses the vertebral column, from left to right, opposite the body of the eighth thoracic vertebra, passing posterior to the aorta, œsophagus, and thoracic duct; and it terminates either in the vena azygos or in the vena hemiazygos. In addition to its intercostal tributaries it receives the left bronchial veins, and some small posterior mediastinal veins, and it communicates with the left superior intercostal vein.

(2) The **vena hemiazygos** commences in the epigastric region of the abdomen. At its origin it is connected either with the left ascending lumbar vein or with the left renal vein. After piercing the left crus of the diaphragm it ascends, on the left sides of the bodies of the lower thoracic vertebræ, and, opposite the eighth or ninth thoracic vertebra, it turns to the right, crosses the front of the vertebral column, posterior to the aorta, œsophagus, and thoracic duct, and terminates in the vena azygos. As it ascends, on the bodies of the vertebræ, it lies lateral to the aorta, and medial to the roots of the splanchnic nerves, and anterior to the lower left intercostal arteries. Through the left ascending lumbar vein it receives blood from the upper lumbar veins of the left side; the left subcostal vein, the lower three posterior intercostal veins, and small mediastinal tributaries also terminate in it.

Abnormalities.—The **vena azygos** may be formed on the left side; it then arches over the root of the left lung, and terminates in the left end of the coronary sinus. This is the normal arrangement in some mammals, and it is due to the persistence of the cephalic end of the left postcardinal vein, the thoracic part of the left supracardinal vein, and the left duct of Cuvier.

Occasionally the azygos vein is the only vessel by which blood is returned to the heart from the lower limbs and the lower parts of the body walls. In such cases that portion of the inferior vena cava which usually extends from the right renal vein to the heart is absent and the azygos vein is the direct continuation of the inferior vena cava. This condition probably results from the absence of those parts of the inferior vena cava which are usually formed from the right vitelline and the right subcardinal veins, and to the enlargement of the whole of the right supracardinal vein.

The **hemiazygos** and the **accessory hemiazygos veins** may be absent. In such cases each left intercostal vein opens separately into the vena azygos. On the other hand the hemiazygos and the accessory hemiazygos veins may form a continuous trunk which may open by a transverse anastomosis into the azygos vein, or it may join the left innominate vein. When the hemiazygos and the accessory hemiazygos veins form a single trunk, which receives the left intercostal veins and opens into the left innominate vein, the condition is due to the persistence of the whole of the thoracic part of the left supracardinal vein and of the lower part of the left postcardinal vein.

Cases also occur in which the thoracic part of the postcardinal vein is represented by three instead of two stems, either the hemiazygos or the accessory hemiazygos vein being represented by two vessels.

(3) The **bronchial veins** do not quite correspond to the bronchial arteries, and they are not found on the walls of the smallest bronchi. On each side the tributaries run, anterior or posterior to the bronchial tubes to reach the root of the lung, where they unite, as a rule, into two small trunks; those of the right side open into the vena azygos, and those of the left into the accessory hemiazygos vein, or into the left superior intercostal vein. On both sides they are joined by tracheal and posterior mediastinal veins. Some few small bronchial veins, including most of those from the smaller tubes, open into the pulmonary veins.

(4) **Venæ Intercostales.**—There are two sets of **intercostal veins**, the anterior and the posterior.

The **anterior intercostal veins** are tributaries of the internal mammary or of the musculo-phrenic veins, and are described with those vessels (pp. 968, 969).

The **posterior intercostal veins** (Fig. 775) are eleven in number on each side. A single vein runs in each intercostal space; it is situated in the costal groove, above the corresponding artery.

On the right side the posterior intercostal vein of the first space accompanies the superior intercostal artery across the front of the neck of the first rib, and terminates in the vertebral or innominate vein. The second, third, and fourth posterior intercostal veins of the right side unite together to form a common trunk, the **right superior intercostal vein**, which terminates by joining the vena azygos. The fifth to the eleventh posterior intercostal veins of the right side open separately into the vena azygos.

On the left side the first posterior intercostal vein follows a course similar to that taken by the corresponding vein on the right side, and terminates in the left vertebral or innominate vein. The second, third, and sometimes the fourth posterior intercostal veins of the left side unite to form the **left superior intercostal vein**, which runs from behind forwards along the left or anterior aspect of the aortic arch. It passes obliquely between the left vagus and phrenic nerves, crosses the root of the left subclavian artery, and ends in the lower border of the left innominate vein. The fifth, sixth, seventh, and eighth, and sometimes the fourth posterior intercostal veins of the left side terminate in the accessory hemiazygos vein, and the ninth, tenth, and eleventh end in the hemiazygos vein.

Each posterior intercostal vein is provided with valves, both at its termination and along its course, which prevent the blood flowing towards the anterior aspect of the thoracic wall. Its tributaries are derived from the adjacent muscles and bones, and a short distance from its termination it receives a posterior tributary which passes to it between the transverse processes of the vertebræ. This posterior vessel is formed by the union of small veins which issue from the muscles of the back, from the anterior and posterior spinal plexuses which lie respectively in front of the bodies and behind the arches of the vertebræ, and by venous channels which issue through the intervertebral foramina; the latter vessels commence in the vertebral canal, where they are connected with the anterior and posterior spinal veins.

VENÆ ANONYMÆ.

The **innominate veins** (Figs. 760 and 727) are two in number, right and left. They return blood from the head and neck, the upper extremities, the upper part of the posterior wall of the thorax, the anterior wall of the thorax, and the upper part of the anterior wall of the abdomen. Each innominate vein commences behind the medial end of the clavicle of the corresponding side, and is formed by the union of the internal jugular and subclavian veins; the two innominate veins terminate by uniting together, at the lower border of the first costal cartilage of the right side, to form the superior vena cava. To reach that point the left vein has to pass from left to right behind the manubrium sterni, and it is therefore about three times as long as the right vein. The innominate veins do not possess valves.

The **right innominate vein** is a little more than 25 mm. (1 inch) in length. It descends almost vertically to the lower border of the first costal cartilage, and terminates in the superior vena cava.

Relations.—It is in relation, anteriorly, with the medial end of the clavicle and the sterno-hyoid and sterno-thyreoid muscles. It partly overlaps the innominate artery, which lies to its left side, and it is in front of the internal mammary artery, the right vagus nerve, and the upper end of the right pleural sac. The phrenic nerve and the accompanying vessels run along its right side, and intervene between it and the right pleural sac.

Tributaries.—In addition to the veins by the union of which it is formed, the right innominate vein receives the right vertebral and internal mammary veins, the first right posterior intercostal vein, and sometimes the right inferior thyreoid vein. The right lymphatic duct also opens into it.

The **left innominate vein** passes from left to right, with a slight obliquity downwards, behind the upper part of the manubrium sterni, to the lower border of the first right costal cartilage, where it terminates in the superior vena cava. It is about 60 to 75 mm. (3 inches) long.

Relations.—It is covered anteriorly, in the greater part of its extent, by the sterno-hyoid and sterno-thyreoid muscles, but at its right extremity it is slightly overlapped by the right pleura, and in the median plane the remains of the thymus intervene between it and the posterior surface of the sternum. It rests, posteriorly, upon the left pleura, the left internal mammary artery, the left subclavian artery, the left phrenic, and the left vagus nerves, the left superior cardiac branch of the sympathetic, the inferior cervical branch of the left vagus, the left common carotid artery, the trachea, and the innominate artery.

Its lower border is in relation with the arch of the aorta, and on its upper border it receives the inferior thyreoid vein of one or both sides.

Tributaries.—It receives the vertebral, internal mammary, inferior thyreoid, superior intercostal veins of its own side, the first left posterior intercostal vein, and some pericardial, thymic, anterior bronchial, and anterior mediastinal veins. Sometimes the right inferior thyreoid vein joins it, but not uncommonly that vessel terminates in the right innominate vein or in the commencement of the superior vena cava.

The thoracic duct opens into it just at the angle of junction of the internal jugular and subclavian veins.

The Internal Mammary Veins.—Each internal mammary artery is accompanied by venæ comites; they commence by the union of the venæ comites of the superior epigastric and musculo-phrenic arteries, between the sixth costal cartilage and the transversus thoracis; and at the upper part of the thorax they fuse into a single vessel which enters the superior mediastinum and ends in the innominate vein of the same side.

The tributaries of the internal mammary veins are—(*a*) The **venæ comites** of the **superior epigastric** and **musculo-phrenic arteries**, which in their turn receive tributaries which correspond with the branches of the arteries they accompany. (*b*) Six **anterior perforating veins** which accompany the corresponding arteries, one lying in each of the upper six intercostal spaces. (*c*) Twelve **anterior intercostal veins** from the upper six intercostal spaces, two veins lying in each space with the corresponding branches of the internal mammary artery. (*d*) Small and irregular **pleural, muscular, mediastinal**, and **sternal veins.**

The internal mammary veins are provided with numerous valves which prevent the blood from flowing downwards.

The Superior Epigastric Veins.—The venæ comites of the superior epigastric artery receive tributaries from the substance of the rectus abdominis, the sheath of the muscle, and the superjacent skin and fascia; they pass, with the artery, between the sternal and costal origins of the diaphragm, and terminate in the internal mammary veins.

Musculo-phrenic Veins.—The venæ comites of the musculo-phrenic artery commence in the abdomen, pass through the diaphragm with the musculo-phrenic artery, and terminate in the internal mammary veins. They receive as tributaries the anterior intercostal veins of the seventh, eighth, and ninth intercostal spaces, and small venules from the substance of the diaphragm and walls of the abdomen.

The **vertebral veins** correspond only to the extra-cranial parts of the vertebral arteries. Each commences by the union of offsets from the intraspinal venous plexuses, and, issuing from the vertebral canal, passes across the posterior arch of the atlas, with the vertebral artery, to the foramen in the transverse process of the atlas. In the foramina in the cervical transverse processes, a plexus of venous channels surrounds the artery. At the lower part of the neck efferents from the plexus unite to form a single trunk which issues from the foramen in the transverse process of the sixth cervical vertebra, and descends, in the interval between the longus colli and scalenus anterior muscles, to terminate in the upper and posterior part of the innominate vein; at its termination there is a uni- or bi-cuspidate valve.

Relations.—In the first part of its course the vein lies in the sub-occipital triangle. The second, plexiform portion, is in the canal formed by the foramina in the transverse processes of the cervical vertebræ, and, with the artery, which it surrounds, lies anterior to the trunks of the cervical spinal nerves. The third part, in the root of the neck, is between the longus colli and scalenus anterior muscles, in front of the first part of the vertebral artery, and behind the internal jugular vein.

Tributaries.—In addition to the offsets from the intraspinal venous plexuses by the union of which it is formed, each vertebral vein receives the following tributaries: (*a*) Small vessels which issue from the muscles, ligaments, and bones of the deeper parts of the neck, and the lower and posterior part of the head. (*b*) Offsets from the intraspinal venous plexuses which pass out of the vertebral canal by the intervertebral foramina. (*c*) The **ascending cervical vein**, a vessel which is formed by the union of tributaries which issue from a venous plexus on the anterior aspects of the bodies and roots of the transverse processes of the cervical vertebræ. This vessel accompanies the ascending cervical artery, and terminates in the lower part of the vertebral vein, immediately after the latter has issued from the foramen in the sixth cervical transverse process. (*d*) The **deep cervical vein**; this commences in the sub-occipital triangle from a venous plexus with which the vertebral and occipital veins communicate. It descends, posterior to the transverse processes of the cervical vertebræ, in company with the profunda cervicis artery, turns forwards at the root of the neck, between the transverse processes of the sixth and seventh cervical vertebræ or between the latter and the neck of the first rib, and opens into the vertebral vein. It receives blood from the muscles, ligaments, and bones of the back of the neck. (*e*) The **posterior intercostal vein** from the first intercostal space sometimes opens into the vertebral vein.

Occasionally the venous plexus around the vertebral artery ends below in two terminal trunks, anterior and posterior, instead of one. In those cases the second terminal vessel lies behind the lower part of the vertebral artery, passes through the foramen in the transverse process of the seventh cervical vertebra, and turns forwards on the lateral side of the artery to join the anterior trunk, thus forming a common terminal vein which ends in the usual manner.

The **inferior thyreoid vein** commences by the union of tributaries which issue from the isthmus and the corresponding lobe of the thyreoid gland. The two veins descend, along the front of the trachea, into the superior mediastinum, where the right inferior thyreoid vein terminates either in the right innominate vein or in the junction of the two innominate veins, and the left in the upper border of the left innominate vein; or the two veins unite to form a single trunk, which ends, usually, in the left innominate vein, but, occasionally, in the right. As they descend in the neck the inferior thyreoid veins anastomose together, and sometimes the anastomoses are so frequent that a venous plexus is formed in front of the lower cervical portion of the trachea.

VEINS OF THE HEAD AND NECK.

Vena Jugularis Interna (Figs. 727, 732, 763, 774 and 775).—Each **internal jugular vein** commences, in the posterior compartment of the jugular foramen, as the direct continuation of the transverse sinus, and terminates, behind the medial part of the clavicle, by uniting with the subclavian vein of the same side to form the innominate vein.

Its commencement, which is dilated, forms the *superior bulb* of the jugular vein. In the upper part of the neck it lies postero-lateral to the internal carotid artery and the last four cerebral nerves. As it descends it accompanies first the internal and then the common carotid artery. It inclines forwards as it descends, and gradually passes from its original position, behind and to the lateral side of the internal carotid artery, until it lies more completely to the lateral side of the internal and common carotid arteries, and, indeed, somewhat overlaps the latter anteriorly. This is more especially the case on the left side, for both internal jugular veins trend slightly towards the right as they descend; consequently, at the root of the neck, the right vein is separated from the right common carotid artery by a small interval filled with areolar tissue, whilst the left vein is more directly in front of the corresponding common carotid artery.

A dilatation, the *inferior bulb*, is present at the inferior extremity of the vein; it is bounded, either above or below, by a valve of two or three semilunar cusps. Sometimes both the superior and inferior ends of the bulb are bounded by valves.

Relations.—The vein lies anterior to the transverse processes of the cervical vertebræ, the rectus capitis lateralis, longus capitis, and scalenus anterior muscles, the ascending cervical artery, which runs upwards in the interval between the attachments of the two latter muscles, and the phrenic nerve; the transverse scapular and the transverse cervical arteries intervene between it and the scalenus anterior. At the root of the neck the vein lies in front of the first part of the subclavian artery and the origins of the vertebral artery and the thyreo-cervical trunk, and on the left side it is anterior to the terminal part of the thoracic duct.

On the antero-medial side of the internal jugular vein, immediately below the skull, are the internal carotid artery and the last four cerebral nerves; in the rest of its extent it is in relation, medially, first with the internal and then with the common carotid artery, whilst to its medial side and somewhat posteriorly, between it and the large arteries, lies the vagus nerve.

Each internal jugular vein is covered, superficially, in the whole of its length, by the sterno-mastoid muscle; near its upper end it is crossed by the styloid process, the stylo-pharyngeus and stylo-hyoid muscles, and the posterior belly of the digastric, whilst in its lower half, the omo-hyoid, the sterno-hyoid, and the sterno-thyreoid muscles are superficial to it, under cover of the sterno-mastoid. Just below the transverse process of the atlas, and under cover of the sterno-mastoid, the vein is crossed, on its lateral side, by the accessory nerve and by the occipital artery; about the middle of its course it is crossed by the communicans cervicis nerve, and near its lower end by the anterior jugular vein; the latter vessel, however, is separated from it by the sterno-hyoid and sterno-thyreoid muscles. Superficial to the vein are numerous deep cervical lymph glands.

Abnormalities.—The internal jugular vein may be either smaller or larger than normal. In either case compensatory changes in size occur in the transverse sinus and internal jugular vein of the opposite side, or in the external and anterior jugular veins of the same side.

Tributaries.—(*a*) A vein from the **cochlea** and (*b*) the **inferior petrosal sinus** join it near its commencement. (*c*) **Pharyngeal branches** from the venous plexus on the wall of the pharynx. (*d*) **Emissary veins** from the cavernous sinus. (*e*) The **common facial vein**, which receives the anterior and posterior facial veins. (*f*) The **lingual veins**, which return part of the blood from the tongue. (*g*) The **vena comitans hypoglossi**, which accompanies the hypoglossal nerve. (*h*) The **superior thyreoid vein**, which accompanies the corresponding artery. (*i*) The **middle thyreoid vein**, which passes backwards from the corresponding lobe of the thyreoid gland and crosses the middle of the lateral aspect of the common carotid artery. (*j*) The **occipital vein** occasionally terminates in the internal jugular vein. In many cases, however, it ends in the sub-occipital plexus, which is drained by the vertebral and deep cervical veins (see p. 969).

The **common facial vein** is formed by the union of the **anterior** and **posterior facial veins.** It accompanies the first part of the external maxillary artery in the carotid triangle, and terminates in the anterior border of the internal jugular vein. Just before it disappears beneath the sterno-mastoid, the common facial vein frequently gives off a large branch which descends along the anterior border of the sterno-mastoid to the supra-sternal fossa, where it joins the anterior jugular vein.

The **anterior facial vein** (Fig. 761) commences at the medial commissure of the eyelids as the *angular vein*, which is formed by the union of the supra-orbital and frontal veins. It passes downwards and backwards in the face, to the lower and anterior part of the masseter muscle, which it crosses, lying in the same plane as the external maxillary artery, but following a much straighter course. After crossing the lower border of the mandible it passes across the submaxillary triangle, superficial to the submaxillary gland, and separate from the external maxillary artery, which there lies in a deeper plane. It terminates, a short distance below the angle of the mandible, by uniting with the posterior facial vein to form the common facial vein.

The anterior facial vein receives tributaries corresponding with all the branches of the external maxillary artery, except the ascending palatine and the tonsillar, which have no accompanying veins, the blood from the region which they supply being returned for the most part through the pharyngeal plexus. The anterior facial vein also communicates with the pterygoid plexus around the external pterygoid muscle, by means of an anastomosing channel, called the **deep facial vein**, which passes posteriorly, between the masseter and buccinator muscles, into the infra-temporal fossa.

The **posterior facial vein**, see p. 974.

The **inferior thyreoid veins** have already been described (see p. 970).

Venæ Subclaviæ.—The **subclavian vein**, of each side, is the direct continuation of the main vein of the upper extremity, *i.e.* the axillary vein; but through its tributary, the external jugular vein, it receives blood both from the head and from the superficial parts of the neck.

From its commencement, at the external border of the first rib, it runs medially, below and anterior to the corresponding artery, from which it is separated by the lower part of the scalenus anterior muscle, and it terminates, behind the medial end of the clavicle, in the innominate vein of the corresponding side. As it passes medially it forms a slight curve, the convexity of which is directed upwards.

Each subclavian vein possesses a single bicuspid valve which is situated immediately to the distal side of the opening of the external jugular vein.

Relations.—The subclavian vein is in relation *anteriorly* with the posterior layer of the costo-coracoid membrane, which separates it from the subclavius muscle, and the nerve to the subclavius, and with the back of the medial end of the clavicle, from which it is partly separated, however, by the fibres of the sterno-hyoid and sterno-thyreoid muscles.

It is closely attached, anteriorly, to the posterior surface of the costo-coracoid membrane; consequently it is expanded when the clavicle is moved forwards, an arrangement which constitutes a distinct danger when operations are being performed in the neighbourhood of the vein; for, in the event of the vessel being wounded, forward movement of the clavicle may cause air to be sucked into the vein, with fatal results.

Posterior to the vein, and on a higher plane, is the first part of the subclavian artery, but it is separated from the second part by the scalenus anterior. As soon as it reaches the medial border of the anterior scalene the subclavian vein unites with the internal jugular vein, immediately anterior to the internal mammary artery.

The upper surface of the first rib is *below* the vein.

Tributaries.—Whilst the subclavian vein is the direct continuation of the axillary vein, and receives, therefore, the blood from the upper extremity, it has, as a general rule, only one named tributary, viz., the external jugular vein.

Vena Jugularis Externa.—The **external jugular vein** (Fig. 761) is formed on the superficial surface of the sterno-mastoid muscle, a little below and posterior to the angle of the mandible, by the union of the posterior auricular vein with a branch from the posterior facial vein. In many cases the branch from the posterior facial vein is so preponderantly large that it is more correct to describe the external jugular vein as commencing as a branch of the posterior facial vein. After its formation the external jugular vein descends, with a slight obliquity backwards, to the anterior part of the subclavian portion of the posterior triangle of the neck, where it pierces the deep fascia, crosses in front of the third part of the subclavian artery, and terminates in the subclavian vein.

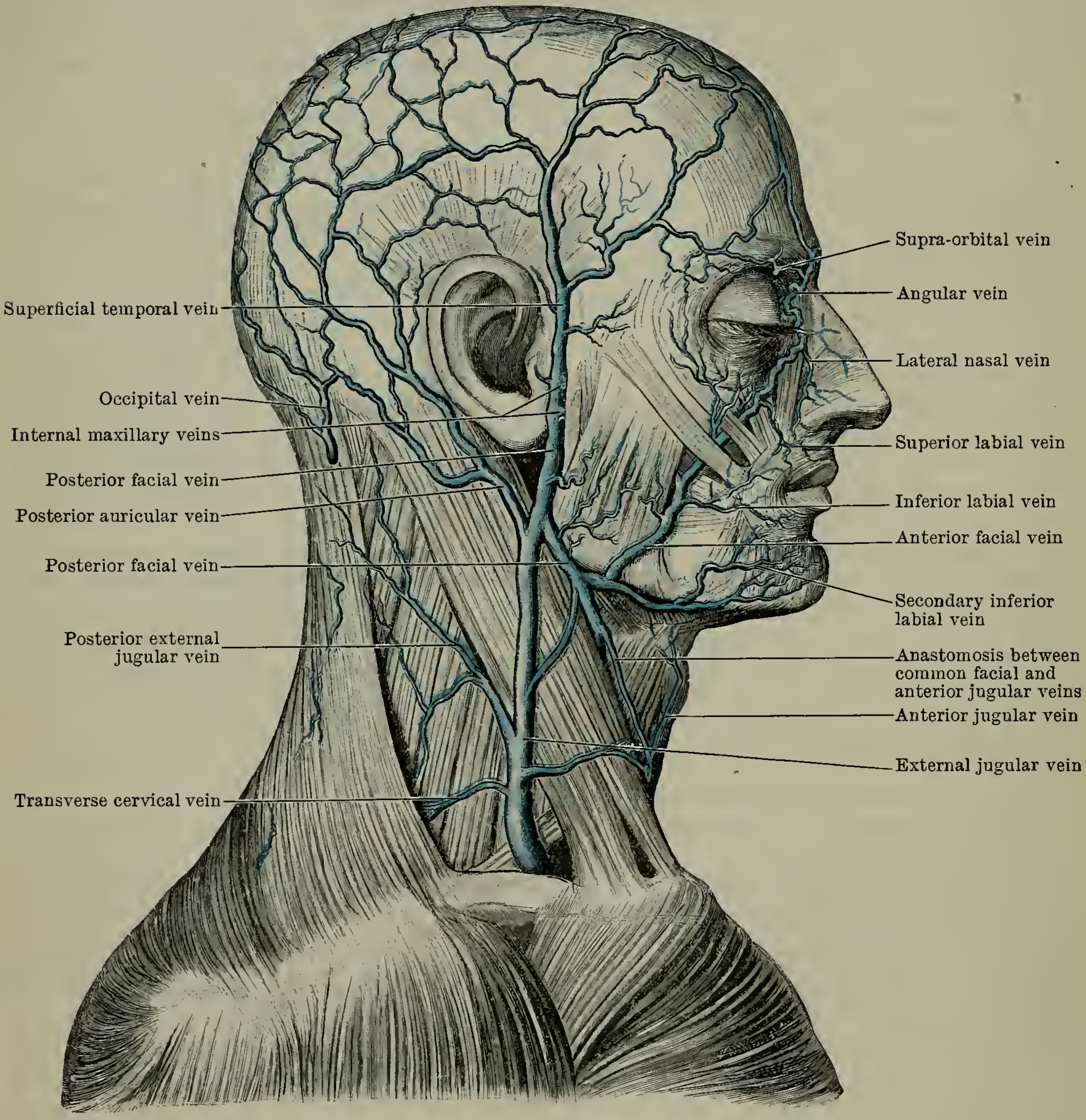

Fig. 761.—Superficial Veins of the Head and Neck.

Whilst on the surface of the sterno-mastoid muscle it is covered by the superficial fascia, and platysma muscle, and it lies parallel with the great auricular nerve; after crossing the nervus cutaneus colli it reaches the posterior border of the sterno-mastoid, where it receives a tributary called the **posterior external jugular vein**, which commences in the superficial tissues of the upper and back part of the neck, and runs downwards and forwards, across the roof of the upper part of the posterior triangle, to its termination in the external jugular vein.

As the external jugular vein pierces the deep cervical fascia in the subclavian triangle, its wall is closely attached to the margin of the opening through which it passes; and as it is crossing in front of the third part of the subclavian artery it is joined by the transverse scapular, transverse cervical, and anterior jugular veins.

There are usually two valves in the lower part of the vein—one, at its termination, which is generally incompetent, and a second at a higher level.

Abnormalities.—The **external jugular vein** is sometimes absent, or it may be smaller than usual; in both cases either the anterior or the internal jugular vein is enlarged. In some of the cases in which the external jugular vein is small it receives no communication from the posterior facial vein, but is merely the continuation of the posterior auricular vein. On the other hand, it may be enlarged, and receive the whole of the posterior facial vein.

Tributaries.—In addition to the posterior auricular vein and the branch from the posterior facial vein by which it is formed, the external jugular vein receives the posterior external jugular vein, which has already been described, the transverse cervical and transverse scapular veins from the region of the shoulder, and the anterior jugular vein. Occasionally the cephalic vein also opens into it.

The **posterior auricular vein** (Fig. 761) receives tributaries from the posterior parts of the parietal and temporal regions and from the medial surface of the auricle. It is considerably larger than the posterior auricular artery, which it accompanies only in the scalp. At the base of the scalp it leaves the artery and descends in the superficial fascia, over the upper part of the sterno-mastoid, to join the external jugular vein.

The **transverse cervical** and **transverse scapular veins** accompany the corresponding arteries; not infrequently they open directly into the subclavian vein.

The **anterior jugular vein** commences in the submental region, and is formed by the union of small veins from the lower lip and chin. It descends, in the superficial fascia, at a variable distance from the median plane, perforates the superficial layer of the deep fascia, a short distance above the sternum, and enters the suprasternal space (Burns) between the first and second layers of the deep fascia. In the space it anastomoses with its fellow of the opposite side and receives a communication from the common facial vein. Then it turns laterally, between the sterno-mastoid superficially and the sterno-hyoid, sterno-thyreoid, and scalenus anterior muscles deeply, and terminates in the external jugular vein at the posterior border of the sterno-mastoid.

Abnormalities.—The **anterior jugular vein** may be absent, or it may be unusually large, especially in the lower part of its extent, and after it has received an occasional tributary from the common facial vein.

The external jugular vein sometimes receives the occipital vein or a communication from it.

The Veins of the Scalp.

The veins which drain the blood from the superficial parts of the scalp are the frontal, the supra-orbital, the superficial temporal, the posterior auricular, and the occipital. The blood from the deeper part of the scalp, in the region of the temporal fossa, on each side, passes into the deep temporal veins, which are tributaries of the pterygoid plexus.

The **frontal** and **supra-orbital veins** receive blood from the medial and anterior part of the scalp. They unite together, near the medial commissure of the eyelids, to form the *angular vein*; before the union is effected the supra-orbital vein sends a branch backwards, through the supra-orbital notch, into the orbital cavity, where it terminates in the ophthalmic vein, and as this branch passes through the notch it receives the frontal diploic vein (p. 975).

The **superficial temporal vein** (Figs. 732, 761) is formed by frontal and parietal tributaries which accompany the corresponding branches of the superficial temporal artery. They drain the lateral frontal, the superficial part of the temporal, and the anterior part of the parietal region of the scalp, and unite to form a single trunk which descends to the upper border of the zygoma, immediately anterior to the auricle, where it terminates in the posterior facial vein (see p. 974).

The **posterior auricular vein** drains the posterior portions of the temporal and parietal areas of the scalp (see above).

The **occipital vein** (Figs. 732, 761) receives tributaries from the parietal and occipital regions. As a rule it pierces the occipital origin of the trapezius, and, passing into the sub-occipital triangle, terminates in a plexus of veins which is drained by the vertebral and deep cervical veins. It sometimes communicates with the external jugular vein, and occasionally an offset from it accompanies the corresponding artery and ends in the internal jugular vein.

It generally receives the mastoid emissary vein; one of its tributaries receives the parietal emissary vein, and occasionally an emissary vein from the confluens sinuum (O.T. torcular Herophili) opens into it.

THE VEINS OF THE ORBIT, THE NOSE, AND THE INFRA-TEMPORAL REGION.

The veins of these three regions are closely associated together; for although the orbital blood is returned, for the most part, to the cavernous sinus by the ophthalmic vein, the latter vein is closely connected with the pterygoid plexus, which lies in the infra-temporal region.

Veins of the Orbit.—The veins of the orbit correspond, with the exception of the naso-frontal vein, with the branches of the ophthalmic artery, and they gradually converge, as they pass backwards in the orbit, until they form two main trunks, a **superior ophthalmic vein** and an **inferior ophthalmic vein.** The two trunks terminate separately, or by a single stem, in the anterior end of the cavernous sinus, to which they pass through the superior orbital fissure, and between the two heads of the lateral rectus muscle.

The superior ophthalmic vein communicates, at the supero-medial angle of the orbit, with the angular vein, and it receives the naso-frontal vein which accompanies the frontal nerve. The inferior ophthalmic vein communicates, through the inferior orbital fissure, with the pterygoid plexus.

Veins of the Nose.—The veins of the walls of the nasal cavity end partly in the ethmoidal tributaries of the superior ophthalmic vein, partly in the septal affluent of the superior labial and in the lateral nasal veins, both of which are tributaries of the anterior facial vein; but the majority of the veins of the nose, both from the septal and lateral walls, join together to form a spheno-palatine vein which passes through the spheno-palatine foramen and the pterygo-palatine fossa, and terminates in the pterygoid plexus.

The Pterygoid Plexus and the **Internal Maxillary Vein.**—The **pterygoid plexus** of veins lies in the infra-temporal and pterygoid fossæ. It covers the lateral surface of the internal pterygoid muscle, and surrounds the external pterygoid. It receives tributaries which correspond with and accompany the branches of the internal maxillary artery—viz., spheno-palatine, pharyngeal, vein of pterygoid canal, infra-orbital, posterior superior alveolar, descending palatine, buccinator, two or three deep temporal, pterygoid, masseteric, and inferior alveolar veins, and the middle meningeal vein. It communicates, superiorly, with the cavernous sinus through the foramen ovale; anteriorly with the inferior ophthalmic vein through the inferior orbital fissure; and between the masseter and the buccinator with the anterior facial vein by the deep facial anastomosing branch. It also communicates posteriorly and medially, on the medial side of the internal pterygoid, with the pharyngeal plexus, and it terminates posteriorly in the internal maxillary vein.

The **internal maxillary vein** is a short vessel which accompanies the first part of the internal maxillary artery, between the spheno-mandibular ligament and the neck of the mandible. Between the neck of the mandible and the antero-medial surface of the parotid gland it joins the upper part of the posterior facial vein. Occasionally the internal maxillary vein is double, and sometimes it is represented by several channels.

The **posterior facial vein** is formed, immediately above the zygomatic arch, by the union of the superficial and middle temporal veins. It crosses the zygomatic arch, dips deep to the upper part of the parotid gland, and, whilst lying between the antero-medial surface of the gland and the posterior border of the mandible, it receives the internal maxillary vein or veins. Then it descends, through the substance of the parotid, and, emerging from its lower end at the angle of the mandible, it passes forwards and downwards to unite with the anterior facial vein in the formation of the common facial vein.

Whilst it is in the substance of the parotid it gives off a comparatively large branch, which emerges from the lower and posterior part of the gland and forms one of the two commencing tributaries of the external jugular vein.

Abnormalities.—The posterior facial vein may terminate entirely in the common facial vein, or in the external or the internal jugular vein. It may be very small, and occasionally it is absent.

VENOUS SINUSES AND VEINS OF THE CRANIUM AND OF ITS CONTENTS.

The venous channels met with in the cranial walls and cranial cavity are:—

(1) The diploic veins, which lie in the spongy tissue between the outer and inner tables of the cranial bones.

(2) The meningeal veins, which accompany the meningeal arteries in the outer layer of the dura mater.

(3) The veins of the brain, which lie between the folds of pia mater and in the subarachnoid space.

(4) The cranial venous sinuses, channels which are situated between the outer and inner layers of the dura mater; they receive the blood from the terminal cerebral veins.

Diploic and Meningeal Veins.

The **diploic veins** are anastomosing spaces in the spongy tissue of the flat bones of the skull; they are lined with endothelium. The number of efferent vessels which emerge from the diploic spaces is not constant, but usually there are at least four on each side—viz., a frontal, two temporal, anterior and posterior, and an occipital.

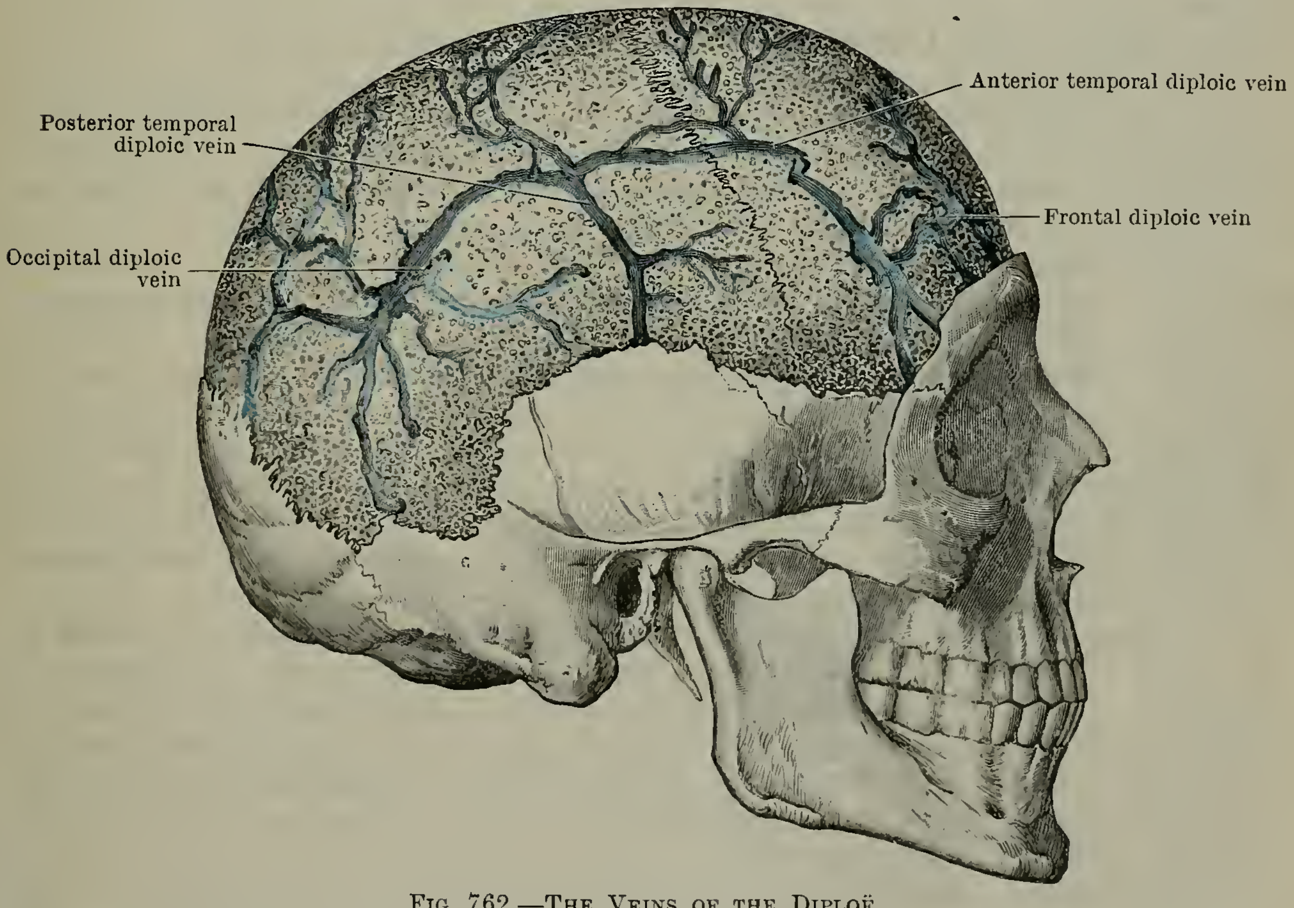
Anterior temporal diploic vein
Posterior temporal diploic vein
Frontal diploic vein
Occipital diploic vein

Fig. 762.—The Veins of the Diploë.

The **frontal diploic vein** is one of the most constant; it drains the anterior part of the frontal bone, passes through a small aperture in the upper margin of the supra-orbital notch, and terminates in the supra-orbital vein.

The **anterior temporal diploic vein** drains the posterior part of the frontal bone and the anterior part of the parietal bone; it pierces the great wing of the sphenoid, and terminates either in the spheno-parietal sinus or in the anterior deep temporal vein.

The **posterior temporal diploic vein** drains the posterior part of the parietal bone; it runs downwards to the posterior inferior angle of the parietal bone and terminates in the transverse sinus, to which it passes either through a foramen in the inner table of the parietal bone or through the mastoid foramen.

The **occipital diploic vein** is usually the largest of the series; it drains the occipital bone, and terminates either externally in the occipital vein or internally in the lateral sinus.

Venæ Meningeæ.—The **meningeal veins** commence in two capillary plexuses, a deep and a superficial. The deep plexus is a wide-meshed network in the inner layer of the dura mater. Its efferent vessels terminate in the superficial plexus. The superficial plexus lies in the outer layer of the dura mater. It consists of numerous vessels of uniform calibre which frequently anastomose together, and terminate in two sets of efferents; of these, one set ends in the cranial blood sinuses, and the other accompanies the meningeal arteries. The efferent meningeal veins are peculiar, inasmuch as they do not alter much in size as they approach their terminations. They lie external to the arteries in the grooves in the inner wall of the cranium, and are very liable to be torn when the bones are fractured (Wood Jones).

VEINS OF THE BRAIN.

The veins of the brain include the veins of the cerebrum, of the mid-brain, of the cerebellum, of the pons, and of the medulla oblongata. They do not possess valves.

The Veins of the Cerebrum.—The **cerebral veins** are arranged in two groups, (*a*) the deep and (*b*) the superficial.

The deep veins issue from the substance of the brain. The superficial veins lie upon its surface in the pia mater and the subarachnoid space. The terminal trunks of both sets pierce the arachnoid membrane and the inner layer of the dura mater, and open into the cranial venous sinuses.

(*a*) The **deep cerebral veins** are the chorioid veins, the venæ terminales, the internal cerebral veins, the great cerebral vein (Galen), the vein of the septum pellucidum and the inferior striate veins.

Each **chorioid vein** is formed by the union of tributaries which issue from the chorioid plexus in the body and inferior horn of a lateral ventricle. It ascends, along the lateral border of the tela chorioidea of the third ventricle (O.T. velum interpositum), and passes forwards, in the lateral border of that fold of pia mater, to the interventricular foramen (Monro), where it receives efferents from the chorioid plexus of the third ventricle, and unites with the vena terminalis to form the internal cerebral vein (Galen).

The **vena terminalis** (O.T. **vein of corpus striatum**), on each side, is formed by the union of tributaries which issue from the corpus striatum and from the thalamus. It runs forwards between the thalamus and the caudate nucleus, in a groove in the floor of the lateral ventricle, and, after receiving tributaries from the walls of the anterior horn of the ventricle, and the vein of the septum pellucidum, it terminates at the apex of the tela chorioidea, where it joins the chorioid vein to form the internal cerebral vein (Galen).

Each **internal cerebral vein** (Galen) commences at the apex of the tela chorioidea, near the interventricular foramen (Monro), by the union of the vena terminalis with the chorioid vein. The two veins run backwards between the layers of the tela, receiving tributaries from the chorioid plexuses of the third ventricle and from the fornix and corpus callosum, and they terminate, beneath the splenium of the corpus callosum, by uniting to form the great cerebral vein (Galen).

The **great cerebral vein (Galen)** passes backwards and slightly upwards from its origin, and ends in the anterior extremity of the straight sinus. In addition to the two internal cerebral veins, by the union of which it is formed, it receives tributaries from the posterior parts of the gyrus cinguli of each side, from the pineal and quadrigeminate bodies, from the medial and inferior surfaces of the occipital lobes of the brain, and from the upper surface of the cerebellum. It also receives the basal vein of each side (see below).

An **inferior striate vein** descends, on each side, from the substance of the corpus striatum, and, after passing through the anterior perforated substance, ends in the basal vein, which, as already stated, is a tributary of the great cerebral vein.

(*b*) The **superficial cerebral veins** are more numerous and of larger calibre than the cerebral arteries. They lie upon the surface of the cerebrum, drain blood from the cerebral cortex, and they are divisible into two sets, the superior and the inferior.

The **superior cerebral veins**, twelve or more in number, lie in the pia mater and subarachnoid space on the upper and lateral aspect of the cerebral hemispheres. They run upwards and medially, to the margin of the longitudinal fissure where they receive tributaries from the medial surface of the hemisphere, and they terminate in the superior sagittal sinus or in the lateral lacunar expansions of the sinus. The anterior veins of this set are small and run transversely, but the posterior are large and run obliquely forwards and medially; they are embedded for some distance in the wall of the sinus, and their orifices are directed forwards against the blood stream.

The **inferior cerebral veins** lie on the lower and lateral aspects of the cerebral hemispheres; they run downwards and medially, and terminate in the sinuses which lie at the base of the skull—viz., the cavernous, the superior petrosal, and the transverse sinuses. One of these veins, the **superficial middle cerebral vein**, runs along the posterior horizontal branch and the stem of the lateral fissure (Sylvius) to the cavernous sinus; occasionally it is united by an anastomotic loop, known as the **great anastomotic vein** (Trolard), with the superior sagittal sinus, and sometimes by the **inferior anastomotic vein** with the transverse sinus.

The **anterior cerebral vein** of each side lies in the longitudinal fissure, and accompanies the corresponding anterior cerebral artery; it receives tributaries from the corpus callosum and the gyrus cinguli. Turning downwards, round the genu of the corpus callosum, it reaches the base of the brain, and terminates in the basal vein.

The **deep middle cerebral vein** lies deeply in the lateral fissure (Sylvius); it anastomoses freely with the superficial middle vein, receives tributaries from the insula and the adjacent opercula, and terminates in the basal vein.

The **basal vein** commences at the anterior perforated substance; it is formed by the union of the anterior cerebral vein with the deep middle vein and with the inferior striate vein. Passing backwards round the pedunculus cerebri, it terminates in the great cerebral vein (Galen). Its tributaries are derived from the tuber cinereum, the corpus mamillare, the posterior perforated substance, the uncus, the inferior cornu of the lateral ventricle, and the pedunculus cerebri.

Veins of the Mid-brain.—The veins of the mid-brain terminate for the most part either in the great cerebral vein (Galen) or in the basal veins.

Cerebellar Veins.—These veins also are divisible into two groups, the superficial and the deep. The former are quite independent of and much more numerous than the arteries. They form two sets, the superior and the inferior.

The **superior superficial cerebellar veins** terminate in a single median or vermian efferent vessel which is sometimes double, and in several lateral efferents. The superior vermian vein runs anteriorly and ends in the great cerebral vein (Galen). The lateral superior cerebellar veins terminate in the transverse sinuses or in the superior petrosal sinuses.

The **inferior superficial cerebellar veins** also form a small vermian and numerous lateral efferents; the former runs backwards and joins either the straight sinus or one of the transverse sinuses, and the latter end in the inferior petrosal and occipital sinuses.

The **deep cerebellar veins** issue from the substance of the cerebellum and terminate in the superficial veins.

Veins of the Pons.—The deep veins from the substance of the pons pass forwards to its anterior surface, where they become superficial, and, anastomosing together, form a plexus which is drained by superior and inferior efferent veins. The superior efferent veins join the basal vein; the inferior efferent veins either unite with the cerebellar veins, or they open into the superior petrosal sinus.

Veins of the Medulla Oblongata.—Deep veins of the medulla oblongata issue from its substance and end in a superficial plexus. This plexus is drained by an anterior and a posterior median vein and by radicular veins.

The **anterior median vein** is continuous below with the corresponding vein of the spinal medulla; it communicates above with the plexus on the surface of the pons.

The **posterior median vein** is continuous below with the posterior median vein of the spinal medulla, from which it ascends to the lower end of the fourth ventricle, where it divides into two branches which join the inferior petrosal sinus or basilar plexus.

The **radicular veins** issue from the lateral parts of the plexus and run with the roots of the last four cerebral nerves; they end in the inferior petrosal and occipital sinuses or in the upper part of the internal jugular vein.

SINUS DURÆ MATRIS.

The **venous sinuses** of the cranium are spaces between the layers of the dura mater; and they are lined with an endothelium which is continuous with the endothelium of the veins. They receive the veins of the brain, communicate frequently with the meningeal veins and with veins external to the cranium, and terminate directly or indirectly in the internal jugular vein. Some of the cranial blood sinuses are unpaired, others are paired.

Unpaired Sinuses.—These are the superior sagittal, the inferior sagittal, the straight, the anterior and posterior intercavernous, and the basilar.

The **superior sagittal sinus** commences in the anterior fossa of the cranium, at the crista galli, where it communicates, through the foramen cæcum, with the veins of the nasal cavity or with the angular vein. It passes backwards in the convex margin of the falx cerebri, grooving the frontal, both the parietal bones, and upper part of the occipital. As it descends along the occipital bone it usually passes slightly to the right side, and it ends, at the level of the internal occipital protuberance, by becoming the right transverse sinus. Instead of passing to the right, it occasionally turns to the left, and ends in the left transverse sinus, and in some cases it bifurcates and ends in both transverse sinuses. When it ends wholly in the right or the left transverse sinus its termination is associated with a well-marked dilatation, the *confluens sinuum,* which is lodged in a depression at one side of the internal occipital protuberance. The confluens sinuum is connected, across the protuberance, by an anastomosing channel, with a similar dilatation which marks the junction of the straight sinus with the lateral sinus of the opposite side. Opening into the superior sagittal sinus are the superior cerebral veins, and it communicates on each side by small openings with a series of spaces in the dura mater, the **lacunæ laterales**, into which the arachnoideal granulations project. It also communicates, by emissary veins, which pass through the foramen cæcum and through each parietal foramen, with the veins on the exterior of the cranium. Its cavity, which is triangular in transverse section, is crossed by several fibrous strands called the **chordæ Willisii.**

The **inferior sagittal sinus** lies, usually, in the posterior two-thirds of the lower free margin of the falx cerebri. It terminates posteriorly by joining with the great cerebral vein (Galen) to form the straight sinus. It receives tributaries from the falx cerebri and from the medial surface of the middle third of each cerebral hemisphere.

Sinus Intercavernosi.—The **anterior intercavernous sinus** is a small transverse channel which crosses from one cavernous sinus to the other in the anterior border of the diaphragma sellæ.

The **posterior intercavernous sinus** also connects the two cavernous sinuses together. It lies in the posterior border of the diaphragma sellæ.

The anterior and posterior intercavernous sinuses and the intervening parts of the cavernous sinuses form collectively the **circular sinus.**

The **basilar plexus** is situated in the dura mater on the basilar part of the occipital bones. It connects the posterior ends of the cavernous or the anterior ends of the inferior petrosal sinuses together, and communicates below with the anterior spinal veins.

The **straight sinus** is formed by the union of the inferior sagittal sinus with the great cerebral vein (Galen). It runs downwards and backwards, along the line of union between the falx cerebri and the tentorium cerebelli. As a general rule it turns to the left at the internal occipital protuberance, dilates somewhat, and becomes continuous with the left transverse sinus, its dilatation being united with the corresponding dilatation on the lower end of the superior sagittal sinus, the "confluens sinuum," by a transverse anastomosing channel. Occasionally the straight sinus terminates in the right lateral sinus; in that case the superior sagittal sinus ends in the left transverse sinus; and sometimes it bifurcates to join both transverse sinuses. It receives some of the superior cerebellar veins and a few tributaries from the falx cerebri.

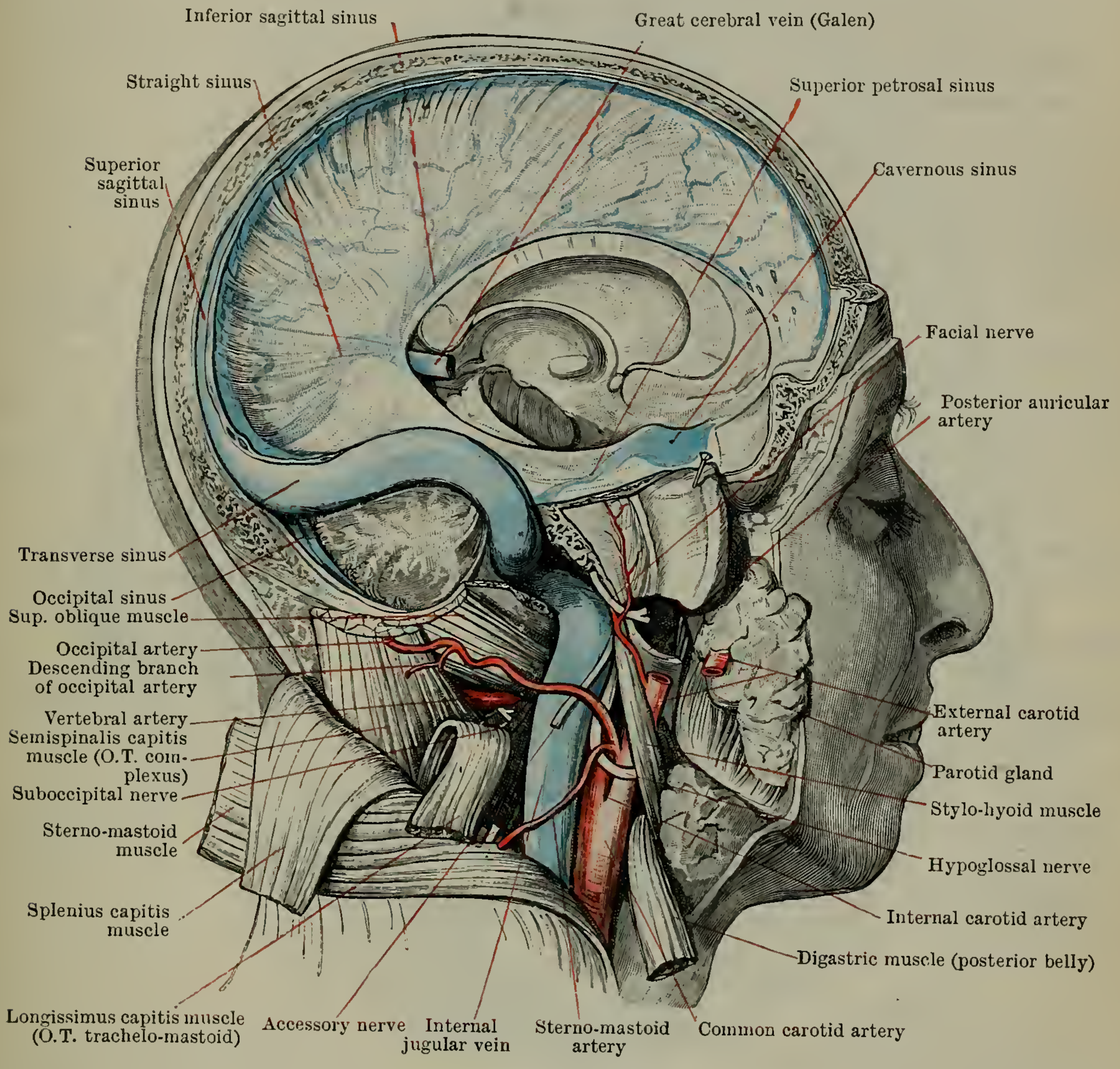

FIG. 763.—DISSECTION OF THE HEAD AND NECK, showing the cranial blood sinuses and the upper part of the internal jugular vein.

Paired Sinuses.—There are six pairs of sinuses, viz., the transverse, the occipital, the cavernous, the superior petrosal, the inferior petrosal, and the spheno-parietal.

Transverse Sinuses.—Each **transverse sinus** commences at the internal occipital protuberance, the right usually as the continuation of the superior sagittal, and the left as the continuation of the straight sinus. Each passes laterally in the postero-lateral part of the attached border of the tentorium cerebelli and in a groove in the occipital bone. From the lateral angle of the occipital bone it passes to the posterior inferior angle of the parietal bone, which it grooves; then it leaves the tentorium and turns downwards on the inner surface of the mastoid portion of the temporal bone; from the latter it passes to the upper surface of the jugular process of the occipital bone, and turns forwards and then downwards into the jugular foramen, where it becomes continuous with the internal jugular vein. The part which descends on the temporal bone and turns forwards on the jugular process of the occipital is called the sigmoid sinus.

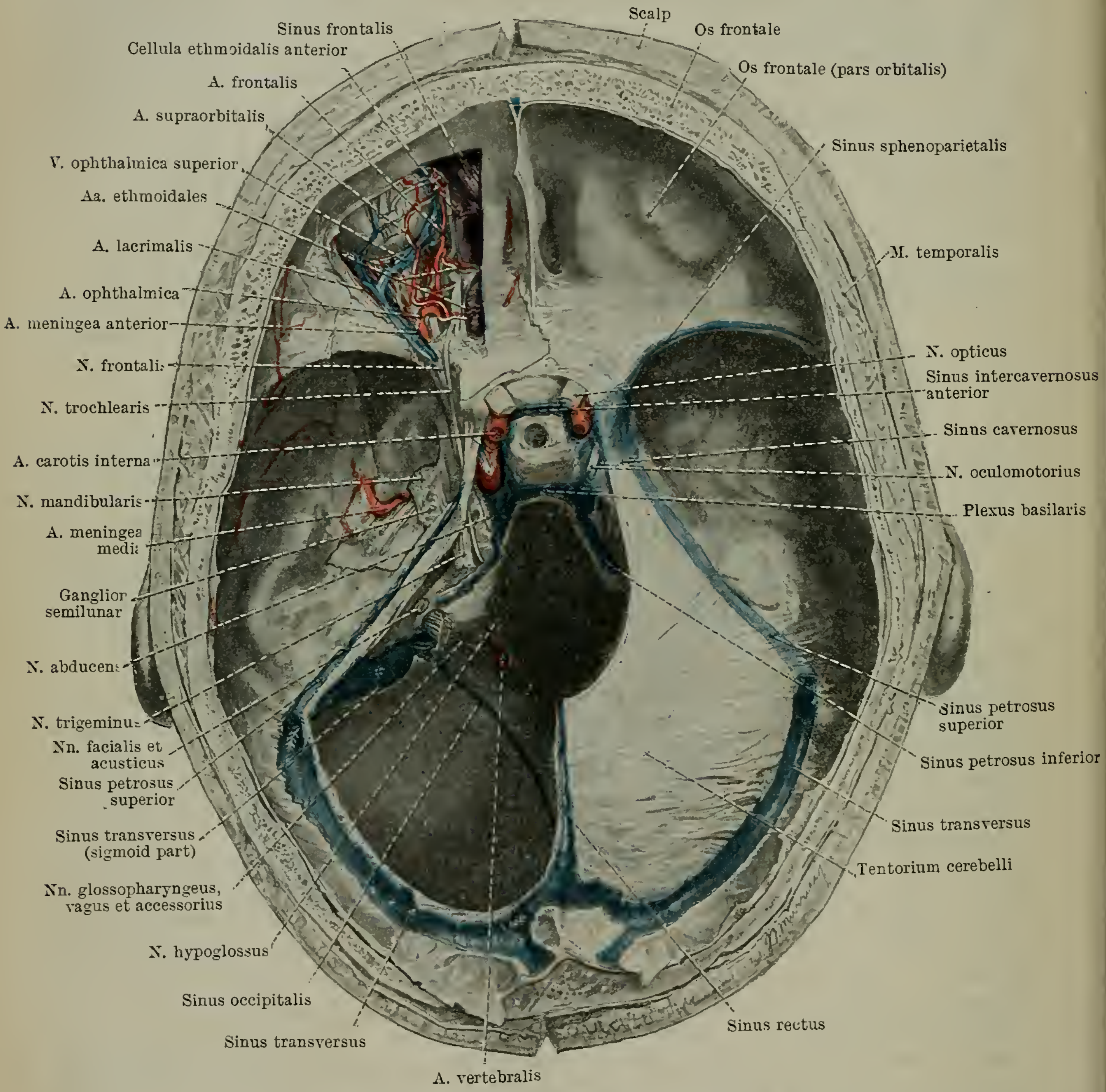

Fig. 764.—The Lower Blood Sinuses of the Dura Mater.

In the specimen represented the superior sagittal sinus opened into both transverse sinuses and chiefly into the left. The straight sinus also opened into both transverse sinuses. The medial part of the left transverse sinus was divided by a horizontal septum into upper and lower parts. The arrow in the figure passes below the septum.

Its tributaries are some of the superior and inferior cerebellar veins, a posterior diploic vein, and the superior petrosal sinus. It is connected with the veins outside the cranium by emissary veins which pass through the mastoid foramen and the condyloid canal.

The **occipital sinuses** lie in the attached border of the falx cerebelli and in the dura mater along the postero-lateral boundaries of the foramen magnum; frequently they unite above and open by a single channel into the commencement of either the right or the left transverse sinus, but their upper extremities may remain separate, and then each communicates with the commencement of the transverse sinus of its own side. On the other hand, either the right or the left sinus may be absent. Each opens below into the terminal part of the corresponding transverse sinus, and both communicate with the posterior spinal veins. Each occipital sinus is an anastomosing channel between the upper and lower extremities of the transverse sinus of the same side, and each receives a few inferior cerebellar veins.

The **cavernous sinuses** lie at the sides of the body of the sphenoid bone. Each sinus commences, anteriorly, at the medial end of the superior orbital fissure, where it receives the corresponding ophthalmic veins, and it terminates, at the apex of the petrous portion of the temporal bone, by dividing into the superior and the inferior petrosal sinuses. Its cavity, which is irregular in size and shape, is so divided by numerous fibrous strands that it assumes the appearance of cavernous tissue; and in its lateral wall are embedded the internal carotid artery with its sympathetic plexus, the oculo-motor, the trochlear, the ophthalmic and maxillary divisions of the trigeminal and the abducent nerves. Its tributaries are the ophthalmic vein, the spheno-parietal sinus and the inferior cerebral veins, including the middle cerebral vein. It communicates with the opposite cavernous sinus by means of the anterior and posterior intercavernous sinuses; with the pterygoid plexus, in the infra-temporal fossa, by an emissary vein which passes either through the foramen ovale or through the foramen Vesalii; with the internal jugular vein by small venous channels which accompany the internal carotid artery through the carotid canal, and by the inferior petrosal sinus; with the transverse sinus by the superior petrosal sinus; and through the superior ophthalmic vein with the angular vein.

The **spheno-parietal sinuses** are lodged in the dura mater on the under surfaces of the small wings of the sphenoid bone close to their posterior borders. Each sinus communicates with the middle meningeal veins, receives veins from the dura mater, and terminates in the anterior part of the corresponding cavernous sinus.

The Superior Petrosal Sinuses.—Each **superior petrosal sinus** commences at the apex of the petrous portion of the temporal bone, in the posterior end of the corresponding cavernous sinus, and it runs backwards and laterally, in the attached margin of the tentorium cerebelli, above the trigeminal nerve. It grooves the superior angle of the petrous portion of the temporal bone, at the lateral end of which it terminates in the transverse sinus, at the point where the latter is turning downwards on the medial surface of the mastoid portion of the temporal bone. It receives inferior cerebral, superior cerebellar, tympanic, and diploic veins.

The Inferior Petrosal Sinuses.—An **inferior petrosal sinus** commences at the posterior end of each cavernous sinus; it runs backwards, laterally, and downwards, in the posterior fossa of the cranium, in a groove formed by the lower angle of the petrous part of the temporal bone and the adjacent border of the basilar part of the occipital bone, to the anterior compartment of the jugular foramen of the same side, through which it passes. It crosses the last four cerebral nerves either on their lateral or on their medial sides, and it terminates in the internal jugular vein. Its tributaries include inferior cerebellar veins and veins from the internal ear, which pass to it through the internal acoustic meatus, the aquæductus cochleæ, and the aquæductus vestibuli.

Abnormalities.—Variations of the cranial blood sinuses are not numerous. One transverse sinus may be absent or very small, when, as a rule, that of the opposite side is enlarged. The inferior sagittal, the occipital, or the spheno-parietal sinuses may be absent, and there may be an additional petro-squamous tributary to the transverse sinus. The petro-squamous sinus, when present, is the remains of a sinus which crossed the temporal bone, passed through the post-condyloid foramen, and terminated in the lateral cerebral vein. In the human adult, in rare cases, it pierces the skull behind the condyle of the mandible, and terminates in the posterior facial vein. This is the normal arrangement in some mammals.

Vv. Emissariæ.—The **emissary veins** are veins which convey blood from the blood sinuses in the interior of the cranium to the veins which lie outside the walls of the cranium. They may be single veins, or plexiform channels surrounding other structures which are passing through the walls of the cranium.

(1) **Frontal.**—In the child, and sometimes in the adult, an emissary vein passes from the anterior end of the superior sagittal sinus through the foramen cæcum. Its lower end divides into two channels which either terminate in the veins of the roof of the nasal cavities or they perforate the nasal bones and join the angular veins.

(2) **Parietal.**—The parietal emissary veins, one on each side, pass through the parietal foramina, from the superior sagittal sinus to the occipital veins.

(3) **Occipital.**—An occipital emissary vein is only occasionally present. It passes from the "confluens sinuum" through the occipital protuberance to one of the tributaries of an occipital vein, and it receives the occipital diploic vein.

(4) **Condyloid.**—When the condyloid canals are present in the occipital bone each is traversed by a condyloid emissary vein, which connects the lower end of the corresponding transverse sinus with the plexus of veins in the sub-occipital triangle.

(5) **Emissary Plexus of the Foramen Ovale.**—This plexus surrounds the mandibular nerve, as it passes through the foramen ovale, and connects the cavernous sinus with the corresponding pterygoid plexus in the infratemporal fossa. If the foramen Vesalii is present, the plexus of the foramen ovale is replaced or supplemented by an emissary vein which passes through that foramen.

(6) **Internal Carotid Plexus.**—The internal carotid plexus accompanies the internal carotid artery through the carotid canal of the temporal bone, and connects the cavernous sinus either with the pharyngeal plexus or with the upper part of the internal jugular vein.

(7) **Plexus of the Hypoglossal Canal.**—As the hypoglossal nerve passes through the hypoglossal canal (O.T. anterior condyloid foramen) it is accompanied either by a venous plexus or by a large vein which connects the veins of the medulla oblongata and the lower part of the occipital sinus with the upper end of the internal jugular vein, or with the extra-cranial part of the inferior petrosal sinus.

Vertebral Veins.

The vertebral veins include—

(1) The basi-vertebral veins.
(2) The external vertebral plexuses.
  (*a*) anterior ,, ,,
  (*b*) posterior ,, ,,
(3) The internal vertebral plexus.
(4) Vertebral longitudinal sinuses.
(5) Intervertebral veins.

The **basi-vertebral veins** are venous channels, enclosed by endothelial walls, which lie in the interiors of the bodies of the vertebræ. They communicate anteriorly with the plexuses of veins on the anterior surfaces of the bodies of the vertebræ, and they converge, radially, towards the posterior surfaces of the bodies of the vertebræ where they open into the transverse anastomoses between the longitudinal vertebral sinuses.

The **external vertebral plexuses**, (*a*) *anterior* and (*b*) *posterior.*

(*a*) The **anterior external vertebral plexuses** are formed by anastomosing venous channels which lie on the anterior surfaces of the vertebræ. They communicate with the basi-vertebral veins and with the intervertebral veins.

(*b*) The **posterior external vertebral plexuses** lie around the postero-lateral aspects of the vertebræ, in the vertebral grooves, around the spines, the articular and the transverse processes of the vertebræ. They communicate with the internal plexuses and with the intervertebral veins, and they open into the vertebral, intercostal, and lumbar veins.

The Longitudinal Vertebral Sinuses. — The veins in the interior of the vertebral canal form a network, the *vertebral venous network,* which lies external to the dura mater and covers the internal surfaces of the arches and the posterior surfaces of the bodies of the vertebræ. The network communicates laterally with the intervertebral veins, posteriorly with the posterior external venous plexuses, whilst anteriorly it receives the basi-vertebral veins. In the anterior part of the network, on the posterior surfaces of the bodies of the vertebræ, at the sides of the posterior longitudinal ligament, there are two large longitudinal channels, the *anterior longitudinal vertebral sinuses.* Two less marked longitudinal channels, the *posterior longitudinal vertebral sinuses,* can sometimes be distinguished on the internal surfaces of the vertebral arches.

The anterior longitudinal vertebral sinuses communicate above with the basilar plexus, the terminal parts of the transverse sinuses, and with the network of veins which accompanies each hypoglossal nerve through the hypoglossal canal.

The posterior longitudinal vertebral sinuses, when they are well established, communicate above with the occipital sinuses.

The Intervertebral Veins.—The internal vertebral venous network is drained not only above into the cranial venous sinuses by the longitudinal vertebral sinuses, but also by a series of intervertebral veins which pass through the intervertebral foramina. In the cervical region the intervertebral veins open externally into the vertebral veins, in the thoracic region into the intercostal veins, in the lumbar region into the lumbar veins, and in the sacral region into the lateral sacral veins. The intervertebral veins convey blood both from the internal vertebral venous plexus and also from the anterior and the posterior external vertebral plexuses.

The Veins of the Spinal Medulla.

The **veins of the spinal medulla** issue from the substance of the spinal medulla, and terminate in a plexus in the pia mater. In that plexus there are six longitudinal channels—one *antero-median*, along the anterior fissure, two *antero-lateral*, immediately behind the anterior nerve-roots, two *postero-lateral*, immediately posterior to the posterior nerve-roots, and one *postero-median*, dorsal to the posterior septum. Radicular efferent vessels issue from the plexus, and pass along the nerve roots to communicate with the internal vertebral venous network. The veins of the spinal medulla vary very much in size, but they are largest on the lower and on the posterior portions.

The postero-median and antero-median veins are continued above into the corresponding veins of the medulla oblongata.

The antero-lateral and postero-lateral veins pour their blood partly into the median veins and partly into the radicular veins; indeed, the greater part of the blood from the spinal medulla is returned by the radicular veins.

THE VEINS OF THE SUPERIOR EXTREMITY.

The veins of each upper limb are divisible into two sets—viz., **superficial** and **deep**. Both sets open eventually into a common terminal trunk which is known as the **axillary vein**. That vein is, therefore, the chief efferent vein of the upper extremity. It is continued as the subclavian vein to the innominate vein, through which its blood, together with that from the corresponding side of the head and neck, reaches the superior vena cava.

The Deep Veins of the Upper Extremity.

The deep veins of the upper limb, with the exception of the axillary vein, are arranged in pairs, **venæ comites**, which accompany the different arteries and are similarly named. So far as these veins are concerned it will be sufficient to state that they are provided with valves, that they are situated one on each side of the artery with which they are associated, and that they are usually united together by numerous transverse anastomoses which cross the line of the artery. The axillary vein, however, requires more detailed consideration.

Vena Axillaris.

The **axillary vein** (Figs. 732 and 741) commences, as the direct continuation of the basilic vein, opposite the lower border of the teres major muscle. It passes upwards and medially, through the axilla, along the medial side of the axillary artery, and terminates, at the external border of the first rib, by becoming the subclavian vein. It possesses one or more bicuspid valves of which one is usually situated opposite the lower border of the subscapularis muscle.

Relations.—Its anterior relations are similar to those of the axillary artery, but, in addition, the vein is crossed anteriorly, under cover of the clavicular part of the pectoralis major, by the pectoral branches of the thoraco-acromial artery, and by branches of the medial anterior thoracic nerve, and it receives anteriorly, just above the upper border of the pectoralis minor, the termination of the cephalic vein.

Posterior to it are the muscles which form the posterior wall of the axilla, the axillary fat, and the first serration of the serratus anterior. The long thoracic nerve intervenes between it and the serratus anterior, and the subscapular and thoraco-dorsal nerves and the subscapular artery pass between it and the subscapularis.

It is separated from the third part of the axillary artery by the ulnar nerve and medial cutaneous nerves of the forearm; from the second part of the axillary artery by the medial cord of the brachial plexus; and in the proximal part of the axilla, behind the costo-coracoid membrane, it is separated from the first part of the artery by the medial anterior thoracic nerve. To its medial side lie the lateral set of axillary glands, and, in the distal part of the axilla, the medial cutaneous nerve of the arm.

Tributaries.—In addition to tributaries corresponding with the branches of the axillary artery, it receives the venæ comites of the brachial artery, at the lower border of the subscapularis; and the cephalic vein, which joins it above the upper border of the pectoralis minor muscle.

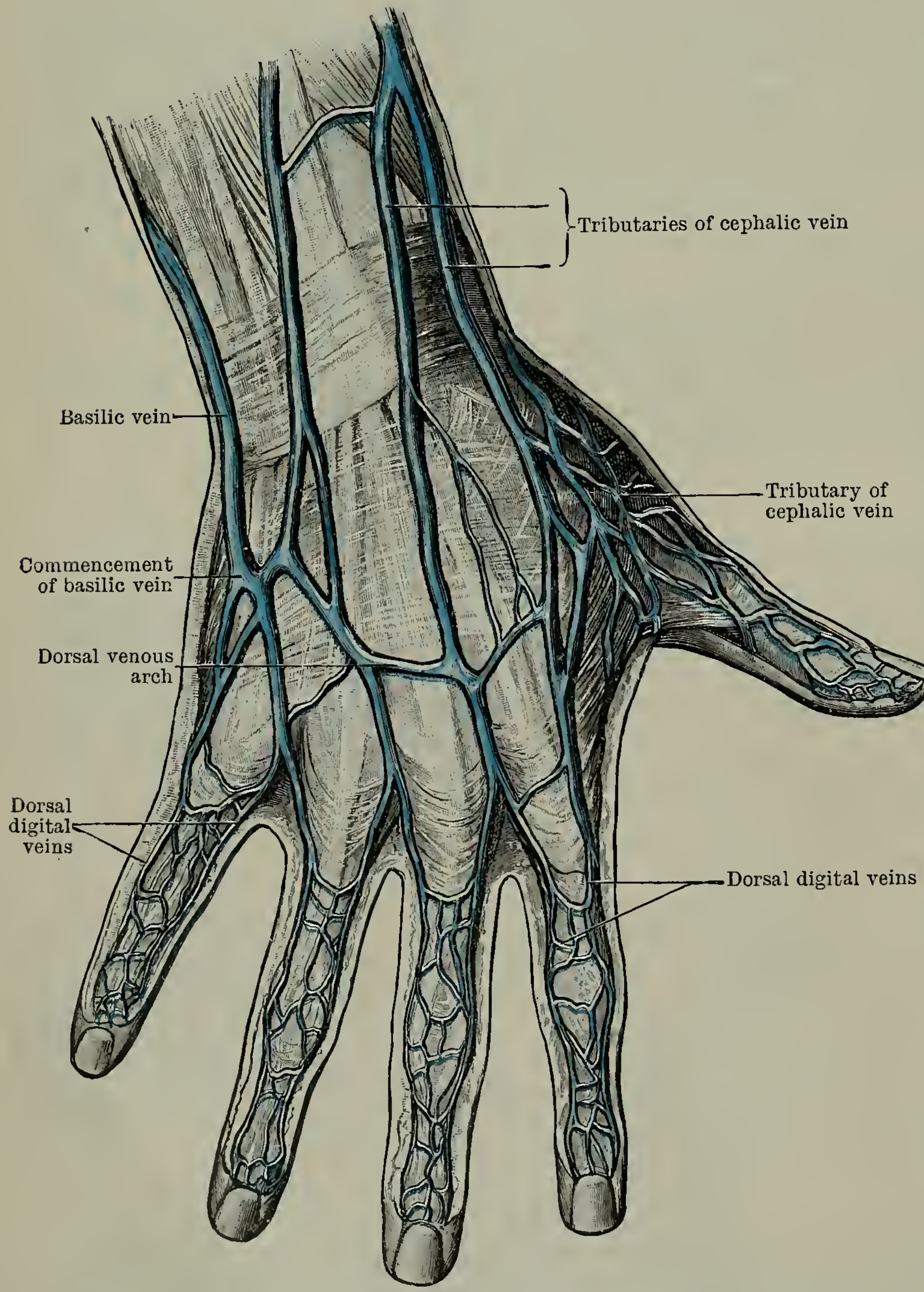
Tributaries of cephalic vein
Basilic vein
Tributary of cephalic vein
Commencement of basilic vein
Dorsal venous arch
Dorsal digital veins
Dorsal digital veins

Fig. 765.—Superficial Veins on the Dorsum of the Hand and Digits.

THE SUPERFICIAL VEINS OF THE SUPERIOR EXTREMITY.

The superficial veins of the upper limb commence in the superficial fascia of the palm and dorsum of the hand and of the digits.

The Veins of the Digits and Hand.—The **special volar digital veins** are two or more fine longitudinal channels which lie in the superficial fascia of the volar aspects of the digits. They communicate, proximally, with a fine venous network which lies in the superficial fascia of the palm, and, at the proximal ends of the interdigital clefts, by means of *intercapitular veins,* which pass dorsally between the heads of the metacarpal bones. They open into the *special dorsal digital veins.*

The **special dorsal digital veins,** two in each digit, anastomose freely together on the dorsal aspects of the digits. At the proximal ends of the interdigital clefts they communicate, through the intercapitular veins, with the special volar digital veins, and then they unite together to form an indefinite series of *dorsal metacarpal veins* which terminate, a little distal to the middle of the dorsum of the hand, in a **dorsal venous arch.**

The Veins of the Forearm and Arm.—The veins of the forearm emerge from the dorsal venous arch and from the volar venous plexus, and they vary considerably in number and in size. As a rule there are two main longitudinal channels, the *cephalic vein* on the radial side and the *basilic vein* on the ulnar side. In some cases there is an additional median vein on the volar aspect of the forearm.

The **cephalic vein** commences in the radial end of the dorsal venous arch. It receives the metacarpal veins of the thumb, turns round the radial margin of the distal part of the forearm, and runs proximally, parallel with the volar border of the brachio-radialis muscle, to the cubital region. There, frequently much reduced in size, it turns laterally and runs, along the lateral border of the prominence of the biceps, to the interval between the deltoid and pectoralis major, along which it ascends to the delto-pectoral triangle. At the delto-pectoral triangle it turns medially, between the pectoralis minor and the pectoralis major, to the anterior aspect of the costo-coracoid membrane, which separates it from the front of the first part of the axillary artery; then, turning backwards, it pierces the costo-coracoid membrane and ends in the axillary vein. In a few cases instead of piercing the costo-coracoid membrane it crosses the front of the clavicle, deep to the platysma, pierces the deep cervical fascia, and joins the lower part of the external jugular vein.

As it runs proximally, on the volar aspect of the forearm, a number of tributaries join its lateral border. Some of these commence in the dorsal venous arch of the hand and others in the superficial fascia of the dorsal aspect of the forearm.

In the cubital region it is connected with the basilic vein by a large obliquely placed anastomosing channel, the *median cubital vein*, which runs along the medial border of the distal part of the biceps prominence, superficial to the lacertus fibrosus which separates it from the distal part of the brachial artery. In the delto-pectoral triangle it is joined by tributaries which correspond with the acromial and pectoral branches of the thoraco-acromial artery.

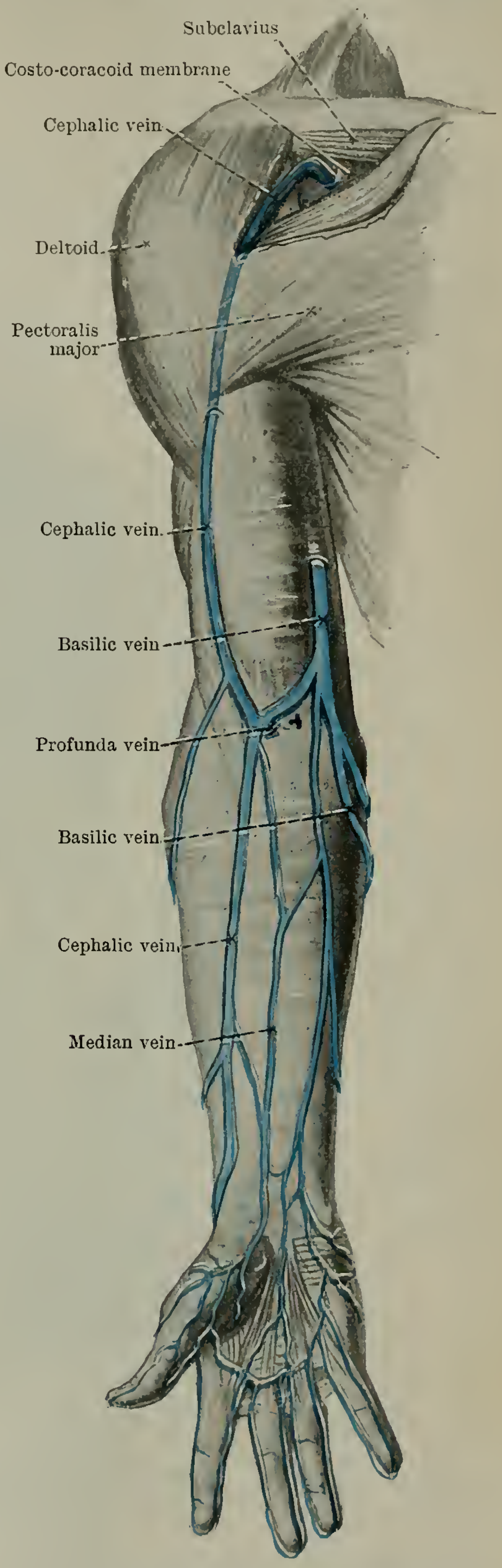

FIG. 766.—SUPERFICIAL VEINS ON THE FLEXOR ASPECT OF THE UPPER EXTREMITY.

The **median cubital vein** not only connects together the cephalic and basilic veins but it receives also the profunda vein which pierces the deep fascia and connects it with the deep veins of the forearm, and one or more superficial veins of varying size, which pass, proximally, along the volar aspect of the forearm.

In many cases the median cubital vein is relatively very large, and in such cases the more proximal part of the cephalic vein, which lies in the arm, is a comparatively small vessel.

The **basilic vein** commences in the ulnar end of the dorsal venous arch of the hand. It runs along the dorsal aspect of the forearm to the junction of the proximal and middle thirds, where it turns round the ulnar border of the forearm, and runs, anterior to the medial epicondyle of the humerus, to the medial bicipital groove. At the middle of the arm, it pierces the deep fascia. After piercing the fascia, it runs proximally, along the medial border of the brachial artery, to the axilla, and there becomes the axillary vein.

As it runs proximally, in the forearm, it is joined by tributaries from both the volar and dorsal aspects and, in the cubital region, by the median cubital vein which connects it with the cephalic vein.

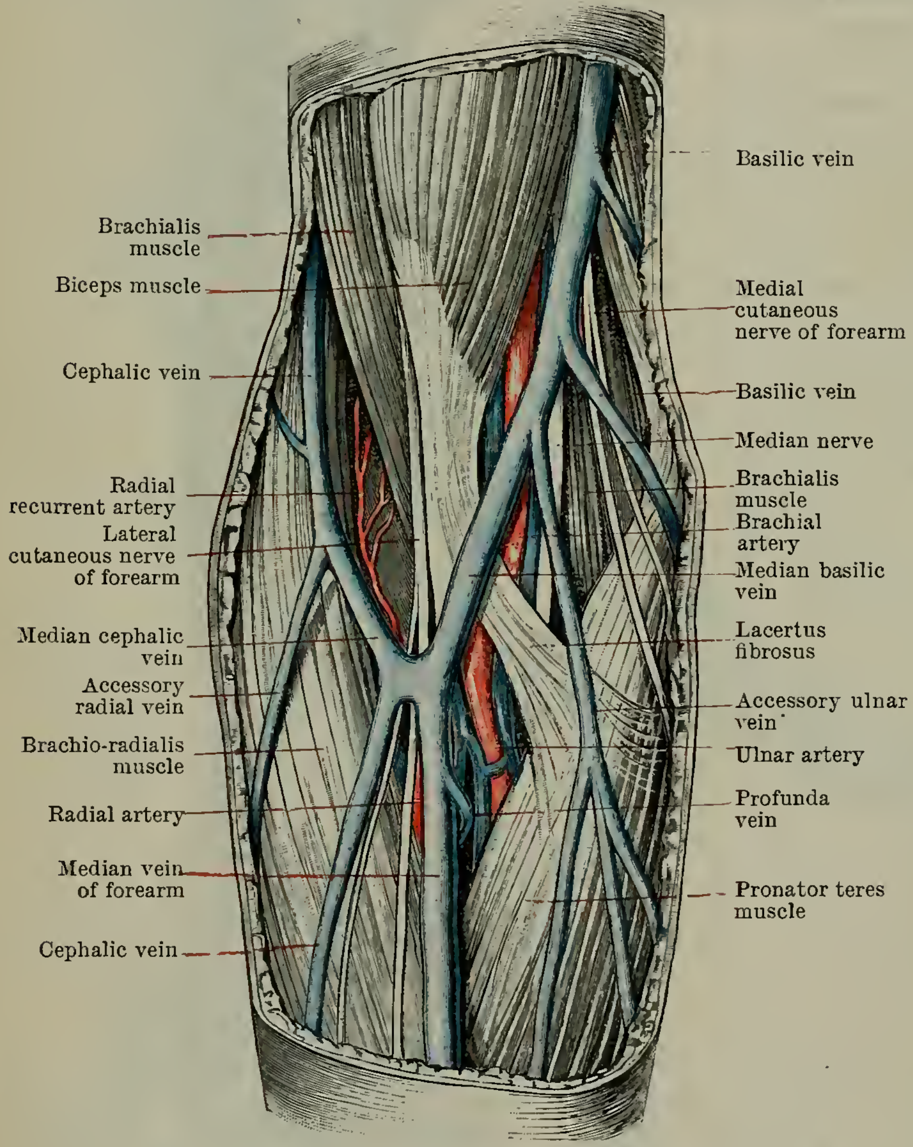

Fig. 767.—Superficial Veins at the Bend of the Elbow in a Specimen in which the Median Vein was large.

The Median Vein of the Forearm.—In a certain number of cases a vein, which commences in the palmar venous plexus, runs along the middle of the volar aspect of the forearm to the cubital region. It is called the median vein of the forearm. At the bend of the elbow it receives the profunda vein and then divides into two branches, the *median cephalic* and the *median basilic* veins (Fig. 767). The median cephalic vein runs along the lateral bicipital sulcus and joins the cephalic vein. The median basilic passes along the medial bicipital sulcus and joins the basilic vein. When the median vein of the forearm is present the median cubital vein is absent.

When venesection is performed in the forearm it is either the median cubital vein or, in its absence, the median basilic vein which is opened.

Abnormalities.—The superficial veins of the forearm are extremely variable; any of them may be absent, but most commonly it is the median or the cephalic vein which is wanting. The median cephalic and the cephalic veins may be small or absent, and, on the other hand, the cephalic vein may be larger than usual. Moreover the cephalic vein may end in the external jugular vein, its original termination; or it may be connected with the external jugular vein by an anastomosing channel which sometimes passes over the clavicle and sometimes through that bone.

The basilic vein is sometimes larger and sometimes smaller than usual, and it may pierce the fascia of the arm at a more proximal or at a more distal level than usual.

The **venæ comites** of the arteries of the upper extremity generally terminate at the lower border of the subscapularis, where they join the axillary vein, but they may end above or below the position of their usual termination.

The **subclavian vein** sometimes passes behind instead of in front of the scalenus anterior muscle, and it has been seen passing between the clavicle and the subclavius muscle.

VENA CAVA INFERIOR AND ITS TRIBUTARIES.

The **inferior vena cava** (Fig. 769) is a large venous trunk which receives the whole of the blood from the lower extremities, and the greater part of the blood from the walls and contents of the abdomen and pelvis. It commences opposite the right side of the body of the fifth lumbar vertebra, behind and to the right of the right common iliac artery. It ascends through the abdomen, anterior and to the right of the vertebral column and the right crus of the diaphragm, and it pierces

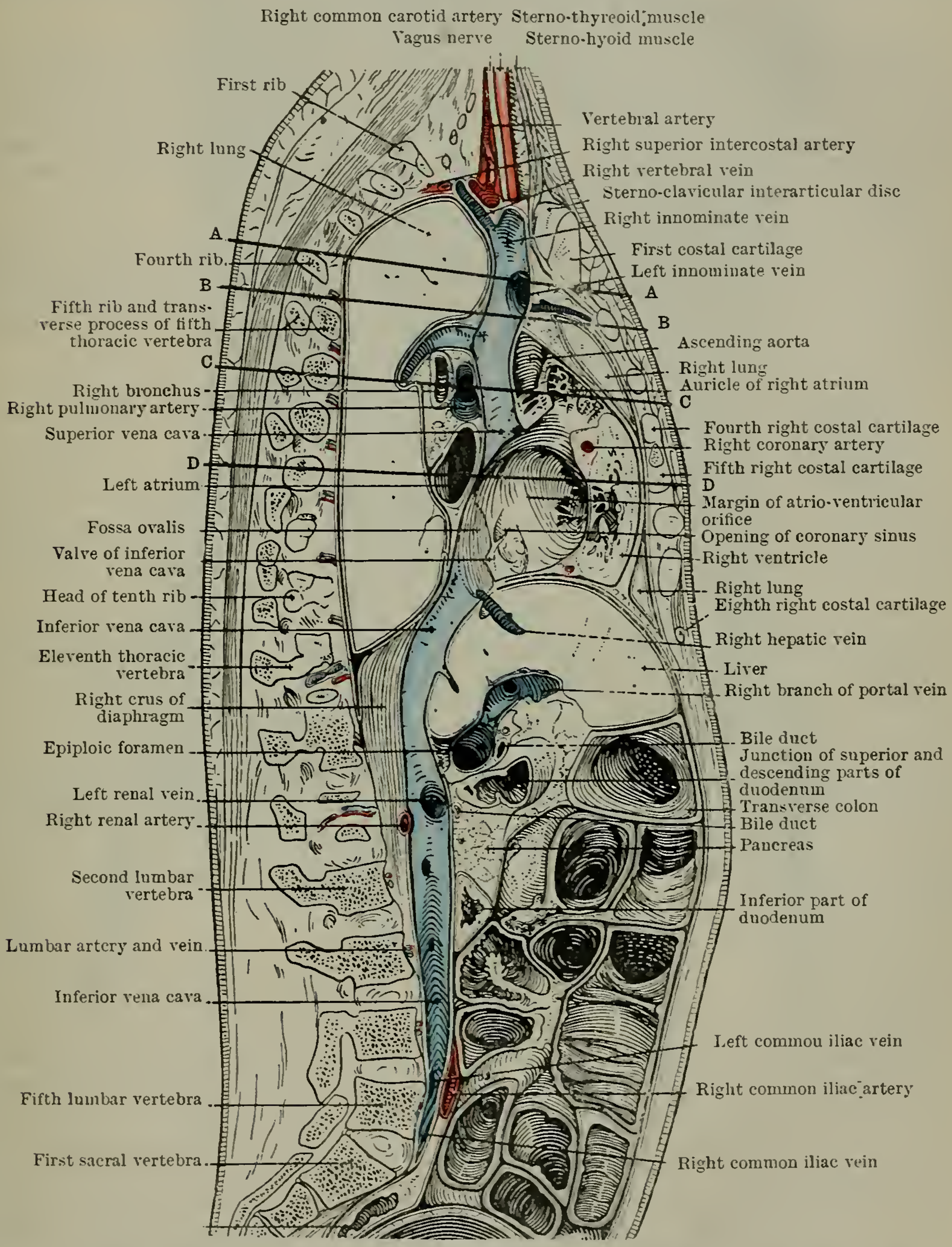

Fig. 768.—A Sagittal Lateral Section of the Body of a Young Male along the Lines of the Superior and the Inferior Venæ Cavæ.

the cupola of the diaphragm, between the middle and right sections of the central tendinous leaflet, at the level of the lower part of the eighth thoracic vertebra. It then enters the middle mediastinum, pierces the fibrous pericardium, and terminates in the lower and posterior part of the right atrium. Its intra-thoracic portion is very short, and its intra-pericardial portion, which is still shorter, is covered anteriorly and on its right and left sides by the parietal portion of the serous layer. Attached to the inferior and anterior margin of its atrial orifice is the *valve of the inferior vena cava* (Eustachius). This is a remnant of an important fold of endocardium by which, in the fœtus, the blood from the inferior vena cava is directed, through the foramen ovale, into the left atrium.

Relations.—The inferior vena cava is in relation, *posteriorly*, with the bodies of the lower lumbar vertebræ and the corresponding part of the anterior longitudinal ligament, the anterior portion of the right psoas major muscle, the right lumbar sympathetic trunk, the roots of the right lumbar arteries, the right crus of the diaphragm, the right renal artery, the right suprarenal artery, the right cœliac ganglion, the right inferior phrenic artery, and the medial and upper portion of the right suprarenal gland.

Anterior to it, from below upwards, are the following structures—the right common iliac artery, the lower end of the mesentery and the superior mesenteric artery, the right internal spermatic artery and the third part of the duodenum, the head of the pancreas, the portal vein and the first part of the duodenum, the foramen epiploicum, and the posterior surface of the liver. More superficially are coils of small intestine, the great omentum, and the transverse colon and mesocolon.

To its left side are the aorta and the right crus of the diaphragm.

On its right side, below, is the right ureter, whilst at a higher level the right kidney is separated from the vein by a short interval only.

Tributaries.—In addition to the two common iliac veins, by the union of which it is formed, and through which it receives blood from the pelvis and from the lower extremities, the inferior vena cava receives the following tributaries:—The hepatic veins, the right inferior phrenic vein, the right suprarenal vein, the right and left renal veins, the right internal spermatic vein, and the right and left lumbar veins.

Abnormalities.—The lower part of the inferior vena cava is sometimes absent, in which case the common iliac veins ascend, one on the right and the other on the left of the aorta, to the level of the second lumbar vertebra, where the left common iliac vein receives the left renal vein, and then crosses in front of or behind the aorta to fuse with the corresponding vein of the right side; in such cases, therefore, the inferior vena cava commences at the level of the second lumbar vertebra, and it represents only the upper and last-formed part of the ordinary vessel; the common iliac veins, each of which receives the lumbar veins of its own side, are exceptionally long, and they may or may not be united at the pelvic brim by a small transverse anastomosing channel. Cases of this kind are sometimes described as partial doubling of the inferior vena cava.

Occasionally the inferior vena cava does not terminate in the right atrium, but is continuous with the vena azygos, which is much enlarged, all the inferior caval blood being then carried to the superior vena cava. In such cases the hepatic veins open directly into the right atrium without communicating with the inferior vena cava.

The lower part of the inferior vena cava sometimes lies to the left instead of to the right of the aorta; this condition is associated with a long right common iliac vein, which crosses obliquely from right to left to join the shorter left common iliac vein. After receiving the left renal vein the misplaced inferior vena cava crosses in front of the aorta, reaching the right side at the level of the second or first lumbar vertebra. In other cases, however, the left inferior vena cava continues upwards through the left crus of the diaphragm, usurping the place of a greater or smaller part of the hemiazygos vein; having entered the thorax, it may cross to the opposite side and terminate in the vena azygos, or it may continue upwards on the same side, and after arching over the root of the left lung, descend behind the left atrium to terminate in the right atrium in the situation of the coronary sinus. In this group of cases also the hepatic veins open separately into the right atrium.

The inferior vena cava may lie ventral instead of dorsal to the right internal testicular artery, in which case the lower part of the vessel has been derived from the subcardinal vein instead of from the posterior cardinal vein. (Johnston, *Journ. of Anat. and Phys.* xlvii., 1913.)

The tributaries of the inferior vena cava are also subject to variation. Additional renal, testicular, ovarian, or suprarenal veins may be present. Two or three lumbar veins of one or both sides may unite into a common trunk which terminates in the inferior vena cava, and the hepatic veins may open separately, or after fusing into a common trunk, into the right atrium near the opening of the inferior vena cava.

No explanation of the variations of the inferior vena cava and its tributaries is necessary, beyond the statement that they are due to persistence of portions of the postcardinal, the subcardinal and supracardinal veins which usually disappear, and to the persistence of transverse anastomoses and tributaries which usually atrophy, or to modifications of those which ordinarily take part in the formation of the inferior vena caval system.

The **hepatic veins** (Fig. 769) convey blood which has passed through the liver from the portal veins and from the hepatic artery, and they open into that portion of the inferior vena cava which lies immediately below the diaphragm, and behind the right lobe of the liver. They form two groups, an upper group of two or three large trunks, and a lower group of smaller veins.

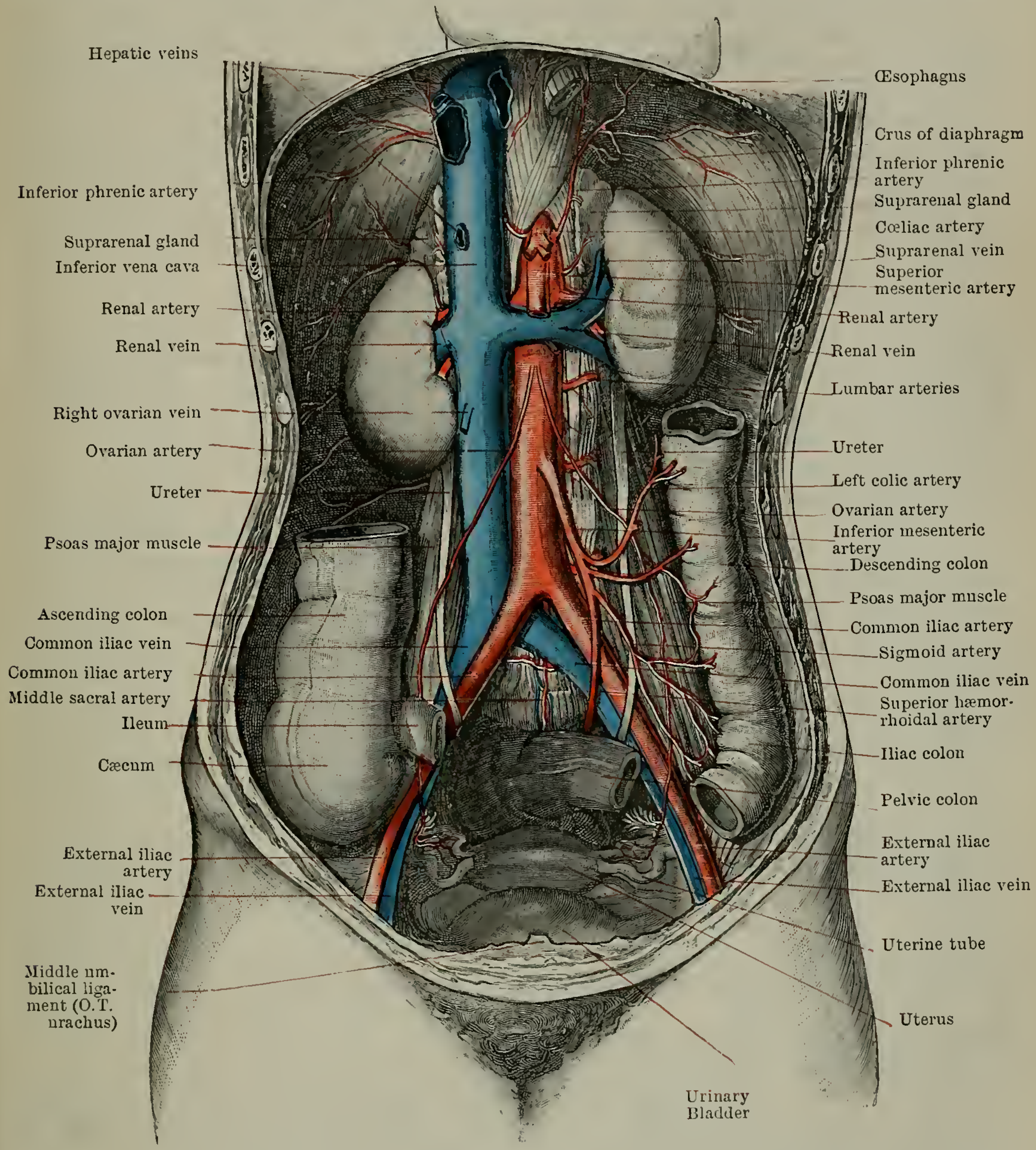

FIG. 769.—THE INFERIOR VENA CAVA AND ITS TRIBUTARIES.

The upper group occasionally consists of only two veins, a right and a left; more frequently there are three vessels, a right, a left, and a middle vein, and in the latter case the middle vein issues from the caudate lobe.

The veins of the lower group vary in number from six to twenty; they return blood from the right and caudate lobes.

The hepatic veins commence in the interiors of the lobules of the liver as *central veins*; the central veins issue from the upper and posterior aspects of the lobules, and unite together to form *interlobular veins*; and the interlobular veins unite with one another, as they converge towards the posterior surface of the liver, to form the larger hepatic veins.

The **inferior phrenic veins** are formed by tributaries which issue from the substance of the diaphragm. The right inferior phrenic vein terminates in the upper part of the inferior vena cava. The left vein passes posterior to the œsophagus, and usually terminates in the left suprarenal vein.

The Suprarenal Veins.—A single **suprarenal vein** issues from the hilum on the anterior surface of each suprarenal gland; the right vein terminates in the inferior vena cava; the left usually ends in the left renal vein, but sometimes it opens directly into the inferior vena cava.

Venæ Renales.—Each **renal vein** is formed by the union of five or six tributaries which issue from the hilum of the kidney, where they lie anterior to or are intermingled with the corresponding arteries.

The **right renal vein** is about 25 mm. (one inch) long; it passes posterior to the descending part of the duodenum, and terminates in the right side of the inferior vena cava.

The **left renal vein** is about 75 mm. long. It crosses anterior to the left psoas major, the left crus of the diaphragm, and the aorta immediately below the superior mesenteric artery. It lies behind the pancreas and the ascending part of the duodenum, and, running above the transverse part of the duodenum, terminates in the left side of the inferior vena cava. The left testicular or ovarian vein, according to the sex, and almost invariably the left suprarenal vein, open into it.

Venæ Lumbales.—There are usually four **lumbar veins** on each side, one with each lumbar artery; the vein with the subcostal artery is not included in this number. By their anterior and posterior branches the lumbar veins drain the lateral and posterior walls of the abdomen. The anterior branches commence in the lateral walls of the abdomen, where they communicate with the superior and inferior epigastric veins. The posterior divisions issue from the muscles of the back, in the lumbar region, and receive tributaries from the spinal plexuses. The main stems pass forwards on the bodies of the vertebræ; on each side they run postero-medial to the psoas major muscle, whilst those of the left side also pass posterior to the aorta. They terminate in the posterior part of the inferior vena cava. Not uncommonly the corresponding veins of opposite sides unite together to form a single trunk which enters the back of the inferior vena cava. All the lumbar veins, of each side, are united together by a longitudinal anastomosing vessel, the **ascending lumbar vein**.

The Ascending Lumbar Vein.—Each ascending lumbar vein passes upwards, between the psoas major and the roots of the transverse processes of the lumbar vertebræ. It commences in the lateral sacral vein of the same side, anastomoses with the ilio-lumbar vein, connects the lumbar veins together, receives tributaries from the anterior external vertebral plexus and anastomoses with the inferior vena cava and the renal vein. The right ascending lumbar vein terminates in the azygos and the left in the hemiazygos vein.

The **testicular veins**, on each side, issue from the testis and epididymis and form a plexus, the *pampiniform plexus.* The plexus is one of the constituents of the spermatic cord, and consists of from eight to ten veins, most of which lie anterior to the ductus deferens; it passes upwards through the scrotum and inguinal canal, and, near the abdominal inguinal ring, terminates in two main trunks which ascend, with the corresponding testicular artery, for some distance, receiving tributaries from the ureter; ultimately the two veins unite together and a single terminal vein is formed. The terminal testicular vein on the right side opens into the inferior vena cava, that on the left side into the left renal vein. The left testicular vein is longer than the right, the left testis being lower than the right, and the termination in the left renal vein being at a higher level than the termination of the right vein in the inferior vena cava. The testicular veins, on each side, lie anterior to the psoas major muscle and the ureter. They are covered by peritoneum, and they are crossed on the right side by the termination of the ileum and the third part of the duodenum, and on the left side by the iliac colon and the lower part of the pancreas. They are provided with valves, one of which usually lies at the terminations of each vein, but, occasionally, the valve at the orifice of the left testicular vein is absent.

The **ovarian veins**, on each side, issue from the hilum in the anterior border of the ovary. They pass between the layers of the broad ligament, where they anastomose freely and form the *pampiniform plexus*, which extends, laterally, towards the upper margin of the pelvis minor. From the plexus two veins issue which accompany the corresponding ovarian artery; they pass anterior to the external iliac artery, and then upwards, behind the peritoneum and anterior to the psoas major muscle and ureter. The veins of the right side, like the corresponding testicular veins, also pass behind the termination of the ileum and the third part of the duodenum; whilst the left veins, near the margin of the pelvis minor, pass behind the commencement of the pelvic colon.

The two veins on each side ultimately fuse together to form a single terminal vein which ends, on the right side in the inferior vena cava, and on the left side in the left renal vein.

VENÆ ILIACÆ COMMUNES.

The **common iliac veins** (Figs. 760 and 769), right and left, are formed by the union of the corresponding external iliac and hypogastric veins. Each commences at the superior aperture of the pelvis minor, immediately posterior to the upper part of the hypogastric artery of its own side, and both vessels pass upwards to the right side of the body of the fifth lumbar vertebra, at the upper part of which, posterior and lateral to the right common iliac artery, they unite together to form the inferior vena cava.

The **right common iliac vein** is much shorter than the left; it passes anterior to the obturator nerve and the ilio-lumbar artery, and at first posterior and then somewhat to the lateral side of the corresponding common iliac artery.

The **left common iliac vein** is much longer than the right, and is also placed more obliquely. It passes upwards and to the right, anterior to the body of the fifth lumbar vertebra, and the middle sacral artery. For some distance it runs along the medial side of the left common iliac artery, and then passes posterior to the right common iliac artery. It also passes posterior to the mesentery of the pelvic colon and the superior hæmorrhoidal vessels.

Abnormalities.—The **left common iliac vein** is short and the right long when the inferior vena cava lies on the left side. The common iliac veins may be absent, the hypogastric veins uniting to form the commencement of the inferior vena cava, into which the external iliac veins open as lateral tributaries.

Tributaries.—Each common iliac vein receives the corresponding external iliac, hypogastric and ilio-lumbar veins. The left common iliac vein receives, in addition, the middle sacral vein.

The **ilio-lumbar veins** receive tributaries from the iliac fossa, from the lower parts of the vertebral muscles, and from the vertebral canal. There is a single vein on each side which accompanies the corresponding artery. It passes posterior to the psoas major muscle and terminates in the corresponding common iliac vein.

The Middle Sacral Vein.—The venæ comites of the middle sacral artery commence by the union of tributaries which issue from the venous plexus in front of the sacrum, through which they communicate with the lateral sacral veins and receive blood from the interior of the sacral canal. They unite, above, into a single **middle sacral vein**, which terminates in the left common iliac vein.

The **hypogastric vein** (Fig. 749) is a short trunk formed by the union of tributaries which correspond to all the branches of the hypogastric artery, with the exception of the umbilical and the ilio-lumbar branches.

It commences at the upper border of the greater sciatic notch, and ascends to the aperture of the pelvis minor; there it unites with the external iliac vein to form the common iliac vein. It lies immediately postero-medial to the hypogastric artery, is crossed laterally by the obturator nerve, and is in relation medially, on the left side with the pelvic colon, and on the right side with the lower part of the ileum.

Tributaries.—The tributaries, which are numerous, are conveniently divisible into extra-pelvic and intra-pelvic groups.

The *extra-pelvic tributaries* are all **parietal**, and include the obturator, internal pudendal, inferior, and superior gluteal veins.

Obturator Vein.—This vein is formed by the union of tributaries which issue from the hip-joint and from the muscles of the proximal and medial part of the thigh. It enters the pelvis minor through the obturator canal, runs backwards, along the lateral wall of the pelvis minor, lying medial to the pelvic fascia, immediately below the corresponding artery, and, passing between the hypogastric artery on the lateral side and the ureter on the medial side, it terminates in the hypogastric vein.

Inferior Gluteal Veins.—The venæ comites of the inferior gluteal artery commence in the subcutaneous tissues on the back of the thigh; they ascend with the artery, and pass into the buttock on the deep aspect of the glutæus maximus, where they receive numerous tributaries from the surrounding muscles. Entering the pelvis, through the greater sciatic foramen, they unite into a single vessel, which terminates in the lower and anterior part of the hypogastric vein below the termination of the obturator vein.

Superior Gluteal Veins.—The venæ comites of the superior gluteal artery are formed by tributaries which issue from the muscles of the buttock. They accompany the artery through the greater sciatic foramen, and terminate in the hypogastric vein; they frequently unite together before reaching their termination.

Internal Pudendal Veins.—The venæ comites of the internal pudendal artery commence by tributaries which emerge from the *pudendal plexus*, which lies below and posterior to the arcuate ligament of the pubis and constitutes the anterior part of the prostatic plexus. They receive blood from the corpus cavernosum penis, or the corpus cavernosum clitoridis, by the deep vein of the penis or clitoris. They follow the course of the internal pudendal artery, and usually join together into a single vessel (the internal pudendal vein) which terminates in the hypogastric vein. They receive as tributaries the veins from the bulb, the perineal and inferior hæmorrhoidal veins, and veins from the muscles of the buttock.

The **inferior hæmorrhoidal veins**, which commence in the substance of the external sphincter of the anus and in the walls of the anal canal, anastomose with the middle and superior hæmorrhoidal veins, and consequently connect the lowest parts of the portal and vena caval systems together.

The *intra-pelvic tributaries* of the internal iliac vein are either (*a*) **parietal** or (*b*) **visceral**; the former comprises the lateral sacral veins, the latter includes the efferent vessels from the plexuses around the several pelvic viscera.

(*a*) **Parietal: Lateral sacral veins** accompany the lateral sacral arteries, and terminate on each side in the postero-medial wall of the corresponding hypogastric vein.

(*b*) **Visceral tributaries** are derived from the rectum and from the plexuses associated with the uterus, vagina, bladder, and prostate. They include the middle hæmorrhoidal, the uterine, the vaginal, and the vesical veins.

The **middle hæmorrhoidal veins** are very irregular; sometimes they cannot be distinguished. When present they are formed by tributaries which commence in the submucous tissue of the rectum, where they communicate with the superior and inferior hæmorrhoidal veins in the hæmorrhoidal plexus; they pass through the muscular coat, and fuse together to form two middle hæmorrhoidal veins, right and left, each of which runs laterally, beneath the peritoneum, on the upper surface of the levator ani, to terminate in the corresponding hypogastric vein. In the male each middle hæmorrhoidal vein receives tributaries from the seminal vesicle and ductus deferens of its own side.

Uterine Plexuses and Veins.—The **uterine plexuses** lie along the borders of the uterus; they receive tributaries, which are entirely devoid of valves, from the uterus; and they communicate above with the ovarian, and below with the vaginal plexuses.

The **uterine veins**, usually two on each side, issue from the lower parts of the uterine plexuses, above their communications with the vaginal plexuses. At first the uterine veins, on each side, lies in the medial part of the base of the broad ligament, above the lateral fornix of the vagina and the ureter; then they pass backwards, accompanying the corresponding artery, in a fold of peritoneum which lies between the back of the broad ligament and the recto-uterine fold; finally they ascend in the floor of the ovarian fossa, and terminate in the corresponding hypogastric vein.

Vaginal Plexuses and Vaginal Veins.—The **vaginal plexuses** lie at the sides of the vagina. They receive tributaries from the walls of the vagina, and communicate with the uterine plexuses above, and with the veins of the bulb below; anteriorly, with the vesical plexus; and posteriorly with the veins which issue from the middle and lower parts of the hæmorrhoidal plexus. A single **vaginal vein** issues from the upper part of the vaginal plexus on each side; it accompanies the corresponding artery, and terminates in the hypogastric vein.

Superior Vesical Plexus.—The superior vesical plexus of veins lies on the outer surface of the muscular coat of the bladder, at the fundus and the sides. It receives tributaries from the mucous and muscular walls, and its efferent vessels terminate in the prostatico-vesical plexus in the male, and in the inferior vesical plexus in the female.

Prostatico-vesical Plexus.—This plexus is distributed around the prostate and the neck of the bladder, and is enclosed between the proper fibrous capsule of the prostate and its sheath of recto-vesical fascia. Anteriorly it is continuous with the pudendal plexus which receives the dorsal vein of the penis; postero-superiorly it communicates with the superior vesical plexus, and receives tributaries from the seminal vesicles and deferent ducts. One or more efferent vessels pass from it on each side and open into the corresponding hypogastric vein.

The **inferior vesical plexus** of the female, which represents the prostatico-vesical plexus of the male, surrounds the upper part of the urethra and the neck of the bladder. It is continuous with the pudendal plexus which receives the dorsal vein of the clitoris, and its efferent vessels terminate in the hypogastric vein.

Dorsal Veins of the Penis.—There are two dorsal veins of the penis—the superficial and the deep.

The **superficial dorsal vein** receives tributaries from the prepuce, and runs backwards, immediately beneath the skin, to the symphysis, where it divides into two branches which terminate in the superficial external pudendal veins.

The **deep dorsal vein** lies on the dorsum of the penis, deep to the deep fascia. It commences in the sulcus behind the glans, by the union of numerous tributaries from the glans and the anterior parts of the corpora cavernosa penis; and it runs backwards in the mid-dorsal line, in the sulcus between the corpora cavernosa penis from which it receives many additional tributaries. At the root of the penis the vein passes between the two layers of the suspensory ligament, and then between the arcuate ligament and the deep transverse ligament of the perineum, where it lies above the membranous part of the urethra. It terminates by dividing into two branches which join the pudendal plexus.

The **dorsal vein of the clitoris** in the female has a similar course to that of the deep dorsal vein of the penis in the male. It terminates in the pudendal plexus.

THE VEINS OF THE INFERIOR EXTREMITY.

The veins of the inferior extremity, like those of the superior extremity, are arranged in two groups, the **superficial** and the **deep**; and in the lower as in the upper limb the deep veins are associated with the arteries as venæ comites, whilst the trunks of the superficial veins, which lie, at first, in the subcutaneous tissues, ultimately terminate in the deep veins. There is, therefore, a general similarity in the arrangement of the veins of the upper and the lower limbs, but there are differences in the details of the arrangement which are of some importance. Thus, in the superior extremity, there are two deep veins with each artery from the fingers to the root of the limb, where a single trunk, the axillary vein, is formed; but in the inferior extremity each main artery has two venæ comites only as far as the middle of the limb, where a single trunk is frequently formed. That vessel, the **popliteal vein**, is the commencement of the main venous stem of the lower extremity; it is continued proximally, through the thigh, as the **femoral vein**, and along the upper margin of the pelvis minor as the **external iliac vein**, which terminates by uniting with the hypogastric vein to form the common iliac vein.

Further, the superficial veins of the upper limb are more numerous than those of the lower limb, for in the arm there are two main superficial veins, and in the thigh only one.

In the upper limb the blood which passes through the superficial veins is poured into the efferent trunk vein at the root of the limb—that is, into the axillary vein; but in the lower limb the blood from the superficies of the lateral parts of the leg and foot passes into the commencement of the main efferent vein, the popliteal vein, at the middle of the limb—that is, in the region of the knee, whilst the blood from the superficial parts of the medial aspect of the lower limb is poured into the femoral vein near the root of the limb in the upper part of the femoral trigone.

In addition to the above-mentioned differences in the general arrangement of the veins of the superior and the inferior extremities, it must be noted also that in the superior extremity all the blood of the limb, both that from the shoulder-girdle region as well as that from the free portion of the limb, is returned to the main efferent venous trunk; but in the inferior extremity the greater part of the blood from the region of the pelvic girdle, and a considerable portion from that of the thigh, is returned by the gluteal, obturator, and pudendal veins to the hypogastric vein, which is not the main efferent vein of the inferior extremity.

Abnormalities.—The **great saphenous vein** is not subject to much variation, but the **small saphenous vein** may terminate by joining the great saphenous, or, after piercing the deep fascia in the distal part of the thigh, it may ascend and join the inferior gluteal vein or one of the tributaries of the profunda vein.

THE DEEP VEINS OF THE INFERIOR EXTREMITY.

All the arteries of the lower limb, except the popliteal and femoral trunks, are accompanied by two *venæ comites.* They usually lie one on each side of the artery; they are connected with one another by transverse channels which pass across the line of the artery, and they are provided with numerous valves.

The **popliteal vein** (Figs. 751, 755, 756) is formed, at the distal border of the popliteus muscle, by the union of the venæ comites of the anterior and posterior tibial arteries. At its commencement it lies to the medial side of and somewhat superficial to the popliteal artery, and to the lateral side of the tibial nerve. As it runs through the popliteal fossa it inclines towards the lateral side of the artery, and in the middle of the space it is directly posterior to the artery, separating the artery from the tibial nerve, which is still more posterior, whilst at the proximal end of the space it is to the lateral side of the artery, and still between it and the tibial nerve. It then passes through the adductor magnus muscle and becomes the femoral vein.

The popliteal vein, which is provided with two or three bicuspid valves, is closely bound to the artery by a dense fascial sheath. Not uncommonly there are one or more additional satellite veins which anastomose with the popliteal vein, and in those cases the artery is more or less completely surrounded by venous trunks.

Tributaries.—In addition to the venæ comites of the anterior and posterior tibial arteries, it receives tributaries which correspond with the branches of the popliteal artery, and it also receives one of the superficial veins of the leg, viz., the small saphenous vein.

The **femoral vein** is the direct continuation of the popliteal vein. It commences at the junction of the middle and distal thirds of the thigh, at the opening in the adductor magnus muscle. It then ascends, through the adductor canal (Hunter), and through the femoral trigone, and terminates, a little to the medial side of the middle of the inguinal ligament (Poupart), by becoming the external iliac vein.

In the adductor canal it lies at first postero-lateral to the femoral artery, and anterior to the adductors magnus and longus which separate it from the profunda vessels. In the distal part of the femoral trigone it is postero-medial to the artery, and immediately anterior to the profunda vein which separates it from the profunda artery, but in the proximal part of the femoral trigone it is directly on the medial side of the femoral artery. About 37 mm. (one and a half inches) below the inguinal ligament it enters the middle compartment of the femoral sheath, through which it ascends to its termination, lying between the compartment for the femoral artery on the lateral side and the femoral canal on the medial side.

It usually contains two bicuspid valves—one near its termination and the other just proximal to the entrance of its profunda tributary.

Tributaries.—It receives tributaries which correspond with the branches of the femoral artery and the larger of the two superficial veins of the lower extremity, viz., the great saphenous vein, which enters the femoral vein where that vessel lies in the middle compartment of the femoral sheath, and, not uncommonly, it is joined by the medial and lateral circumflex veins.

The **external iliac vein** (Figs. 752, 753, and 769) is the upward continuation of the femoral vein. It commences, on the medial side of the termination of the external iliac artery, immediately posterior to the inguinal ligament, and ascends, along the aperture of the pelvis minor, to a point opposite the sacro-iliac joint, and at the level of the lumbo-sacral articulation, where it ends, immediately behind the hypogastric artery, by joining the hypogastric vein to form the common iliac vein. It lies, at first, on the medial side of the external iliac artery, but on a somewhat posterior plane, and then directly posterior to the artery, whilst just before its termination it crosses the lateral side of the hypogastric artery, and separates that vessel from the medial border of the psoas major muscle. In its whole course the vein lies anterior to the obturator nerve. It is usually provided with one bicuspid valve; sometimes there are two, but both are usually incompetent. Its tributaries correspond to the branches of the external iliac artery; that is, the deep circumflex iliac and inferior epigastric veins open into it, close to its commencement, whilst, in addition, it frequently receives the pubic vein.

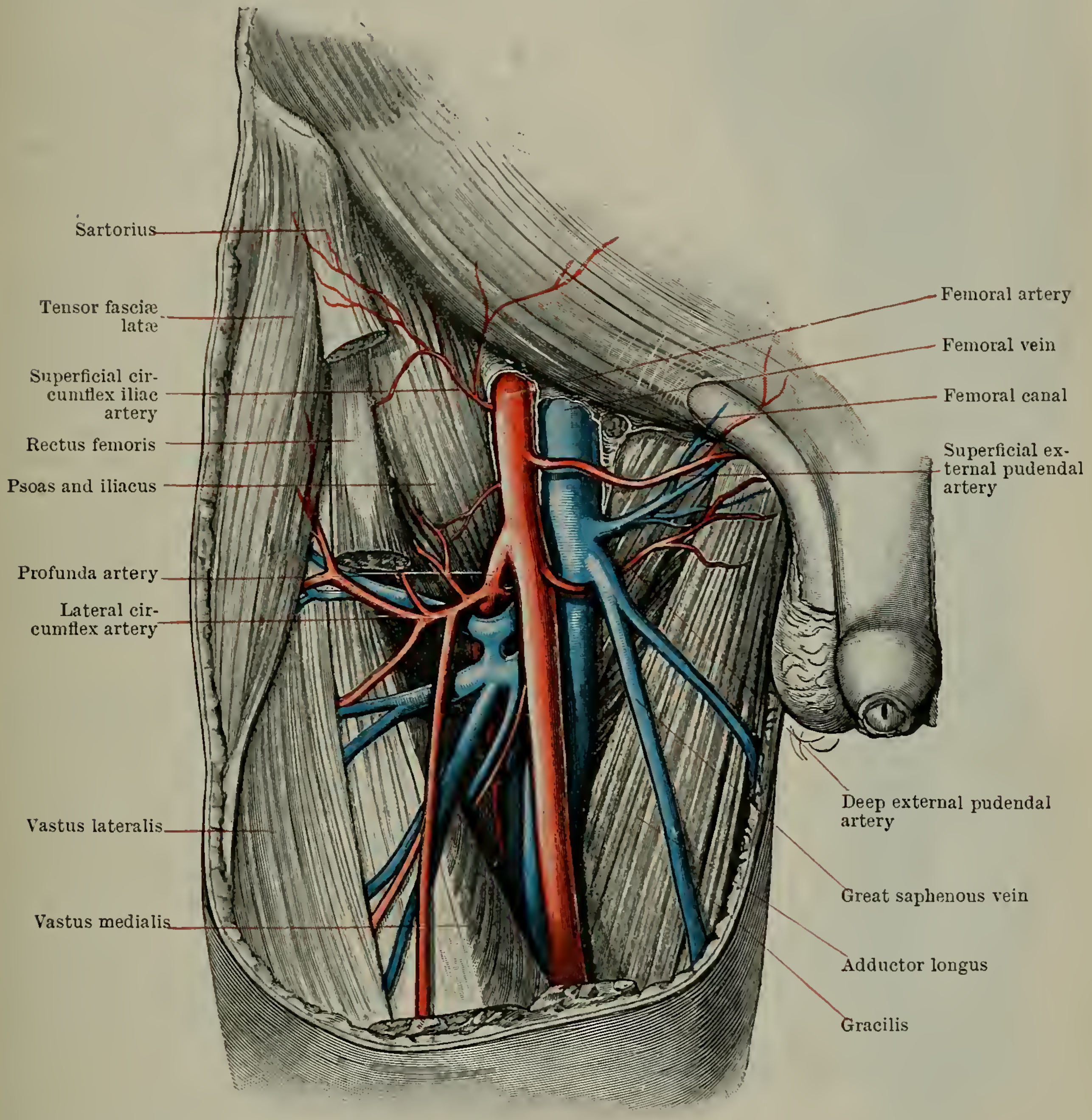

Fig. 770.—The Femoral Vessels in the Femoral Trigone.

The **pubic vein** forms a communication between the obturator vein and the external iliac vein. It varies in size, and may form the main termination of the obturator vein, from which it arises. Commencing in the obturator canal, it ascends, along the pubic branch of the inferior epigastric artery, to reach the external iliac vein.

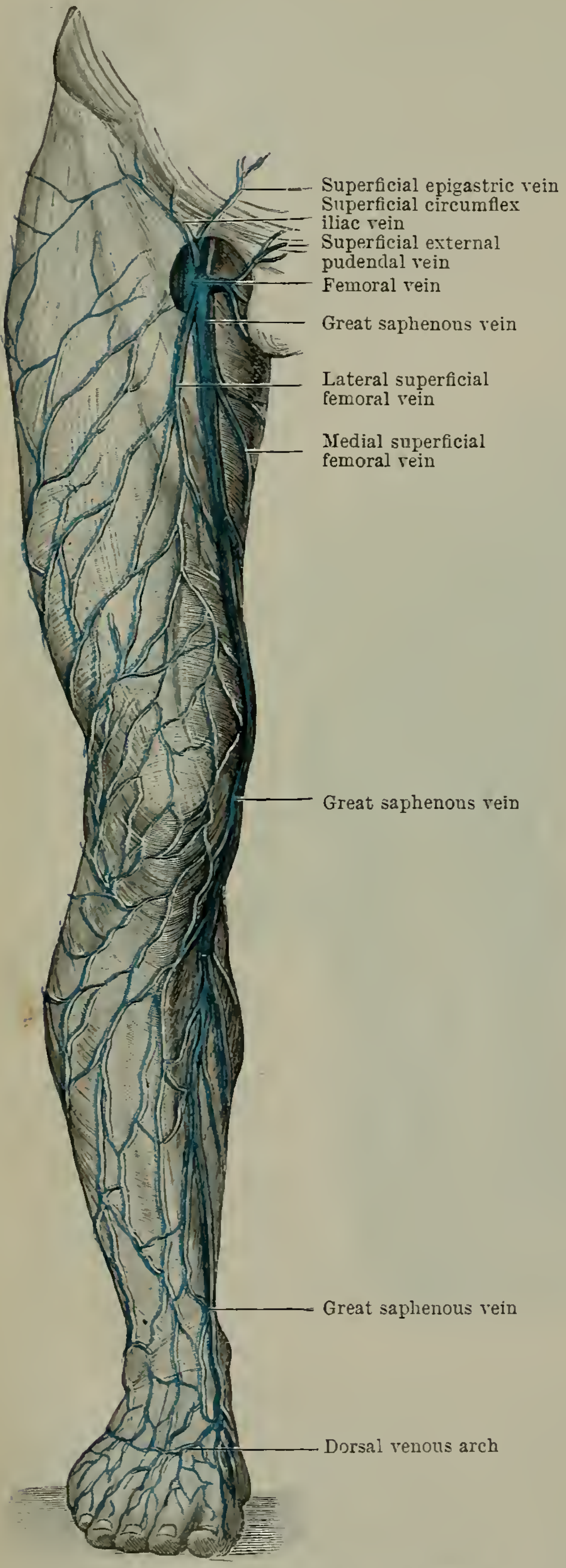
Superficial epigastric vein
Superficial circumflex iliac vein
Superficial external pudendal vein
Femoral vein
Great saphenous vein
Lateral superficial femoral vein
Medial superficial femoral vein
Great saphenous vein
Great saphenous vein
Dorsal venous arch

Fig. 771.—The Great Saphenous Vein and its Tributaries.

The Superficial Veins of the Inferior Extremity.

The superficial veins of the lower limb terminate in two trunks, one of which, the **small saphenous vein**, passes from the foot to the popliteal space; whilst the other, the **great saphenous vein,** extends from the foot to the groin.

The superficial veins of the sole of the foot form a fine plexus, immediately under cover of the skin, from which anterior, medial, and lateral efferents pass. The anterior efferents terminate in a transverse arch which lies in the furrow at the roots of the toes, and the medial and lateral efferents pass round the sides of the foot to the great or small saphenous veins. The transverse arch receives also small plantar digital veins from the toes, and it communicates by **intercapitular veins** with the veins on the dorsum of the foot.

The superficial veins on the dorsal aspect of each toe unite to form two **dorsal special digital veins**, which run along the borders of the dorsal surface. The special dorsal digital veins of the adjacent borders of the interdigital clefts unite, at the apices of the clefts, to form four dorsal metatarsal veins which terminate in the dorsal venous arch. The dorsal digital vein from the medial side of the great toe ends in the great, and that from the lateral side of the little toe in the small saphenous vein.

The **dorsal venous arch** lies in the subcutaneous tissue, between the skin and the dorsal digital branches of the superficial peroneal nerve, opposite the anterior parts of the bodies of the metatarsal bones. It ends, medially, by uniting with the medial dorsal digital vein of the great toe to form the great saphenous vein, and laterally by joining the lateral dorsal digital vein of the little toe to form the small saphenous vein. The dorsal venous arch receives the dorsal metatarsal veins; interdigital efferents from the plantar transverse arch; and numerous tributaries from the dorsum of the foot, which anastomose freely together forming a wide-meshed dorsal venous plexus, open into it posteriorly.

The great saphenous vein is formed by the union of the medial extremity of the dorsal venous arch with the medial dorsal digital vein of the great toe. It passes anterior to the medial malleolus, crosses the medial surface of the distal third of the body of the tibia, and ascends, immediately posterior to the medial margin of the tibia, to the knee, where it lies just posterior to the medial condyle of the femur; continuing proximally, with an inclination forwards and laterally, it gains the proximal part of the femoral trigone, where it perforates the fascia cribrosa and the femoral sheath to reach its termination in the femoral vein. In the foot and leg it is accompanied by the saphenous nerve, and for a short distance distal to the knee by the superficial or saphenous branch of the arteria genu suprema. In the thigh, branches of the medial cutaneous nerve (O.T. internal) lie in close relation with it. It contains from eight to twenty bicuspid valves.

Tributaries.—It communicates freely, through the deep fascia, with the deep intermuscular veins. In the foot, it receives tributaries from the medial part of the sole and from the dorsal venous plexus. In the leg it is joined by tributaries from the dorsum of the foot, the medial and posterior parts of the heel, the front of the leg and the back of the calf, and it anastomoses freely with the small saphenous vein. In the thigh it receives numerous tributaries, and amongst them are two **superficial femoral veins.** Of these, the *lateral* ascends from the lateral side of the knee and terminates in the great saphenous vein at the distal part of the femoral trigone; the other, the *medial*, ascends from the posterior aspect of the thigh, along its medial side, and terminates in the great saphenous vein near the fossa ovalis. In many cases the medial superficial femoral vein communicates distally with the small saphenous vein, and when that condition exists the medial superficial femoral vein is called the *accessory saphenous vein.* The last tributaries to enter the great saphenous vein are the **superficial circumflex iliac, superficial epigastric,** and **superficial external pudendal veins.** They accompany the corresponding arteries, and terminate in the great saphenous vein immediately before it perforates the fascia cribrosa.

The superficial circumflex iliac vein receives blood from the lower and lateral part of the abdominal wall and the proximal and lateral parts of the thigh. The superficial epigastric vein drains the lower and medial part of the abdominal wall, and the superficial external pudendal vein receives blood from the dorsum of the penis and the scrotum in the male, and from the labium majus in the female.

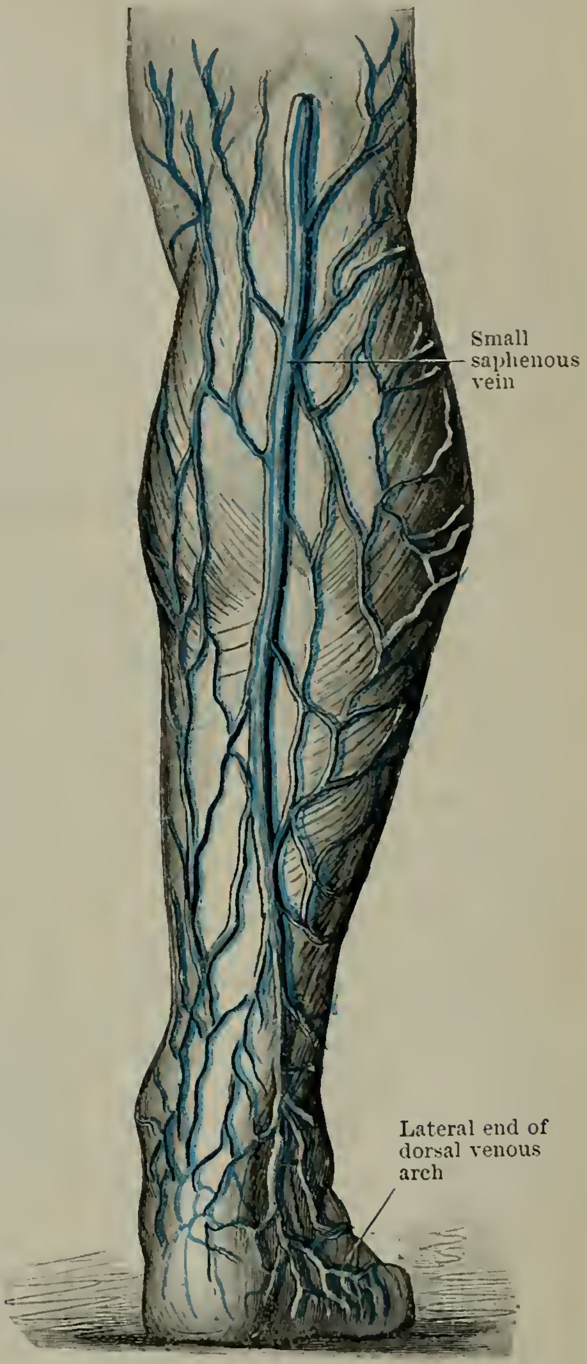

FIG. 772.—THE SMALL SAPHENOUS VEIN AND ITS TRIBUTARIES.

The small saphenous vein is formed by the union of the lateral extremity of the dorsal venous arch with the lateral dorsal digital vein of the little toe. At first it passes posteriorly, along the lateral side of the foot and distal to the lateral malleolus, lying on the peroneal retinacula (O.T. ext. ann. lig.), in company with the nervus suralis; then it passes posterior to the lateral malleolus, and along the lateral border of the tendo calcaneus, still in company with the nervus suralis, to the middle of the calf, proximal to which it is continued in the superficial fascia, accompanied by the superficial sural artery, to the distal part of the popliteal fossa, where it pierces the deep fascia, and terminates in the popliteal vein. It communicates, round the medial side of the leg, with the great saphenous vein, and through the deep fascia with the deep veins, and it contains from six to twelve bicuspid valves.

Tributaries.—It receives tributaries from the lateral side of the foot, the lateral side and back of the heel, the back of the leg, and, occasionally, a descending tributary from the back of the thigh. Just before it pierces the popliteal fascia it frequently gives off a small branch which ascends round the medial side of the thigh and unites with the medial superficial femoral vein to form the accessory saphenous vein. In that way a communication is established between the great and small saphenous veins, which may become enlarged, and constitute the main continuation of the small saphenous vein.

Abnormalities.—The **venæ comites** are generally described as terminating in the lower extremity, at the distal part of the popliteal fossa, but they may ascend as far as the femoral trigone; as a matter of fact, one or more small additional veins usually accompany the popliteal and femoral arteries, although as a rule there is only one large popliteal and one large femoral vein.

In a few cases the popliteal vein does not pierce the distal part of the adductor magnus, but ascends behind that muscle and becomes continuous with the profunda vein, the femoral artery being unaccompanied by any large vein during its passage through the adductor canal.

THE PORTAL SYSTEM.

The veins which form the **portal system** are the portal, the superior and inferior mesenteric and the splenic veins and their tributaries. They convey blood to the liver—(1) from almost the whole of the abdominal and pelvic parts of the alimentary canal, (2) from the pancreas, and (3) from the spleen. The tributaries of origin correspond closely with the terminal branches of the splenic, and the superior and inferior mesenteric arteries, after which they are named and which they accompany for a considerable distance. The larger or terminal veins, however, leave their associated arteries; the **inferior mesenteric vein** joins the **splenic vein**, and the latter unites with the **superior mesenteric vein** to form the **portal vein**, which passes to the liver. All the larger vessels of this system are devoid of valves, but valves are present in the tributaries.

Vena Portæ.—The **portal vein** is a wide venous channel, about 75 mm. (three inches) long, which conveys blood from the stomach, from the whole of the intestine, except the terminal portion of the rectum, and from the spleen and pancreas to the liver. Unlike other veins, it ends like an artery, by breaking up into branches which ultimately terminate in capillaries in the substance of the liver; from the capillaries, which also receive the blood conveyed to the liver by the hepatic artery, the hepatic veins arise; and, as the hepatic veins open into the inferior vena cava, the portal blood ultimately reaches the general systemic circulation.

The portal vein commences by the union of the superior mesenteric and the splenic veins, posterior and to the left of the neck of the pancreas, and either anterior to the left border of the inferior vena cava, at the level of the body of the second lumbar vertebra, or in front of the upturned extremity of the processus uncinatus of the head of the pancreas. It ascends, anterior to the inferior vena cava and posterior to the neck of the pancreas and the first part of the duodenum, to the lower border of the epiploic foramen (Winslow), where it passes forwards, in the right gastro-pancreatic fold of peritoneum, and enters the lower border of the gastro-hepatic ligament. Continuing its upward course, it lies posterior to the bile-duct and hepatic artery, and anterior to the epiploic foramen (Winslow); it ultimately reaches the right end of the porta hepatis, where it ends by dividing into a short and wide right and a longer and narrower left branch. Just before its termination it enlarges, forming the *sinus of the portal vein*.

The **right branch** generally receives the **cystic vein** and then enters the right lobe of the liver, in which it breaks up into numerous branches which terminate in the portal capillaries around the periphery and in the substance of the liver lobules.

The **left branch** runs from right to left, along the porta hepatis, giving off branches to the caudate and quadrate lobes; it crosses the umbilical fossa, and ends in the same manner as the right branch, but in the substance of the left lobe of the liver.

As it crosses the umbilical fossa, the left branch of the portal vein is joined, anteriorly, by the **round ligament** of the liver and some small veins, and, posteriorly, by the **ligamentum venosum**. The round ligament is a fibrous cord which passes from the umbilicus to the left branch of the portal vein. It represents the remains of the left umbilical vein of the fœtus. The small veins which accompany it connect the left branch of the portal vein with the superficial veins round the umbilicus. The ligament venosum connects the left branch of the portal vein with the upper part of the inferior vena cava. It is the remains of a fœtal blood-vessel, the **ductus venosus**, through which blood, carried from the placenta by the left umbilical vein, passed to the inferior vena cava without going through the liver.

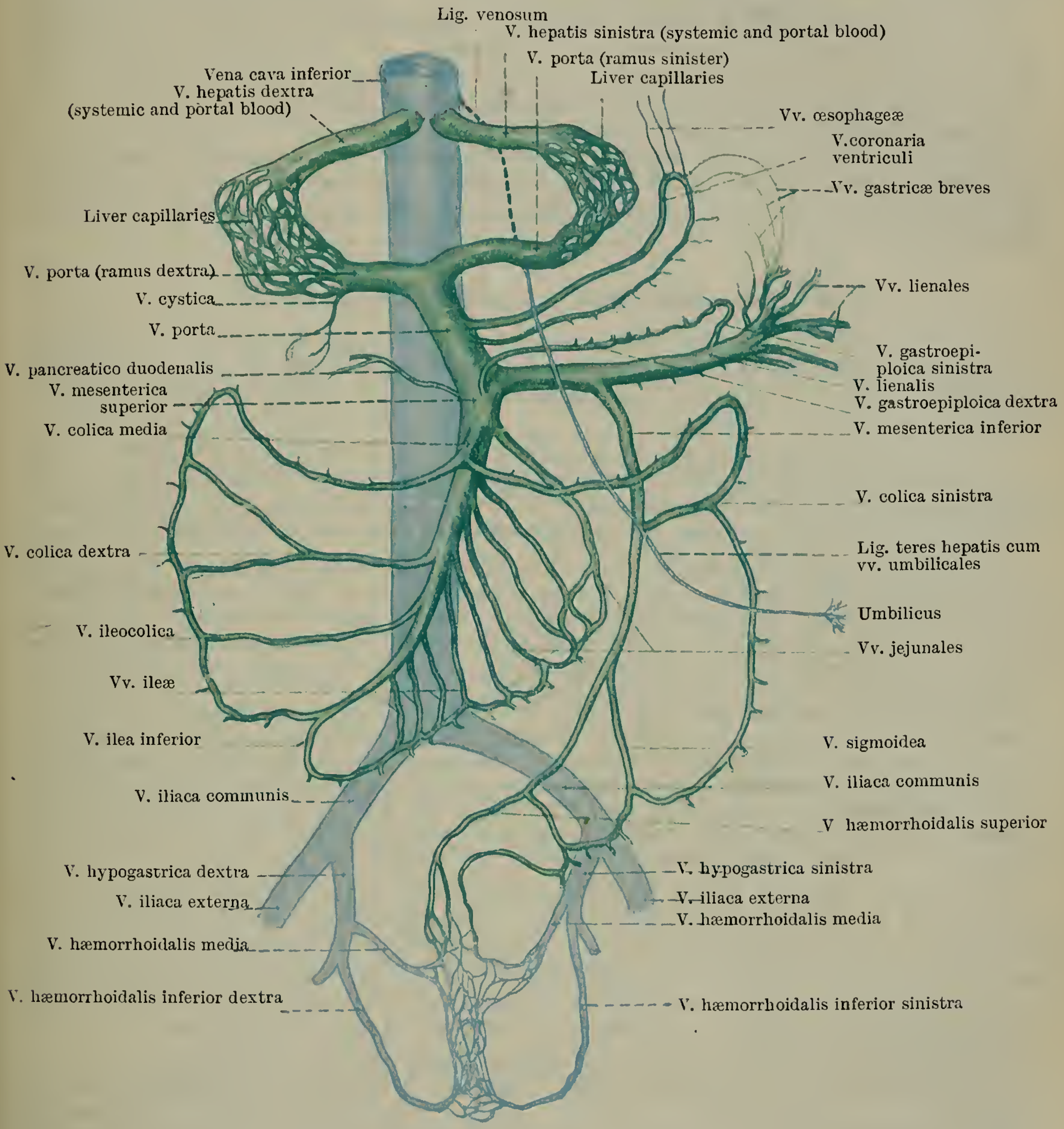

FIG. 773.—SCHEMA OF THE PORTAL SYSTEM OF VEINS AND ITS CONNEXIONS WITH THE SYSTEMIC SYSTEM.—It must be remembered that systemic blood carried by the hepatic artery also enters the liver capillaries, therefore the hepatic veins contain both portal and systemic blood.

The portal vein is accompanied by numerous lymph vessels, and it is surrounded, in the lesser omentum, by filaments of the hepatic plexus of nerves.

Tributaries.—Soon after its formation the portal vein receives the coronary and right gastric veins, and the cystic vein opens into its right branch.

Vena Coronaria Ventriculi.—The **coronary vein** commences in the lesser omentum by the union of tributaries from both surfaces of the stomach. It runs to the left between the layers of the lesser omentum, and along the lesser curvature of the stomach, with the left gastric artery, to the œsophagus, where it receives œsophageal tributaries. It then turns posteriorly, in the left gastro-pancreatic fold, and reaches the posterior wall of the abdomen, where it again changes its direction to run from left to right, behind the omental bursa, to the right gastro-pancreatic fold, at the root of which it opens into the portal vein.

The **right gastric vein** is a small vessel which is formed by the union of tributaries from the upper parts of both surfaces of the stomach. It runs from left to right along the right portion of the lesser curvature, between the layers of the lesser omentum, and terminates in the portal vein, after that vessel has entered the lesser omentum.

Vena Cystica.—The **cystic vein** is formed by the union of tributaries which accompany the branches of the cystic artery on the anterior and posterior surfaces of the gall-bladder; it ascends along the cystic duct and, as a rule, terminates in the right branch of the portal vein. Some small veins pass directly from the gall-bladder into the substance of the liver.

THE MESENTERIC AND SPLENIC VEINS.

The **superior mesenteric vein** commences in the right iliac fossa, in connexion with the lower part of the ileum. It ascends, along the right side of the superior mesenteric artery, in the root of the mesentery, forming a curve with the convexity to the left.

As it ascends it passes anterior to the right ureter, the lower part of the inferior vena cava, the third part of the duodenum, and the uncinate process of the head of the pancreas; and, after passing behind the root of the transverse mesocolon, it terminates, behind the neck of the pancreas, by uniting with the splenic vein to form the portal vein.

Its **tributaries** correspond with the branches of the superior mesenteric artery. It is formed by the union of the ileo-cæcal and appendicular veins. Anteriorly and towards the left side it receives intestinal tributaries (**venæ intestinales**) from between the layers of the mesentery; the right colic and ileo-colic veins enter its right side; the middle colic vein joins it anterior to the lower border of the head of the pancreas, and close to its termination it receives the right gastro-epiploic and the pancreatico-duodenal veins.

The **right gastro-epiploic vein** runs from left to right along the lower border of the stomach, between the two anterior layers of the greater omentum. It receives tributaries from both surfaces of the stomach, and near the pylorus turns posteriorly, in the right gastro-pancreatic fold of peritoneum, passes in front of the neck of the pancreas, and ends in the superior mesenteric vein.

The **pancreatico-duodenal** vein receives tributaries from the head of the pancreas and the adjacent parts of the duodenum; it ascends along the superior pancreatico-duodenal artery, and terminates in the upper part of the superior mesenteric vein or in the portal vein.

The **splenic vein** is formed by the union of five or six tributaries which issue from the hilum on the gastric surface of the spleen. It passes posteriorly and medially, in the lieno-renal ligament, to the kidney, then, turning to the right, it runs behind the upper border of the pancreas and below the splenic artery; it crosses the front of the abdominal aorta, immediately below the origin of the cœliac artery, and terminates, behind the neck of the pancreas, by joining the superior mesenteric vein to form the portal vein.

Tributaries.—It receives the vasa brevia or short gastric veins, the left gastro-epiploic vein, the pancreatic veins, and the inferior mesenteric vein. Occasionally the coronary vein terminates in it.

The **short gastric veins** are a series of small venous channels which gather blood from the region of the left portion of the greater curvature of the stomach; they pass backwards towards the spleen, in the gastro-splenic ligament, and terminate either in the trunk of the splenic vein or in one of its main tributaries.

The **left gastro-epiploic vein** runs from right to left along the lower border of the stomach between the layers of the greater omentum. At the left extremity of the lower part of the greater curvature of the stomach it enters the gastro-splenic ligament, through which it passes towards the hilum of the spleen, and it terminates in the commencement of the splenic vein. It receives tributaries from both surfaces of the stomach.

The **pancreatic veins** issue from the substance of the pancreas, and terminate directly in the splenic vein.

The **inferior mesenteric vein** commences, as the **superior hæmorrhoidal vein**, in the venous plexus which lies between the muscular and mucous coats of the rectum. The **superior hæmorrhoidal vein** drains the greater part of the blood from the hæmorrhoidal plexus, through which it communicates with the middle and inferior hæmorrhoidal veins. It ascends, in company with the superior hæmorrhoidal artery and between the layers of the pelvic mesocolon, to the aperture of the pelvis minor, where it passes in front of the left common iliac artery and becomes the inferior mesenteric vein.

The inferior mesenteric vein runs upwards, on the left of the aorta, behind the peritoneum and in front of the left psoas major muscle and the left internal spermatic artery. Near its termination it crosses in front of the left renal vein, and, passing behind the body of the pancreas, ends in the splenic vein. Occasionally it terminates in the angle of union of the superior mesenteric and splenic veins.

Tributaries.—In addition to the superior hæmorrhoidal vein, of which it is the direct continuation, the inferior mesenteric vein receives **sigmoid tributaries** from the iliac and pelvic colon, and the **left colic vein** from the descending colon and left colic flexure.

THE LYMPH VASCULAR SYSTEM.

The vessels of the lymph vascular system, **vasa lymphatica**, contain a colourless fluid, rich in white corpuscles, which is called **lymph**.

In many respects the lymph vessels resemble blood-vessels, especially veins, and, like the veins, many of the lymph vessels, but not all, contain numerous valves, which control the direction of the circulation. Unlike the veins, however, the lymph vessels communicate directly or indirectly with the great serous cavities of the body; and also unlike the veins, the continuity of the lymph vessels is interrupted by interposed nodular aggregations of lymphoid tissue which are known as **lymph glands**.

The corpusculated fluid called lymph, which fills the interiors of the lymph vessels, is partly collected from the serous cavities, and, in part, it passes into the lymph vessels from the surrounding tissues. It is carried by the lymph vessels to the veins; for the smaller lymph vessels gradually unite together to form larger and larger channels until, ultimately, all the lymph passes into two main trunks—the **thoracic duct**, which terminates in the commencement of the left innominate vein, and the **right lymph duct**, which ends in the beginning of the right innominate vein.

Obviously, therefore, all the lymph vessels are afferent inasmuch as they carry the lymph towards the great central vessels, but it is customary to speak of some of the lymph vessels as **vasa afferentia** and others as **vasa efferentia**, the former being vessels which carry lymph to lymph glands, and the latter, those which convey the lymph from more peripheral towards more central glands.

The lymph vessels merely collect and convey lymph; the lymph glands probably serve in part as filters and in part as the sources of origin of some of the lymph corpuscles, which are called **lymphocytes** and which become white blood corpuscles when they enter the blood stream.

In its course from the tissues to the blood-vessels the greater part, if not the whole, of the lymph passes through one and generally through more than one lymph gland.

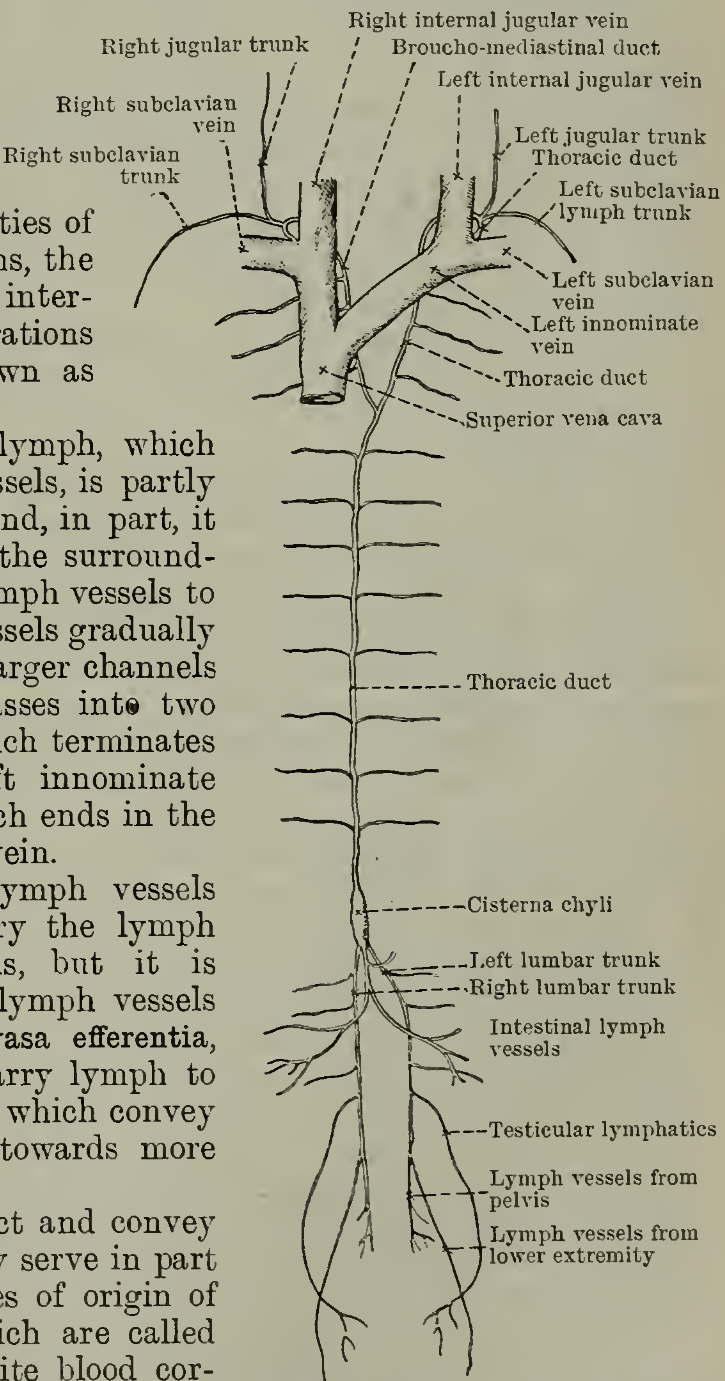

Fig. 774.—Diagram of Main Lymph Vessels.

All parts of the body which possess blood-vessels, except the central nervous system, the eye and the internal ear, are plentifully provided with lymph vessels, which are divided, according to their positions, into superficial and deep vessels.

The *superficial lymph vessels* lie in the skin and subcutaneous tissues; they frequently accompany the superficial veins and, in the limbs, they join the deep vessels in definitely localised situations.

The *deep lymph vessels* drain the lymph from all parts of the body which lie internal to the deep fascia; they tend to accompany the blood-vessels of the various parts and organs.

The lymph glands also are divided into superficial and deep groups. The former lie in the superficial fascia and are comparatively few in number. They are associated more particularly with the superficial lymph vessels of the limbs. The deep lymph glands of the limbs are also comparatively few in number, but those of the head, neck, and trunk are very numerous.

Vasa Lymphatica.—The smaller lymphatics are channels of various shapes but of greater calibre than the blood capillaries. They anastomose freely together, forming lymphatic plexuses.

Their walls are formed by a single layer of endothelial cells of irregular shape and sinuous outline, which are in close contact, externally, with the tissue elements amidst which they lie. In some cases lymph vessels, or plexuses of lymph vessels, surround the blood-vessels forming *perivascular lymph channels.* It has been generally believed that such perivascular channels are numerous in the central nervous system, but the researches of Bruce tend to show that, whilst the lymphocytes travel along the walls of the blood-vessels of the central nervous system, they pass along cleft-like spaces in the adventitial sheaths, and not in distinct perivascular channels.

As the lymph vessels attain a larger size their walls are strengthened by the deposition of a layer of elastic fibres on the outer surface of the endothelial coat. The fibres run longitudinally, and in some cases fuse together to form a fenestrated elastic membrane.

The walls of all the largest lymph vessels, like those of the blood-vessels, are formed by three tunics, external, middle, and internal. The **tunica intima** consists of a layer of endothelium covered externally by elastic fibres or fenestrated elastic membrane. The **tunica media** is formed of transverse and oblique unstriped muscle fibres, intermingled with elastic fibres. The **tunica externa** consists of longitudinal connective tissue elements, with which are intermingled oblique and longitudinal unstriped muscle fibres; the latter feature being peculiarly characteristic, for it is not met with in the blood vascular system, except in the walls of the large veins.

Bicuspid valves, formed by semilunar folds of the tunica intima are extremely numerous in the lymph vascular system. They are either absent or they are few and incompletely developed in the small vessels and the lymph plexuses, but they are very prevalent in the larger vessels; consequently when the latter are injected they assume a modulated outline. Valves are present also at the entrances of the great lymph channels into the venous system.

Lymphoglandulæ.—Lymph glands are globular, ovoid, flattened, or irregular bodies, and each gland presents a localised depressed area which is known as the *hilum.* The lymph glands vary considerably in size, some being no larger than a pin's-head, whilst others are as large as a bean. In colour they are usually grayish pink, but the tint varies with the position, vascularity, and state of activity of the gland. The lymph glands of the lung are generally blackened by the deposition of carbonaceous material in their substance, and those of the liver and spleen frequently have a brownish hue. The lymph glands of the mesentery are creamy or white whilst the chyle is rapidly passing through them, but when the absorption of food-material from the intestine ceases they become a rosy pink.

The lymph glands are embedded in the connective tissues, some lying superficially in the subcutaneous tissues, but the majority more deeply and usually at the sides of the great blood-vessels. As a rule, they are arranged in groups of from two to fifteen, but a few of those which lie in the subcutaneous tissues are solitary.

They form centres to which afferent lymphatic vessels converge, and from which efferent vessels pass onwards to other glands or to the larger lymph channels.

The student should, therefore, acquaint himself with the various groups of glands, with their afferents and efferents, and with the exact position and relations of the large lymphatic trunks; he will then be in a position to understand the course which minute organisms or particles, which have gained access to the lymph spaces, may take as they are carried in the lymph stream; and he will realise that such structures may either be entangled in the glands through which the lymph passes, or, having escaped all obstructions, that they will finally enter the veins at the root of the neck. At the same time, if he bears in mind the existence of the numerous anastomoses between the lymph vessels, he will have no difficulty in appreciating that variations from any regular course may not infrequently occur, and his clinical experience at a later period will show that such variations are by no means uncommon.

Structure of Lymph Glands.—Lymph glands consist of (1) a skeleton or framework, (2) lymph sinuses, and (3) lymph follicles and cords; and each gland is separable into cortex and medulla. The cortex lies immediately internal to the capsule, except at the hilum, where it is absent. The medulla forms the internal part of the gland, and reaches the surface at the hilum.

(1) The **skeleton** or framework consists of a **capsule** and of primary, secondary, and tertiary **trabeculæ.**

The *capsule* is formed of white fibrous tissue, interspersed with elastic fibres, and in some cases with unstriped muscular fibres.

The *primary trabeculæ* spring from the deep surface of the capsule and radiate through the cortex into the medulla. In the cortex they are flattened lamellæ, but as they reach the medulla they break up into flattened, rounded, and angular bands which unite freely together; their structure is the same as that of the capsule, and from their surfaces the secondary trabeculæ are given off. The *secondary trabeculæ* spring from the surfaces of the primary trabeculæ, cross the lymph sinuses and enter the follicles of the cortex and the cords of the medulla, where they terminate by dividing into tertiary trabeculæ. As they cross the lymph sinuses they unite together freely, forming a fine mesh-work through which the lymph passes in its course from the afferent to the efferent vessels. The secondary trabeculæ consist of fine strands of fibrous tissue devoid of nuclei. The *tertiary trabeculæ* are finer and more delicate than the secondary trabeculæ, from the terminations of which they spring, but they have a similar structure. They unite together, forming a fine network in the lymph cords and follicles, and the spaces of the network are filled with lymph corpuscles. The surfaces of the trabeculæ which bound the lymph sinuses are covered with flat cells which according to some observers are endothelial plates, similar to those which line all tubes of the vascular system, but it is also asserted that the flat cells are continuous with the fibrils of the reticulum and are, therefore, merely flattened connective tissue cells.

(2) The **lymph sinuses** lie internal to the capsule and around the primary trabeculæ which form their boundaries on one side, whilst on the other they are limited by the lymph cords and follicles. They are traversed by the secondary trabeculæ, and their channels are thus converted into a kind of sponge-work through which the lymph stream flows. In the cortical parts of the glands they form more or less cylindrical channels, but in the medulla they become moniliform. Afferent vessels enter the sinuses of the cortex, and the efferent vessels emerge from the medulla at the hilum.

The **lymph follicles** lie in the cortical portions of the lymph glands, where they form the inner boundaries of the lymph sinuses. They consist of dense masses of lymphoid cells, embedded in a stroma formed by the tertiary trabeculæ, and they are continuous internally with the lymph cords of the medullary substance.

The **lymph cords** are continuous with the lymph follicles, and have the same structure, but they lie in the medullary portions of the glands; they are cord-like and not nodular in shape, and they form the peripheral boundaries of the lymph sinuses of the medulla.

The Blood-Vessels of the Lymph Glands.—Blood-vessels are distributed to the capsule and through the capsule to the primary trabeculæ of the glands; but the main blood-vessels to each gland enter the hilum and ramify in the lymph cords and follicles, amidst the tertiary trabeculæ which are connected with the walls of the vessels.

Hæmal Lymph Glands.—In various parts of the body, but more particularly in the retro-peritoneal region, and especially along the line of the abdominal aorta, a number of bodies may be found which have all the ordinary structural characters of lymph glands, but they differ from lymph glands inasmuch as some of their sinuses contain blood. These structures are called hæmal lymph glands. The sinuses of the hæmal lymph glands which contain lymph are in continuity with lymphatics, whilst the blood-filled sinuses open into blood-vessels. It is stated that communications exist between the blood and the lymph containing sinuses of the hæmal lymph glands, but the evidence on this point is not quite satisfactory.

Hæmal Glands.—The term "hæmal gland" is applied to nodules possessing the structure of ordinary lymph glands, but which contain only blood in their sinuses;

they probably belong, however, as their development shows, to the lymph vascular and not to the blood vascular system.

THE TERMINAL LYMPH VESSELS.

The terminal lymph vessels are the **thoracic duct** and the **right lymph duct.**

The **thoracic duct** is by far the larger and the longer of the two terminal lymph vessels. It commences, in the epigastric region of the abdomen, as an elongated ovoid dilation—the **cisterna chyli**—which measures 6 to 8 mm. (¼ to ⅓ in.) in its broadest diameter, and from 50 to 75 mm. (2 to 3 in.) in length. The cisterna chyli lies between the aorta and the lower part of the vena azygos,

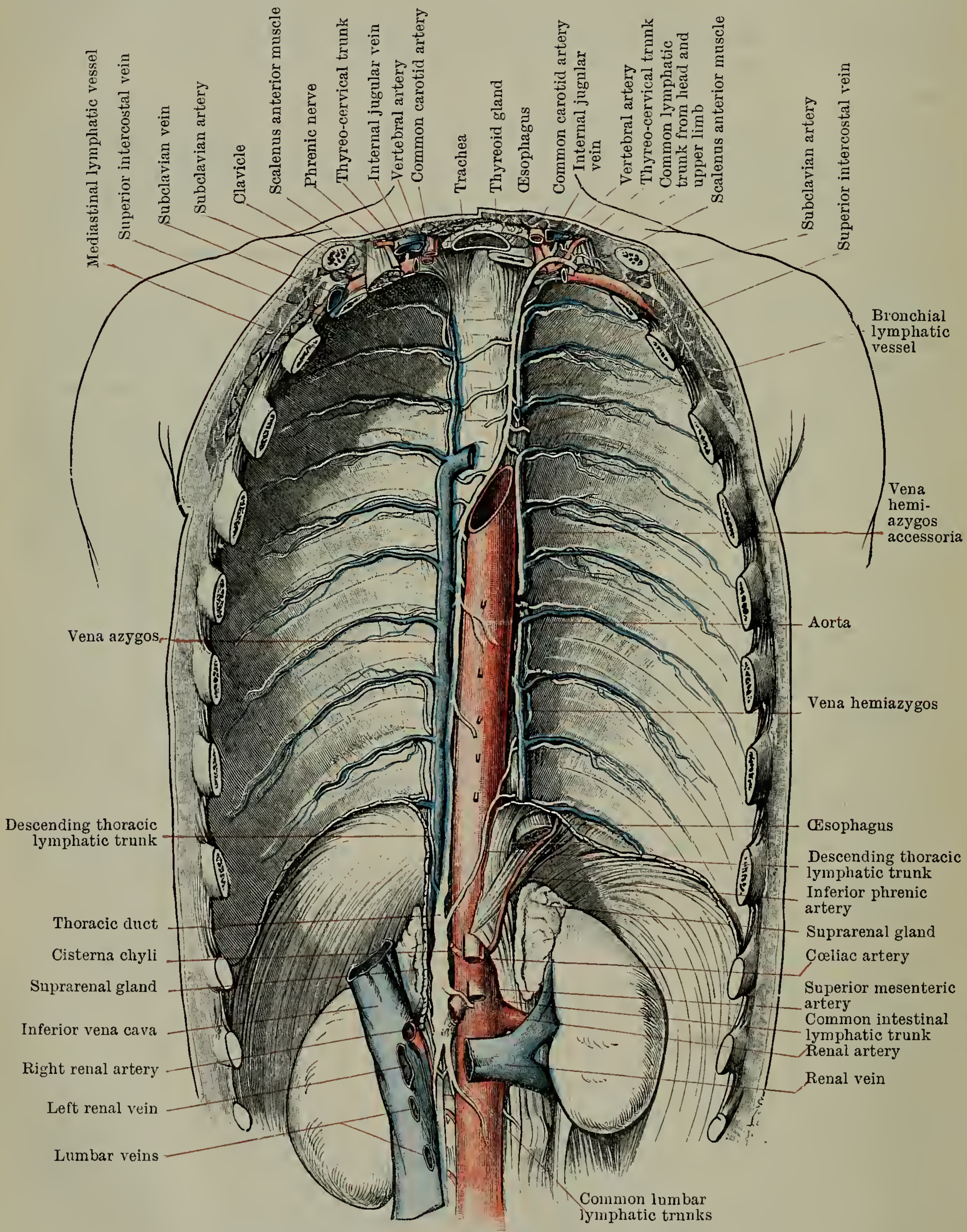

Fig. 775.—The Thoracic Duct and its Tributaries.

posterior to the right crus of the diaphragm, and opposite the first and second lumbar vertebræ. Passing upwards from the cisterna, the thoracic duct traverses the aortic opening of the diaphragm and enters the posterior mediastinum, through which it ascends, lying anterior to the vertebral column and to the right of the median plane, to the level of the fifth thoracic vertebra; it then crosses somewhat abruptly from the right to the left of the median plane, and ascends through the superior mediastinum to the root of the neck, where it turns laterally, between the vertebral and common carotid arteries, and it terminates, at the medial border of the left scalenus anterior, by joining the left innominate vein at its commencement.

Length and Diameter.—The total length of the duct averages about 45 cm. (18 inches). It is dilated at both its origin and termination. As a rule it is narrowest opposite the fifth thoracic vertebra, but its calibre is very variable, and sometimes the thoracic portion is broken up into a series of anastomosing channels. The widest portion of the tube is usually the cisterna, but occasionally that dilatation is entirely absent. The duct is provided with several valves, formed by semilunar folds of the tunica intima, arranged in pairs, and the most perfect of them is situated at or near the orifice of communication with the left innominate vein.

Relations.—*In the abdomen* the cisterna chyli lies anterior to the upper two lumbar vertebræ and the corresponding lumbar arteries, between the aorta on the left and the vena azygos and the right crus of the diaphragm on the right. *In the posterior mediastinum* the thoracic duct is separated from the vertebral column and the anterior longitudinal ligament by the right aortic intercostal arteries and the transverse parts of the hemiazygos and accessory hemiazygos veins; it is covered, in front, in the lower part of its extent by the right pleural sac, and in the upper part by the œsophagus; to its right is the vena azygos, and to its left the descending aorta. *In the superior mediastinum* it passes forwards from the vertebral column, and it is separated from the left longus colli muscle by a mass of fatty tissue; the œsophagus lies in front of it in that region, but the left margin of the duct projects beyond the œsophagus, and is in relation anteriorly, and from below upwards, with the termination of the arch of the aorta, the left subclavian artery and the pleura. As the duct enters the root of the neck it passes behind the left common carotid artery, whilst to its right and somewhat anterior is the œsophagus, and the left pleura is still in association with its left border.

At the root of the neck it arches laterally above the apex of the pleural sac and the first part of the left subclavian artery. It passes anterior to the vertebral artery and vein, the roots of the inferior thyreoid, transverse cervical, and transverse scapular arteries, the medial border of the scalenus anterior and the left phrenic nerve, and posterior to the left carotid sheath and its contents.

Tributaries. — The cisterna chyli commonly receives five tributaries. (1) **Truncus Intestinalis.**—The **intestinal trunk**, which is formed by the efferents of mesenteric and upper pre-aortic glands, and which conveys lymph from the lower and anterior part of the liver, the stomach, the small intestine, the spleen, and the pancreas. (2) Two **trunci lumbales**, one on each side; they are formed by the efferents of the lumbar glands. They carry lymph from the lower extremities, from the deep portions of the abdominal and pelvic walls, the large intestine and the pelvic viscera, and from the kidneys, suprarenal glands, and genital glands. (3) Two **descending lymphatic trunks**, one on each side, each of which is formed by the efferent vessels from the corresponding lower intercostal glands; these descend to the cisterna through the aortic opening of the diaphragm. Occasionally they unite to form a single trunk, and in others they, or the tributaries from which they are usually formed, open directly into the thoracic duct (Figs. 774, 775).

In its course through the posterior mediastinum the thoracic duct receives efferents from the upper and posterior part of the liver, and from the posterior mediastinal and œsophageal glands; the latter carry lymph from the œsophagus, the pericardium, and the left side of the thoracic wall.

In the superior mediastinum the vessels which open into it are derived from the upper left intercostal glands; it receives lymph also from the heart and left lung by efferents from the left peritracheo-bronchial glands and the intertracheo-bronchial glands, but the efferents of those glands may unite with the internal mammary lymphatic to form a common trunk which may open either into the thoracic duct or into the innominate vein. In the superior mediastinum, therefore, it may receive lymph from the upper and median part of the abdominal wall, the liver, the diaphragm, the wall of the thorax, and the mammary gland of the left side, the thymus, the pericardium, the left lung, and the left part of the heart.

At the root of the neck, just before its termination, it receives the efferents from the glands of the left superior extremity, which frequently unite to form a subclavian trunk, and the left jugular trunk, which conveys the lymph from the left side of the head and neck; but either of those vessels or both of them may end separately in the innominate vein.

The **right lymph duct** (Fig. 775) is not always present. It is a short trunk, from 12 to 17 mm. (half to three-quarters of an inch) in length, which lies at the right side of the root of the neck along the medial border of the right scalenus anterior, and it is formed by the confluence of (1) the **right jugular trunk**, (2) the **right subclavian trunk**, and (3) the **right broncho-mediastinal trunk**, which carries lymph from the bronchial, the posterior, and the anterior mediastinal and the sternal glands. It thus receives lymph from the right side of the head and neck, the right upper limb and the right side of the trunk, including the upper part of the thoracic wall, the right lung and pleura, the right half of the heart and pericardium, the right side of the diaphragm, and the upper surface of the liver. As a rule, the right lymph duct is not present as a definite stem, and the right jugular trunk carrying the lymph from the head and neck, the right subclavian trunk bearing lymph from the right upper extremity, and the right broncho-mediastinal trunk, end separately in the upper part of the right innominate vein, but any two of the three main trunks of the right side may unite together. The right broncho-mediastinal trunk frequently communicates, below, with the thoracic duct.

LYMPH GLANDS OF HEAD AND NECK.

THE LYMPH GLANDS OF THE HEAD.

All the lymph glands of the head are extracranial.

The **occipital lymph glands**, two or three in number, lie, in or deep to the deep fascia, upon the upper part of the trapezius muscle, or, if the trapezius is small, upon the upper part of the semispinalis capitis or on the splenius muscle. They receive *afferent* vessels from the occipital region of the scalp and from the superficial parts of the upper and back portion of the neck. Their *efferents* terminate in the deep cervical glands. Some of the lymph vessels of the occipital region pass directly to the deep cervical glands (Fig. 776).

The **posterior auricular lymph glands** (O.T. **mastoid**) lie on the upper part of the sterno-mastoid muscle and on the mastoid portion of the temporal bone, and they are bound down by a sheathing of deep cervical fascia. They receive *afferent* vessels from the posterior part of the parietal region of the scalp, and from the medial surface of the auricle. Their *efferents* join the superficial and the deep cervical glands (Fig. 776).

The **anterior auricular lymph glands** (O.T. **parotid**) lie both superficial and deep to the parotid fascia on the lateral surface of the parotid gland. They receive *afferents* from the frontal and the temporal regions of the scalp, from the eyebrow, the upper and lower eyelids, the upper part of the cheek, the root of the nose, and the lateral surface of the auricle. Their *efferents* pass to the superficial and the upper deep cervical glands, and to the parotid lymph glands (Fig. 776).

The **parotid lymph glands** (O.T. **deep parotid glands**) lie embedded in the deeper parts of the parotid gland. They receive *afferents* from the external acoustic meatus, the tympanum, the soft palate, the posterior part of the nose, and the deeper portions of the cheek. Their *efferents* open into the upper deep cervical glands.

The Superficial Facial Lymph Glands.—Several lymph glands, or groups of lymph glands, have been found in the region of the face but, apparently, they are irregular, both in occurrence and in position. Those which appear to be most frequently found are: **Infra-orbital**, which lie along the angle between the nose and the cheek, and below the margin of the orbit. Their *afferents* are derived from the surrounding parts; and their *efferents* pass to the anterior auricular and the submaxillary lymph glands. **Buccinator lymph glands** have been found on the superficial surface of the anterior part of the buccinator, both anterior and posterior to the anterior facial vein. Those posterior to the vein usually lie close to the point where the parotid duct turns, medially, round the anterior border of the masseter. They receive lymph from the eyelids and cheeks, and transmit it to the anterior auricular glands. **Supra-mandibular lymph glands** lie superficial to the mandible at the anterior border of the masseter, between the anterior facial vein and the external maxillary artery. They receive lymph from the region of the lower lip, and transmit it to the anterior auricular and superficial cervical glands.

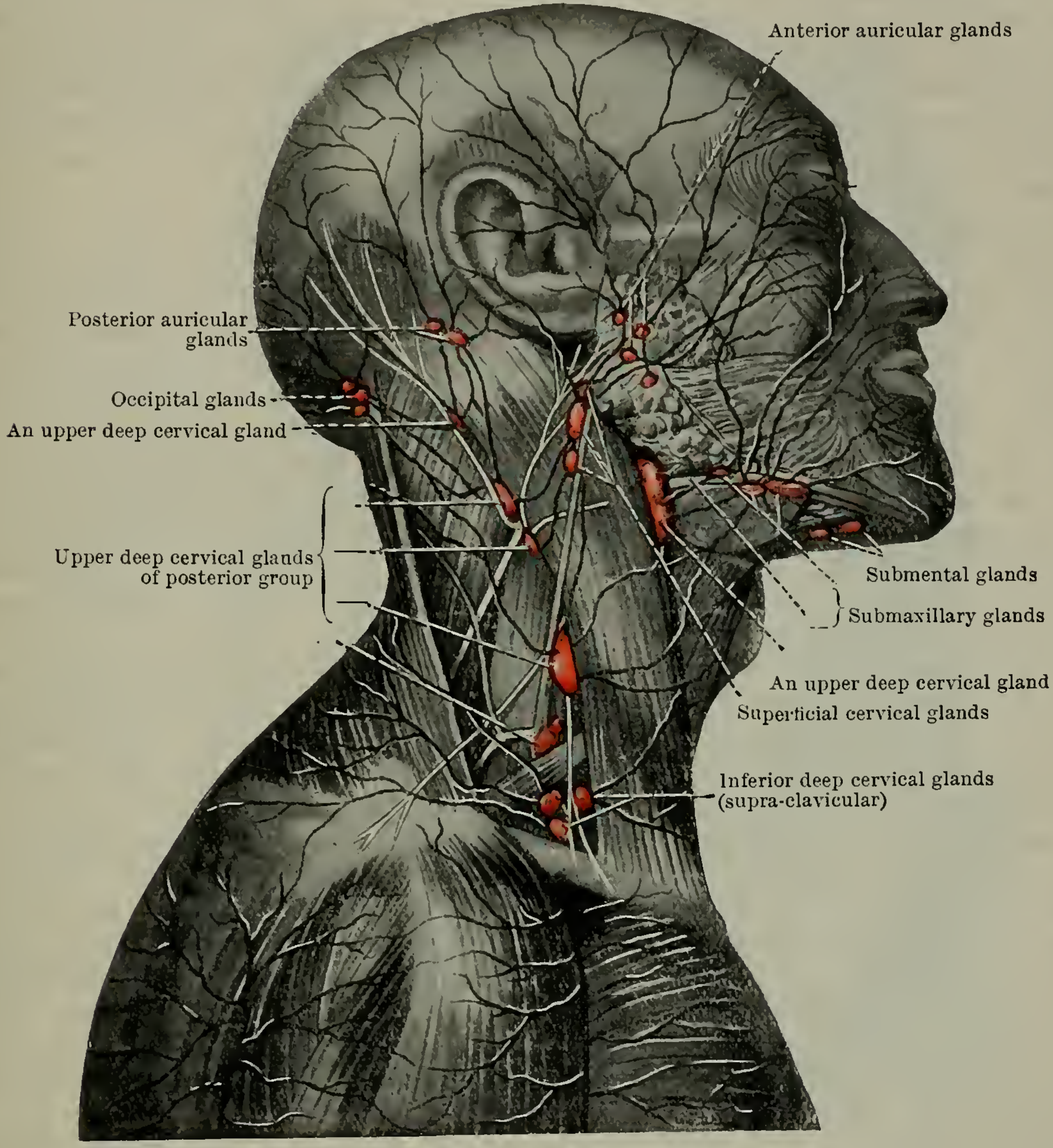
Anterior auricular glands
Posterior auricular glands
Occipital glands
An upper deep cervical gland
Upper deep cervical glands of posterior group
Submental glands
Submaxillary glands
An upper deep cervical gland
Superficial cervical glands
Inferior deep cervical glands (supra-clavicular)

FIG. 776.—LYMPH GLANDS OF THE HEAD AND NECK AS SEEN WHEN THE STERNO-MASTOID IS IN ITS USUAL POSITION. The occipital and the posterior and anterior auricular glands are inserted in accordance with descriptions. The other glands were present in one or other of the two bodies from which the drawing was made. Compare Fig. 778.

The **deep facial lymph glands** are very variable both in number and size; they lie in association with the internal maxillary artery on the external pterygoid muscle, or on the adjacent part of the wall of the pharynx. Their *afferent* vessels are derived from the orbit, the temporal fossa, the infra-temporal fossa, the palate, the nose, and the cerebral meninges. Their *efferent* vessels open into the upper deep cervical glands.

The **lingual lymph glands** lie between the genio-glossi muscles and, on the lateral surfaces of the hyo-glossi and genio-glossi muscles, deep to the mylo-hyoid muscles; they are simply small lymph nodules interposed in the course of the lymphatics which are passing from the tongue and the floor of the mouth to the deep cervical glands.

THE LYMPH GLANDS OF THE NECK.

The **superficial cervical lymph glands** lie on or are embedded in the deep fascia along the course of the external jugular vein, superficial to the sterno-mastoid (Fig. 776). They receive *afferent* vessels from the superficial tissues of the neck, the posterior and anterior auricular, and the submaxillary lymphatic glands. Their *efferent* vessels terminate in the upper deep cervical glands and the supra-clavicular glands. The uppermost superficial cervical glands are sometimes described as infra-auricular glands.

The **submaxillary lymph glands** vary in number from three to six. They lie under cover of the deep fascia of the neck, in the angle between the lower border of the mandible and the submaxillary gland, and the largest of the series is usually situated near the point where the external maxillary artery turns round the lower border of the mandible (Fig. 776). Occasionally some smaller gland nodules are found on the deep surface of the submaxillary gland, but these are comparatively rare. The *afferent* vessels of the submaxillary lymph glands carry lymph from the side of the nose, the upper lip, the lateral part of the lower lip, the anterior third of the border of the tongue, the gums, the submaxillary and sublingual glands, and the adjacent parts of the floor of the mouth. The *efferents* descend, over the superficial surface of the submaxillary gland, and terminate in the upper deep cervical glands, more particularly in those in the immediate neighbourhood of the termination of the common carotid artery.

Paramandibular Lymph Gland.—This term is applied to one or more lymph glands which lie inside the capsule of the submaxillary gland, in close relation with the gland or embedded in its substance. They receive lymph from the gland and the adjacent parts of the mouth and transmit it to the submaxillary and deep cervical glands.

The **submental lymph glands** lie below the chin, superficial to the mylo-hyoid muscles and between the anterior bellies of the two digastric muscles. There are usually two on each side, a medial or superior close to the median plane, and a lateral or inferior on the anterior border of the anterior belly of the digastric. They are apt to become enlarged in diseased conditions of the middle part of the lower lip, the adjacent part of the gums, the anterior part of the floor of the mouth, the tip of the tongue, and the skin beneath the chin, for their afferent vessels drain those parts. The *efferents* from this group of glands pass partly to the submaxillary lymph glands, and partly to a deep cervical gland situated on the superficial surface of the internal jugular vein at the level of the cricoid cartilage (Figs. 777, 778).

The **retro-pharyngeal lymph glands** lie posterior to the upper part of the pharynx, embedded in the fascia covering the superior constrictor muscle. They are separable into two groups, lateral and median.

The *lateral retro-pharyngeal glands*, 1-3, appear to be constant both in children and adults. Each lateral gland, or group of glands, lies at the level of the atlas, anterior to the upper part of the longus capitis, and posterior to the internal carotid artery.

The *median retro-pharyngeal glands*, commonly present in children and frequently absent in adults, lie at the same level as the lateral glands, but in the median plane. They are irregular in number and size.

The retro-pharyngeal lymph glands receive lymph from the adjacent muscles and bones, from the nasal part of the pharynx, from the auditory tube and tympanum, and from the posterior parts of the nasal cavities. Their *efferents* pass to the medial and the lateral deep cervical glands.

The Anterior Cervical Lymph Glands.—The lymph glands of the anterior part of the neck are separable into two groups, superficial and deep.

The **superficial anterior cervical lymph glands** are very irregular in number and size. When they are present they lie in association with the anterior jugular veins. The exact origin of their afferents and the terminations of their efferents are unknown, but it is probable that they receive lymph from the superficial tissues of the anterior parts of the neck, and transmit it to the lower deep cervical glands.

The **deep anterior cervical lymph glands** are—

(*a*) *Infra-hyoid glands,* which lie anterior to the hyo-thyreoid membrane. They receive lymph from the region of the epiglottis and transmit it to the deep cervical glands. They are not constantly present.

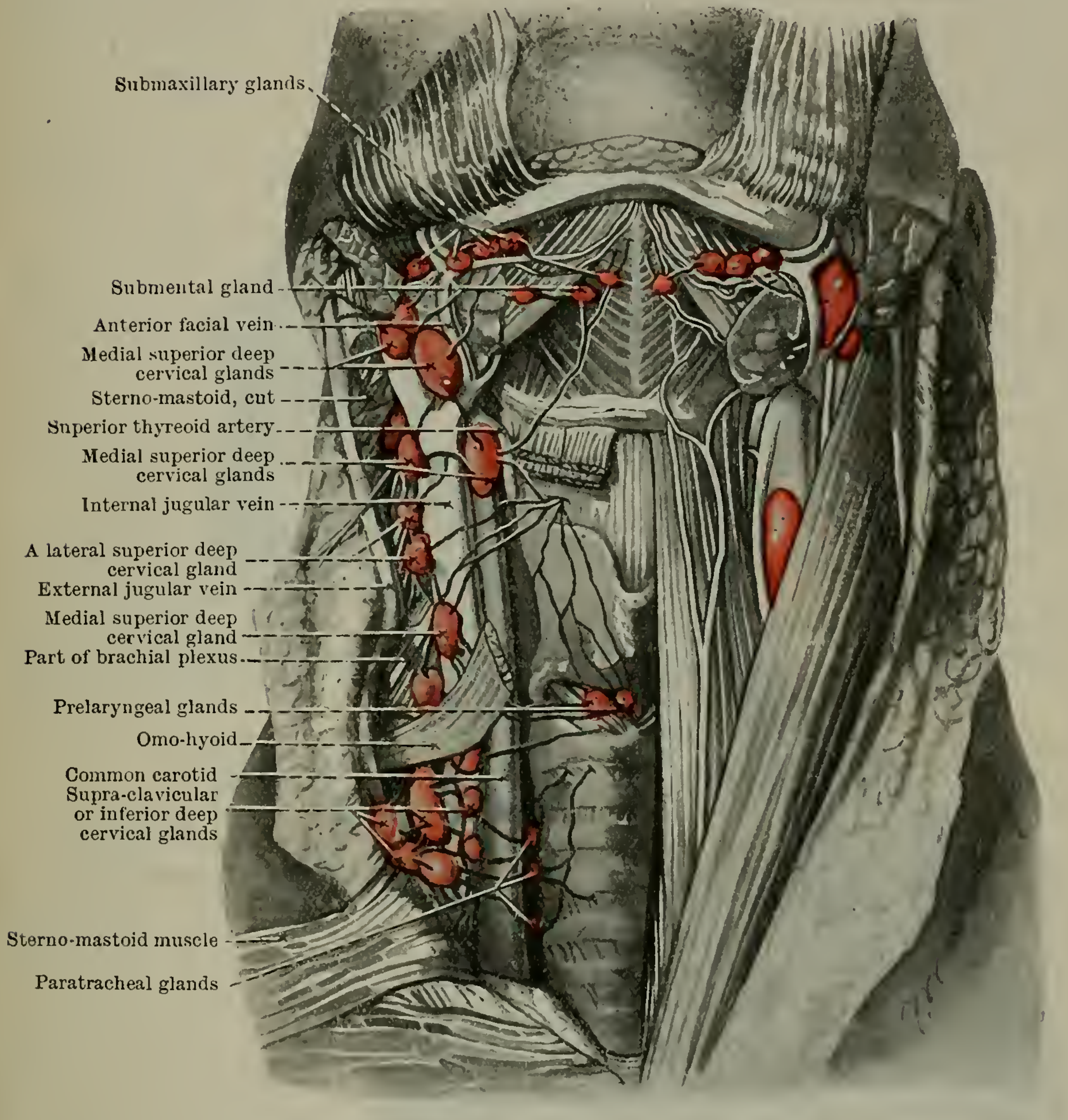

Fig. 777.—Lymph Glands of the Neck seen from the Front.
Infra-hyoid glands and pretracheal glands were not present.

(*b*) The *prelaryngeal gland,* which lies either anterior to the cricoid cartilage or to the crico-thyreoid ligament. Its occurrence is very constant. It receives lymph from the anterior part of the larynx and from the isthmus and the adjacent parts of the right and left lobes of the thyreoid gland. Its efferents terminate in the deep cervical and the pretracheal glands.

(*c*) The *pretracheal lymph glands* are numerous small nodules which lie along the inferior thyreoid veins. They receive lymph from the trachea, the lower part of the larynx, and from the lobes and the isthmus of the thyreoid gland; and they transmit it to the lower deep cervical glands.

(*d*) The *paratracheal lymph glands* lie along the sulcus between the larynx and the trachea, anteriorly, and the pharynx and œsophagus, posteriorly, in association with the branches of the superior and inferior thyreoid arteries and the recurrent nerves. They receive lymph from the adjacent parts and transmit it to the deep cervical glands (Fig. 777).

Deep Cervical Lymph Glands.—The **deep cervical lymph glands** lie in the anterior and posterior triangles of the neck and under cover of the sterno-mastoid muscle. They form a more or less continuous sheet of gland nodules and intercommunicating lymph vessels; but the glands are divided into two main groups, the (*a*) superior, and (*b*) inferior, and each group is separable into (1) medial, and (2) lateral components.

(*a*) **The Superior Deep Cervical Lymph Glands.**—(1) The *medial group* of upper deep cervical lymph glands lies on the superficial surface of the internal jugular vein and in the carotid triangle of the neck. One of the largest, which is closely associated with the tongue, lips, gums, cheeks, and the outer part of the nose, is frequently situated in the region of the union of the common facial vein with the internal jugular vein. The lowest gland of the group lies on the lateral surface of the internal jugular vein immediately above the omo-hyoid muscle; it receives a communication from the submental glands. The highest members of the group may be under cover of the postero-medial surface of the parotid gland, in association with the posterior belly of the digastric muscle. (2) The members of the *lateral group* of superior deep cervical lymph glands lie under cover of the posterior

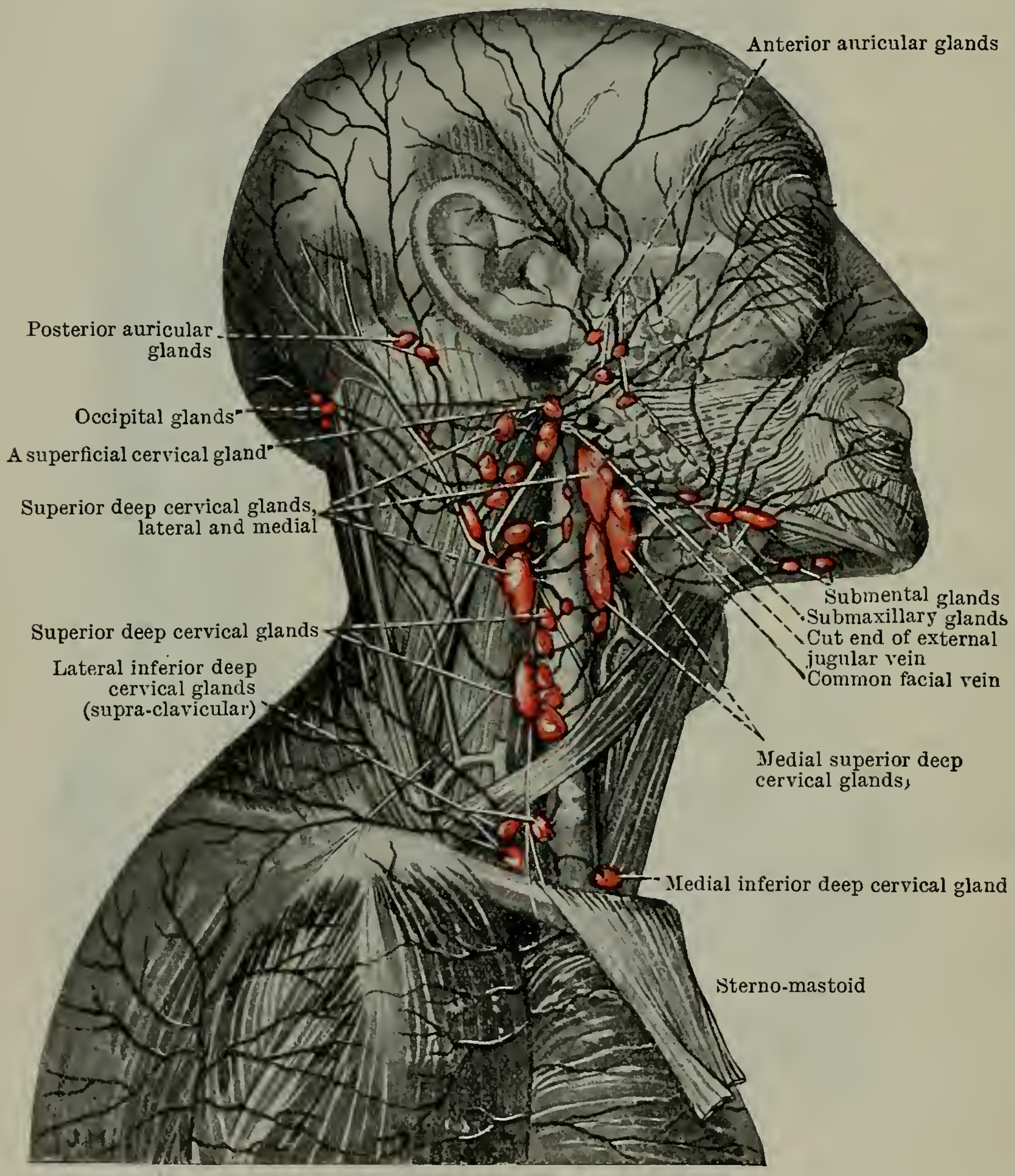
Anterior auricular glands
Posterior auricular glands
Occipital glands
A superficial cervical gland
Superior deep cervical glands, lateral and medial
Submental glands
Submaxillary glands
Cut end of external jugular vein
Common facial vein
Superior deep cervical glands
Lateral inferior deep cervical glands (supra-clavicular)
Medial superior deep cervical glands
Medial inferior deep cervical gland
Sterno-mastoid

Fig. 778.—Lymph Glands of the Head and Neck as seen after the Removal of the Sterno-Mastoid Muscle. The anterior and posterior auricular and the occipital glands are inserted in accordance with descriptions. The other glands were present in one or other or in both the bodies from which the figure was made. Compare Fig. 776.

part of the upper portion of the sterno-mastoid, and in the upper part of the posterior triangle of the neck. They are embedded in the fat-laden fascia which covers the roots of the cervical plexus and the upper part of the brachial plexus, and the levator scapulæ and the scalene muscles, and several of them are in close relation with the accessory nerve (Fig. 778).

The superior deep cervical glands are connected by *afferent* vessels with the various groups of glands which lie in the regions of the pharynx, the face, and the upper part of the neck. They receive lymph, therefore, from the nose, the mouth, the tongue, the upper parts of the pharynx and larynx, the tonsil, the upper part of the thyreoid gland, the submaxillary, sublingual, and parotid salivary glands, and from the interior of the cranium. Their *efferents* pass either to the inferior deep cervical glands or to the jugular lymph trunk. In some cases the medial and lateral members of the superior group are connected with the corresponding members of the lower group only, but in other cases the medial or lateral members of the superior group may be connected with both the medial and the lateral members of the inferior glands.

The **inferior deep cervical lymph glands** (Figs. 776, 778), which are also termed the supra-clavicular glands, are situated below the level of the omo-hyoid muscle. (1) The members of the *medial group* lie in relation with the lower part of the internal jugular vein, opposite the interval between the sternal and the clavicular heads of the sterno-mastoid. They receive *afferents* from the members of the upper medial group and from the pretracheal and the paratracheal glands and from the upper part of the thorax. Their *efferents* unite with some of the efferents of the upper medial group and pass with them to the jugular lymph trunk.

(2) The members of the *lateral group* of inferior deep cervical glands lie in the subclavian triangle, in the fatty tissue superficial to the lower part of the brachial plexus and the third part of the subclavian artery. They receive lymph from the lower parts of the neck, from the upper part of the thorax, and from the upper lateral glands. They receive lymph also from the deep parts of the mammary gland, and they are in communication with the axillary glands. Their *efferents* join the jugular lymphatic trunk.

THE LYMPH VESSELS OF THE HEAD AND NECK.

The lymph vessels of the head and neck may be separated into two groups, intracranial and extracranial.

Intracranial Lymph Vessels and Lymph Spaces.—The cerebro-spinal fluid which fills the ventricles of the brain, the central canal of the spinal medulla, and the subarachnoid and subdural spaces, differs in chemical constitution from true lymph; nevertheless it plays the part of lymph, to some extent, and there can be little doubt that some of it eventually passes into lymph vessels; therefore it may be considered as a modified form of lymph. The fluid is secreted by the chorioid plexuses of the cerebral ventricles, and it passes through the medial and lateral foramina of the fourth ventricle into the cerebello-medullary subarachnoid cistern. Part of the fluid transudes through the arachnoideal granulations into the superior sagittal and other cerebral blood sinuses; and part, probably, passes by osmosis into the subdural space and thence into the meningeal lymphatics, by which it is conveyed to the exterior of the cranium.

Cerebral Lymph Channels.—It appears probable that the so-called peri-vascular and peri-cellular lymph spaces which have so frequently been described in the central nervous system are merely artifacts produced by unsatisfactory methods of preparation. Nevertheless, the fluid which pervades the cerebral substance must have some exit, and it is not unlikely that it passes, with the lymphocytes, through cleft-like intercommunicating spaces in the adventitial coats of the blood vessels, similar to those demonstrated by Bruce in the case of the spinal medulla, and so reaches the pia-mater and subarachnoid space; that is, it runs along the walls of the arteries, enters the meningeal lymphatics, and passes through them to the exterior of the cranium where it enters the extracranial lymph vessels. The above statements are based upon Bruce's researches and the fact that the lymph vessels of the nose, the ear, and the deep lymph vessels of the neck have been injected from the subdural space.

The Superficial Lymph Vessels of the Head.—(1) The superficial lymphatics from the *frontal* and *anterior temporal regions* of the head accompany the branches of the superficial temporal artery and terminate in anterior auricular glands, from which efferents pass to the parotid, the superficial cervical, and to the medial glands of the superior deep cervical group.

(2) The lymphatics of the *posterior temporal* and *parietal region* run to the posterior auricular glands. It is stated that they sometimes communicate directly with the lateral glands of the superior deep cervical group.

(3) The lymphatics from the *occipital part of the scalp* pass along the branches of the occipital

artery and terminate in the occipital glands, which transmit the lymph to the lateral superior deep cervical glands.

The Superficial Lymph Vessels of the Neck.—The majority of the lymph vessels from the skin and the subcutaneous tissues of the upper part of the neck pass to the inferior deep cervical glands, but some end in the occipital glands and others in the superior deep cervical glands.

The superficial lymph channels of the lower part of the neck terminate in the axillary glands.

The Lymph Vessels of the Eyelids and the Conjunctiva.—The lymph vessels which drain the region of the eyelids and the conjunctiva form two groups, a medial and a lateral. (*a*) The *medial vessels* pass from the superficial and deeper parts of the medial portions of the superior and inferior eyelids and, following the course of the angular and the external maxillary arteries, they pass to the submaxillary lymph glands. The more superficial vessels lie anterior, and the deeper vessels posterior to the orbicularis oculi. Both groups may be connected with the infra-orbital and anterior buccinator glands. (*b*) The lymph vessels from the *lateral parts of the eyelids* pass posteriorly, along the line of the transverse facial artery. They end in the anterior auricular and the parotid lymph glands. In some cases they become connected also with the buccinator and superficial cervical glands.

Lymph Vessels of the Eyeball.—It is doubtful if any true lymph vessels exist in the eyeball. Lymph spaces have been described in association with the coats of the eyeball, and lymph vessels are stated to exist in the chorioid coat, but their existence is uncertain. The sinus venosus scleræ (Schlemm), formerly looked upon as a lymph channel, is probably a venous canal. If lymph vessels are absent then the fluids in the tissues and spaces of the eye must pass into the capillaries of the veins, unless channels exist in the adventitia of the vessels similar to those described by Bruce in the spinal medulla.

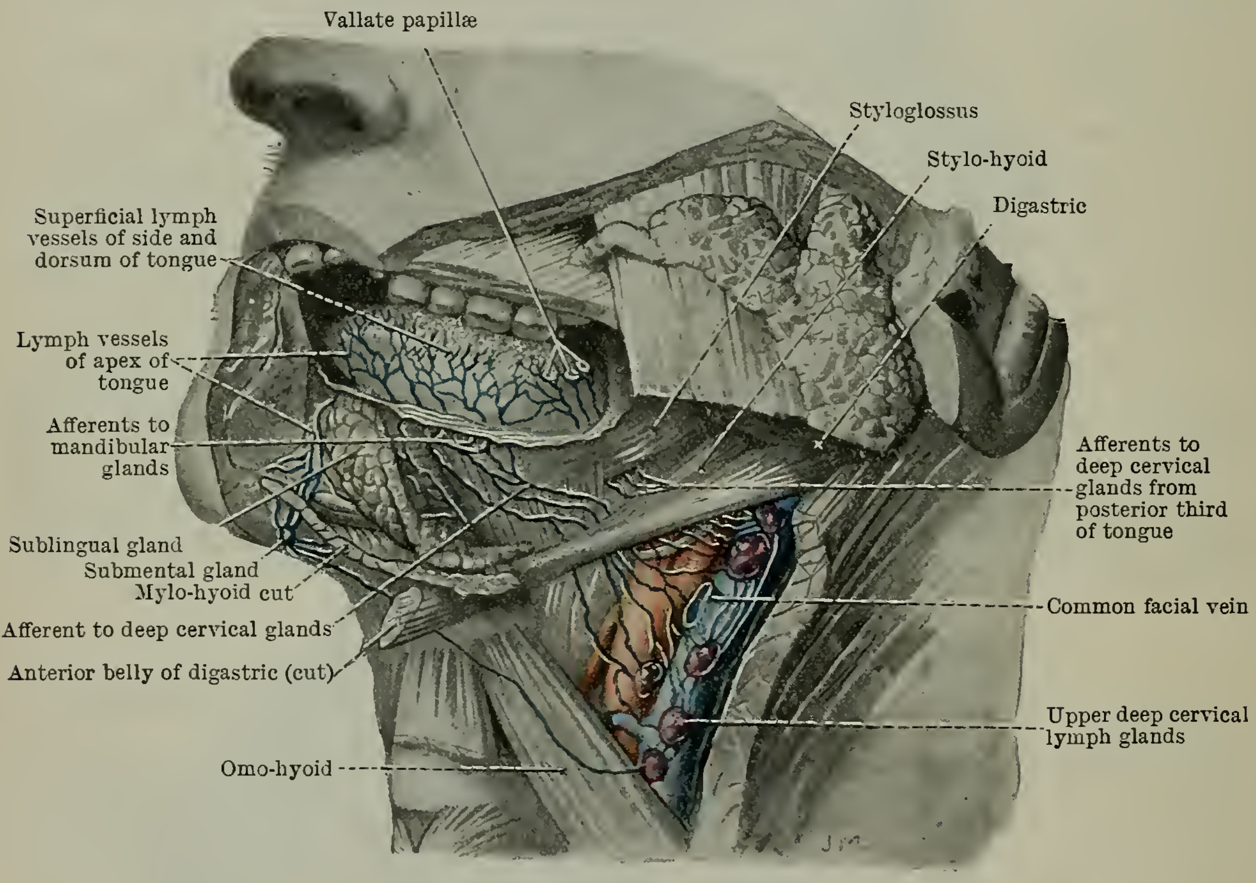
Vallate papillæ
Styloglossus
Stylo-hyoid
Digastric
Superficial lymph vessels of side and dorsum of tongue
Lymph vessels of apex of tongue
Afferents to mandibular glands
Sublingual gland
Submental gland
Mylo-hyoid cut
Afferent to deep cervical glands
Anterior belly of digastric (cut)
Omo-hyoid
Afferents to deep cervical glands from posterior third of tongue
Common facial vein
Upper deep cervical lymph glands

FIG. 779.—LYMPH VESSELS OF THE TONGUE.

The Lymph Vessels of the Ear.—The **lymph vessels** from the upper and lateral parts **of the auricle** end in the anterior auricular glands. Those from the lower part of the auricle go to the upper superficial cervical glands. The lymph channels from the medial surface of the auricle end in the posterior auricular glands, but in a few cases they establish direct communication with the superior deep cervical glands.

The **lymph vessels of the external acoustic meatus** end in the anterior and posterior auricular glands.

The **lymph vessels of the middle ear** pass in two directions. Those from the more laterally situated parts of the walls of the cavity join the vessels of the external acoustic meatus and terminate in the posterior auricular glands. The lymph vessels which drain the more medial parts of the middle ear and the auditory tube terminate in the lateral retro-pharyngeal glands.

It is doubtful if any lymph vessels exist in the **internal ear.** It is possible that the perilymph drains into the subarachnoid space of the posterior fossa of the skull along the line of the ductus endolymphaticus and that the endolymph reaches the subarachnoid space along the fibres of the acoustic nerve.

The Lymph Vessels of the Nose.—The lymph vessels from the external part of the nose form two groups, superior and inferior. The *superior group* accompanies the vessels from the lateral parts of the eyelids and ends in the anterior auricular glands. The *inferior group* accompanies the angular and the external maxillary arteries, and the majority of the vessels end in the submaxillary glands, but in some cases one or more vessels of this group pass to the upper superficial cervical glands.

The Lymph Vessels of the Nasal Muco-periosteum.—The vessels from the anterior part of the nasal muco-periosteum accompany the vessels of the lower portion of the external part of the nose and end in the submaxillary glands. Those from the posterior part of the muco-periosteum end partly in the medial superior deep cervical glands, and partly in the lateral retro-pharyngeal glands.

There is little definite knowledge regarding the lymph vessels of the accessory sinuses of the nose, but it is probable that they follow the lines of the blood-vessels which supply the muco-periosteum of the cavities.

The Lymph Vessels of the Lips.—The vessels from the skin of the medial part of the lower lip pass to the submental glands and, occasionally, direct to the superior deep cervical glands. The vessels from the deeper parts of the lower lip unite with those from the upper lip and end in the submaxillary glands, but some of the superficial vessels of the upper lip may end in the superficial cervical glands.

The Lymph Vessels of the Cheeks.—The majority of the superficial and deep lymph vessels of the cheeks pass to the submaxillary glands, but in some cases they communicate directly with the superficial or with the superior deep cervical glands. They may communicate also with the buccinator glands.

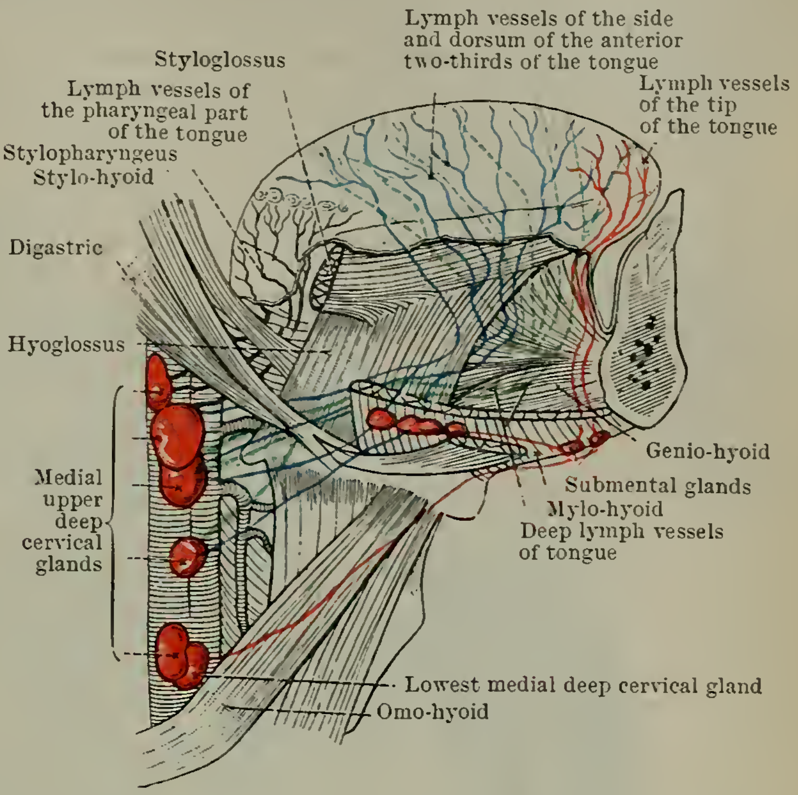
Lymph vessels of the side and dorsum of the anterior two-thirds of the tongue
Styloglossus
Lymph vessels of the pharyngeal part of the tongue
Lymph vessels of the tip of the tongue
Stylopharyngeus
Stylo-hyoid
Digastric
Hyoglossus
Medial upper deep cervical glands
Genio-hyoid
Submental glands
Mylo-hyoid
Deep lymph vessels of tongue
Lowest medial deep cervical gland
Omo-hyoid

FIG. 780.—DIAGRAM OF SIDE-VIEW ORIGINS AND TERMINATIONS OF THE LYMPH VESSELS OF THE TONGUE. (After Poirier, modified.)

The Lymph Vessels of the Gums.—The vessels from the outer part of the anterior portion of the mandibular gum pass to the submental glands. Those from the posterior part, together with the vessels from the outer part of the gum of the maxilla, terminate in the submaxillary glands. The vessels of the gum of the maxilla may also communicate with the buccinator glands.

The vessels from the inner part of the gum of the mandible end in the submaxillary glands; those of the inner part of the gum of the maxilla, together with the vessels of the hard and the soft palate, end in the medial superior deep cervical glands.

The Lymph Vessels of the Teeth.—It is known that lymph vessels exist in connexion with the teeth of the mandible as well as with the mandible itself, but their terminations are not definitely established. It is probable that they end in the submaxillary or the superior deep cervical glands.

The lymph vessels of the teeth of the maxilla pass partly into the infra-orbital canal and so to the face, where they join the vessels from the lateral parts of the eyelids, and terminate in the anterior auricular and submaxillary glands. The remaining vessels of the maxillary teeth end in the submaxillary glands.

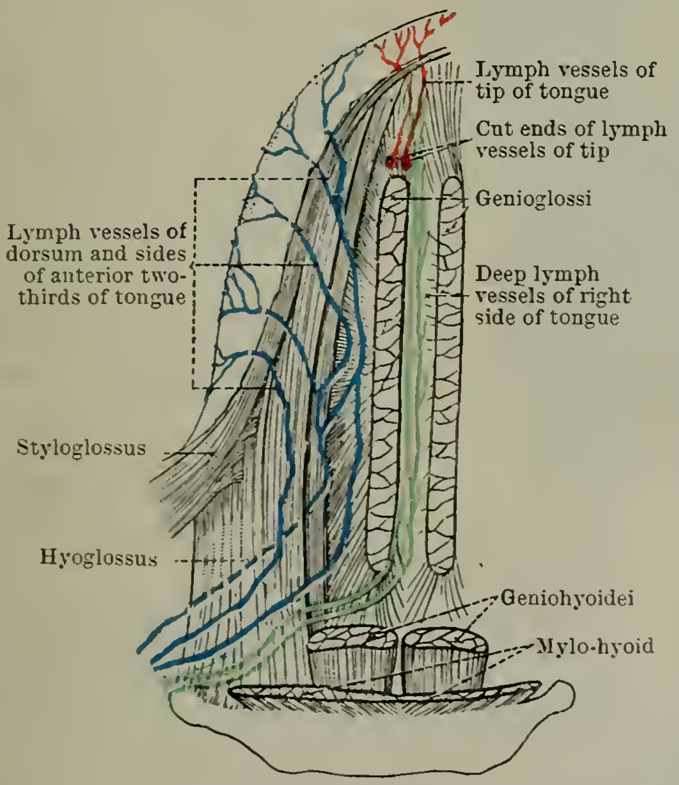
Lymph vessels of tip of tongue
Cut ends of lymph vessels of tip
Genioglossi
Lymph vessels of dorsum and sides of anterior two-thirds of tongue
Deep lymph vessels of right side of tongue
Styloglossus
Hyoglossus
Geniohyoidei
Mylo-hyoid

FIG. 781.—DIAGRAM OF LYMPH VESSELS OF ANTERIOR TWO-THIRDS OF TONGUE, SEEN FROM BELOW. (After Poirier, modified.)

The Lymph Vessels of the Tongue.—The lymph vessels of the tongue form three groups—(1) anterior, (2) middle, (3) posterior. The anterior and middle groups communicate freely with one another and with their fellows of the opposite side, but the posterior group have little or no communication with the middle group. (1) The anterior lymph vessels drain the tip and the lower surface of the anterior free portion of the tongue. The main trunks pierce the mylohyoid muscle and end in the submental glands. (2) The middle group of lymph vessels of the tongue drain the anterior two-thirds, exclusive of the tip, and they terminate partly in the submaxillary glands and partly in the medial superior deep cervical glands. Small lingual glands are intercalated in the course of some of these vessels. (3) The posterior lymph vessels drain the portion of the tongue which lies in the anterior wall of the pharynx posterior to the papillæ vallatæ; they pass to the medial superior deep cervical glands. (4) The lymph vessels from the deeper central portions of the tongue go, mainly, to the upper deep cervical glands.

The Lymph Vessels of the Salivary Glands.—The lymph vessels of the parotid gland terminate in the parotid and superior deep cervical lymph glands. The lymph vessels of the submaxillary gland terminate, according to Most, not in the submaxillary lymph glands but in the medial superior deep cervical glands. Practically nothing is known of the lymph vessels of the sublingual gland.

The Lymph Vessels of the Pharynx.—From the upper part of the pharynx, and from the posterior wall and lateral borders of the middle and lower parts, the lymph stream flows to the median line posteriorly. There the larger vessels pierce the walls of the pharynx, then they turn laterally and end in the lateral retro-pharyngeal glands.

From the lower and anterior part of the pharynx, that is, from the region of the piriform recesses and the adjacent part of the larynx, the lymph vessels pass along the course of the laryngeal branch of the superior thyreoid artery, pierce the hyo-thyreoid membrane and terminate in the medial superior deep cervical glands; they may be connected also with the infra-hyoid, and with the prelaryngeal glands.

The lymph vessels of the palatine tonsil and the adjacent parts of the glosso-palatine and pharyngo-palatine arches pierce the lateral wall of the pharynx and end in a gland, or group of glands, which lies on the lateral surface of the internal jugular vein, immediately below the posterior belly of the digastric at the level of the angle of the mandible.

The Lymph Vessels of the Thyreoid Gland.—The lymph vessels of the thyreoid gland form a plexus common to both lobes and the isthmus, therefore the lymph can pass from the lobe of one side to the terminal glands of the opposite side. The terminal vessels end in the prelaryngeal, the pretracheal, the paratracheal, the superior and inferior deep cervical, and the upper mediastinal glands.

The Lymph Vessels of the Larynx.—The lymph plexus of the larynx is separable into upper and lower portions; they are connected together on the posterior wall of the cavity, but are separated, laterally and anteriorly, by the plicæ vocales which contain extremely few lymph vessels. The efferent stems of the upper part pass mainly along the laryngeal branch of the superior thyreoid artery, and they end in the superior deep cervical glands, but are frequently connected also with the infra-hyoid glands. The efferent vessels from the lower part of the larynx form two subordinate groups. Those from the anterior region pierce the median crico-thyreoid ligament and end in the prelaryngeal, the pretracheal, and the deep cervical glands. The efferents from the posterior region pierce the crico-tracheal membrane and end in the paratracheal glands (Fig. 777).

The Lymph Vessels of the Cervical Part of the Trachea and Œsophagus.—The terminal vessels of the cervical part of the trachea and the adjacent portion of the œsophagus and the paratracheal and the inferior deep cervical glands. From the upper part of the trachea some vessels pass to the prelaryngeal glands also.

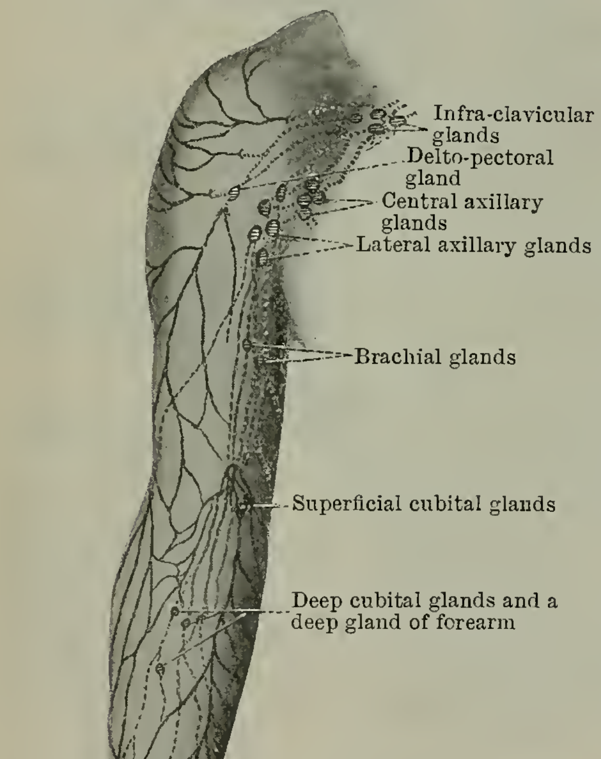

Fig. 782.—Schema of the Lymph Vessels and Glands of the Upper Extremity.

LYMPH GLANDS OF THE SUPERIOR EXTREMITY.

The lymph glands of the superior extremity form two groups—(1) superficial, (2) deep.

(1) The **superficial cubital lymph glands**, one or two in number, lie on the medial side of the basilic vein, a short distance proximal to the medial epicondyle of the humerus. They receive lymph from both aspects and from the ulnar border of the forearm, and their *efferents* pass to the deep glands of the arm.

(2) **Deep Cubital Lymph Glands.**—Occasionally small glands are found in association with the arteries of the forearm, but in most cases the lymph from the deeper parts of the hand and forearm, below the region of the elbow, passes to the deep cubital glands or to the brachial or axillary glands.

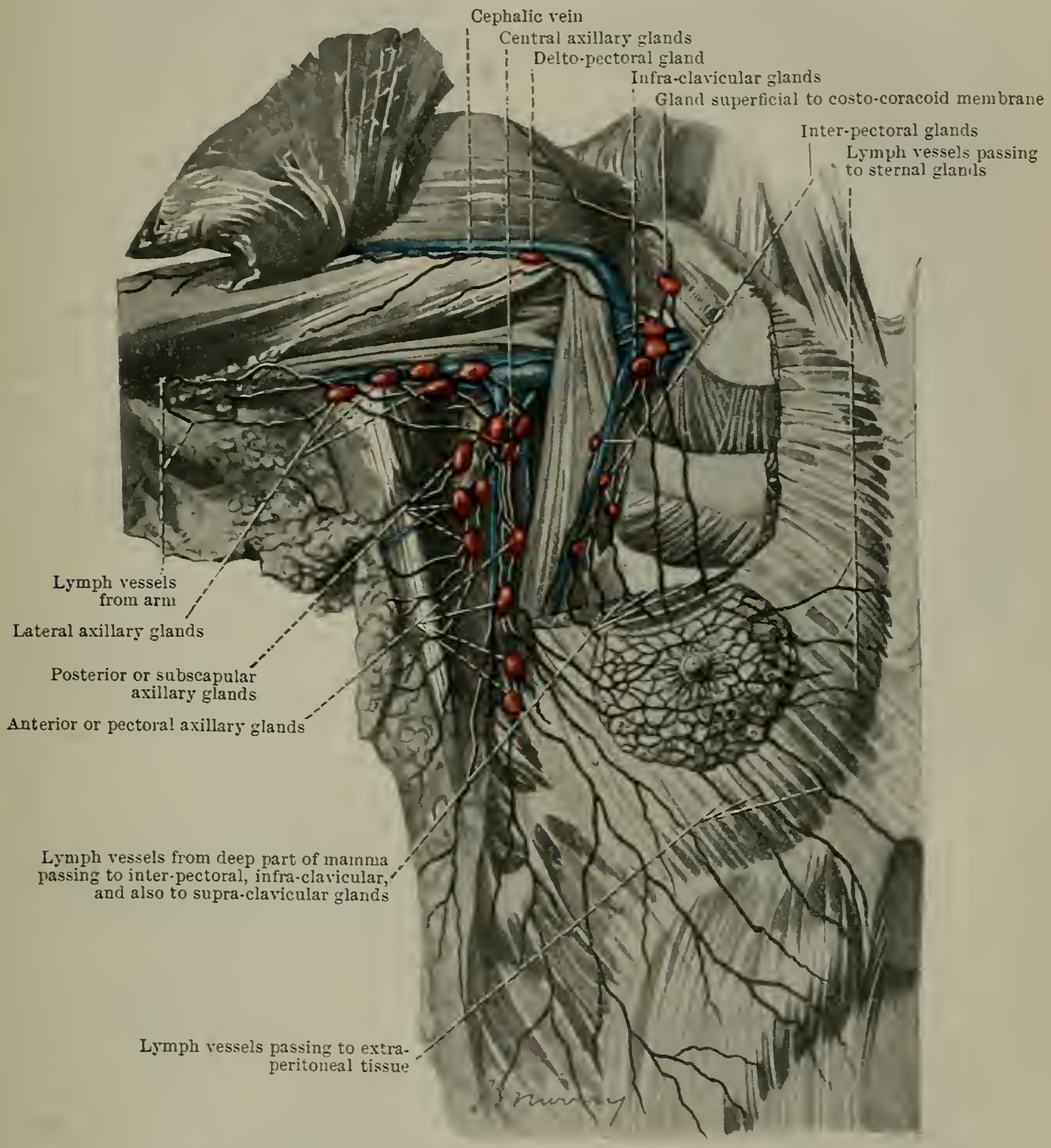
Cephalic vein
Central axillary glands
Delto-pectoral gland
Infra-clavicular glands
Gland superficial to costo-coracoid membrane
Inter-pectoral glands
Lymph vessels passing to sternal glands
Lymph vessels from arm
Lateral axillary glands
Posterior or subscapular axillary glands
Anterior or pectoral axillary glands
Lymph vessels from deep part of mamma passing to inter-pectoral, infra-clavicular, and also to supra-clavicular glands
Lymph vessels passing to extra-peritoneal tissue

FIG. 783.—DISSECTION OF AXILLA AND ANTERIOR PART OF THORACIC WALL, SHOWING LYMPH GLANDS AND VESSELS. (Semi-diagrammatic.)

The **deep cubital lymph glands** lie anterior to the elbow in the neighbourhood of the terminal part of the brachial artery. They receive many of the deep lymph vessels of the forearm and their *efferents* pass to the brachial and axillary glands.

Brachial lymph glands, irregular in number and size, are found along the course of the brachial artery. Their *afferents* are derived from the forearm, from the deep cubital and superficial cubital glands, from adjacent parts, and from the elbow-joint. Their *efferents* end in lateral group of axillary glands.

In addition to the glands which lie along the course of the brachial artery other deep glands are occasionally met with in the arm. (1) One in the sulcus

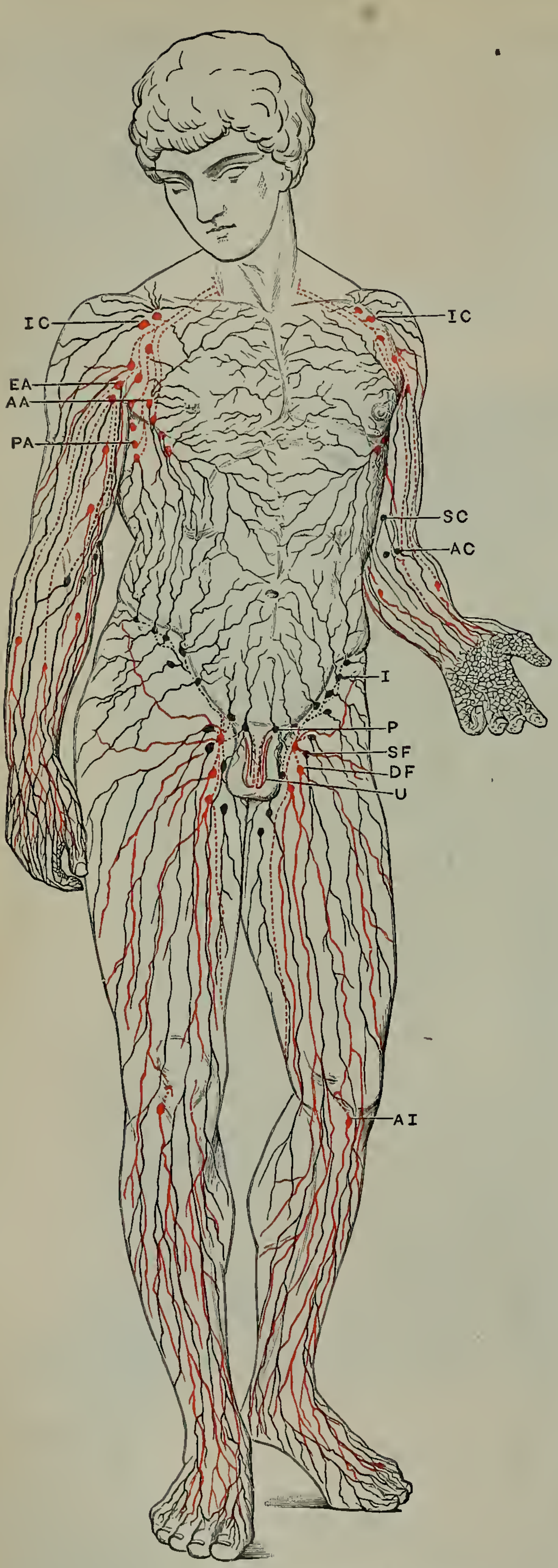

Fig. 784.—Superficial Lymph Vessels of the Trunk, and the Lymph Glands and Vessels—Superficial and Deep—of the Limbs (diagrammatic). All superficial lymph vessels are printed black; the deep lymph vessels throughout are coloured red. Afferent vessels are represented by continuous lines; efferent and interglandular vessels by dotted lines.

A.A.	Anterior axillary glands.	E.A.	Lateral axillary glands.	P.A.	Posterior axillary glands.
A.C.	Superficial cubital glands.	I.	Superficial subinguinal glands.	S.C.	Superficial cubital glands.
A.I.	Superficial tibial glands.	I.C.	Infra-clavicular or subclavian glands.	S.F.	Subinguinal glands.
D.F.	Deep Subinguiual glands.	P.	Pubic glands.	U.	Urethral lymphatics.

between the brachioradialis and the brachialis; (2) another in the radial sulcus. When they are present both of these glands receive lymph from the ligaments of the elbow-joint as well as from other adjacent soft parts.

Axillary Lymph Glands.[1]—The axillary lymph glands lie in the region of the axilla, where they form several groups, some of which are practically constant, whilst others are very variable.

(*a*) The **lateral** or **brachial group of axillary lymph glands**, 1-7, lies in relation with the lateral boundary of the axillary space along the line of the great axillary vessels. The glands receive the lymph from the greater part of the upper extremity. Their *efferents* anastomose with the lymph vessels of the central glands; some terminate in the inferior deep cervical glands and others pass to the subclavian lymph trunk (Fig. 774).

(*b*) The **posterior** or **subscapular lymph glands** lie in relation with the posterior wall of the axilla, along the line of the subscapular vessels. Their *afferents* are the vessels of the lateral and posterior walls of the body, above the level of the umbilicus, and lymph vessels from the lower and posterior part of the neck. Their *efferents* join the lateral, the central, and the infraclavicular axillary glands (Fig. 783).

(*c*) The **anterior** or **pectoral group of axillary lymph glands**, 2-4, lies along the line of the lateral thoracic artery, in the angle between the lower border of the pectoralis major and the serratus anterior. The glands extend from the third to the sixth intercostal space, sometimes in a single and sometimes in a double row. Occasionally one or two outlying members of this group, called the *paramammary glands*, are found on the superficial surface of the pectoralis major. The *afferents* of the anterior glands are derived from the anterior wall of the body above the umbilicus from the lateral two-thirds of the mamma. Their *efferents* pass to the central, lateral, and infra-clavicular axillary glands (Fig. 783).

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[1] The B.N.A. axillary lymph glands are the lateral glands of the axilla, but, as the other groups mentioned also lie in the axillary region, the general term "axillary" is used here to include all the groups.

(*d*) The **central axillary lymph glands**, 2-6, lie in the central part of the axilla, and frequently along the line of the intercosto-brachial nerve. They receive afferents from the anterior, the subscapular, and the lateral glands. Their *efferents* pass to the infra-clavicular glands (Fig. 783).

(*e*) The **subpectoral group of axillary lymph glands**, 3-14, is formed by several small glands which lie posterior to the pectoralis minor and anterior or medial to the axillary artery. They receive lymph from the glands situated at a lower level and from the lateral wall of the thorax. Their *efferents* pass to the infra-clavicular glands.

(*f*) The **infra-clavicular group of axillary lymph glands**, 1-11, lies in the region between the upper border of the pectoralis minor and the clavicle, along the medial side of the axillary artery. The glands receive efferents from the arm, from the other groups of axillary glands, and directly from the mamma and the pectoral muscles, along the line of the pectoral branches of the thoraco-acromial artery, and from the inter-pectoral glands. Their *efferents* pass to the inferior deep cervical glands and to the subclavian lymph trunk (Fig. 774).

(*g*) A **delto-pectoral lymph gland** is occasionally found in the groove between the deltoid and the pectoralis major muscles. It receives *afferents* from the superficial parts of the arm and the shoulder, and gives *efferents* to the subclavian trunk and to the infra-clavicular glands.

(*h*) Small **inter-pectoral lymph glands** are sometimes found between the great and small pectoral muscles. They are connected with the lymph vessels which pass from the posterior part of the mamma to the infra-clavicular glands (Fig. 783).

THE LYMPH VESSELS OF THE SUPERIOR EXTREMITY.

The lymph vessels of the superior extremity, like the glands, form two groups—(1) superficial, and (2) deep.

(1) The **superficial lymph vessels** lie in the skin and the subcutaneous tissues. They commence in cutaneous plexuses, which are finest and most dense on the volar aspects of the fingers and hand. The efferents from the volar digital plexus of each finger pass to the dorsum of the digit. There they unite to form dorsal digital vessels, 2-4, which run to the dorsum of the hand, where they unite together to form new vessels.

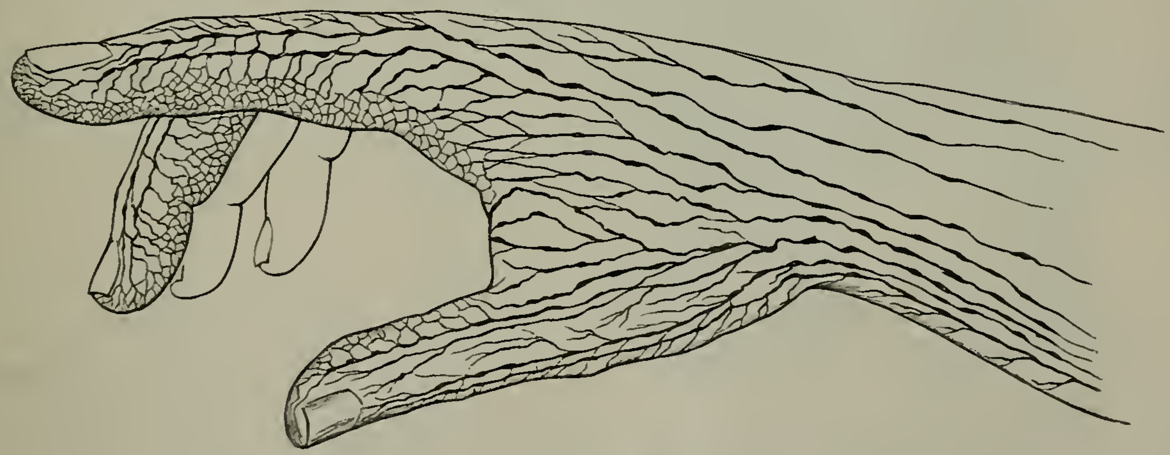

Fig. 785.—Superficial Lymphatics of the Digits and of the Dorsal Aspect of the Hand.

The efferents from the volar plexus of the hand run proximally, distally, and to the lateral and medial margins of the hand. The lateral efferents, as they turn round the lateral border of the hand, join the efferents of the thumb. The medial efferents turn round the medial border of the hand, and join the efferents of the little finger. The afferents which run proximally are few and variable; when they are present they lie along the line of the superficial median vein of the forearm. The efferents which run distally pass to the interdigital clefts where they turn dorsally and join the vessels on the dorsum of the hand (Figs. 784, 785).

As the superficial lymphatics pass towards the elbow they tend to form two main streams—(1) a lateral stream which accompanies the cephalic vein, and (2) a medial stream which accompanies the basilic vein. The lymph vessels which commence on the dorsum of the hand and forearm converge to one or other of the two main groups of vessels. In the region of the elbow the vessels of the two streams anastomose together and some pass through the fascia and join the deep cubital glands.

As they pass from the forearm to the arm, the majority of the lymph vessels converge towards the medial side. Some join the superficial cubital glands, but others pass those glands and accompany their efferents, along the basilic vein, to the axilla, where they join the lateral group of axillary glands. There is, however, a varying number of lymph vessels, from the lateral stream of the forearm, which accompany the cephalic vein in the arm. Some of these terminate in the delto-pectoral gland, if it is present, but, whether it is present or not, some pass directly to the infra-clavicular glands.

The superficial lymph vessels of the arm terminate, for the most part, in the lateral group of axillary glands.

The **deep lymph vessels** of the upper extremity accompany the deeper blood-vessels. Some of the lymph vessels of the hand and forearm end in the deep glands, which are occasionally present in the forearm, but the majority either end in the deep cubital glands, or they pass directly to the lateral group of axillary glands.

The Lymph Vessels of the Mamma.—As the mamma is a modified skin gland, and as it is embedded in the superficial fascia, the lymph vessels which issue from it pass first into the superficial fascia and thence into the deep fascia. Having traversed the deep fascia, more or less obliquely, they either end in lymph glands or enter and traverse other layers of the body wall.

The main outflow of lymph from the substance of the mamma is towards the areola, where a subcutaneous plexus of lymph vessels is formed. From that plexus two or more main vessels of large size pass laterally (Fig. 783), pierce the deep fascia and join the anterior group of axillary glands. There are, however, other groups of vessels by which lymph may pass from the mamma. Some vessels issue from the medial border of the gland and run along the lines of the neighbouring anterior perforating branches of the internal mammary artery to the anterior ends of the intercostal spaces; there they pass through the deeper parts of the thoracic wall and end in the sternal lymph glands. Clinical evidence (Sampson Handley) has shown that some vessels, from the lower and medial part of the gland, pass to the angle between the seventh rib and the xiphoid process, where they pierce the fibrous layers of the abdominal wall and join the lymph vessels in the extra-peritoneal fascia of the upper part of the abdomen. It is through those vessels that cancer cells not uncommonly travel from the mamma to the abdomen (Fig. 783).

Lymph vessels pass also from the deep part of the mammary gland, through the deep fascia and the pectoralis major, and then ascend, along the line of the pectoral branches of the thoraco-acromial artery, to the infra-clavicular region, where they terminate either in the inter-pectoral or the infra-clavicular glands, or in both groups. It is possible that some of those vessels, after piercing the costo-coracoid membrane, may pass directly to the inferior deep cervical glands (Fig. 778).

It is stated, further, that some of the lymph vessels which issue from the mamma pierce the whole thickness of the thoracic wall and join the lymph vessels which lie in the endo-thoracic fascia, which intervenes between the ribs and the intercostal muscles externally and the pleural membrane internally. Finally it should be noted that the lymph vessels of opposite sides anastomose across the front of the sternum.

THE LYMPH GLANDS OF THE THORAX.

The lymph glands of the thorax form 5 named groups, with subdivisions.

(1) The **sternal lymph glands** form two groups each of which lies at the corresponding margin of the sternum along the line of the internal mammary artery. The glands are variable in number (4-18) and in size. They receive *afferents* from the upper part of the muscles of the abdominal wall, from the diaphragm, from the anterior part of the wall of the thorax, and from the medial portions of the mammæ. Their *efferents* communicate with the upper anterior mediastinal glands and with the inferior deep cervical glands, and they terminate on the right side in the right lymphatic or the right broncho-mediastinal duct and on the left in the thoracic duct. Occasionally, also, they end directly in the internal jugular or the subclavian vein.

(2) The **intercostal lymph glands** are lateral and medial. The *lateral glands* lie in the posterior parts of the intercostal spaces, the *medial* are placed in front of the heads of the ribs. Their *afferents* are derived from the boundaries and contents of the spaces. The *efferents* of the glands of the upper spaces pass

either to the posterior mediastinal glands or to the thoracic duct. Those of the lower spaces, on each side, form a descending trunk which passes through the aortic opening of the diaphragm and ends in the cisterna chyli.

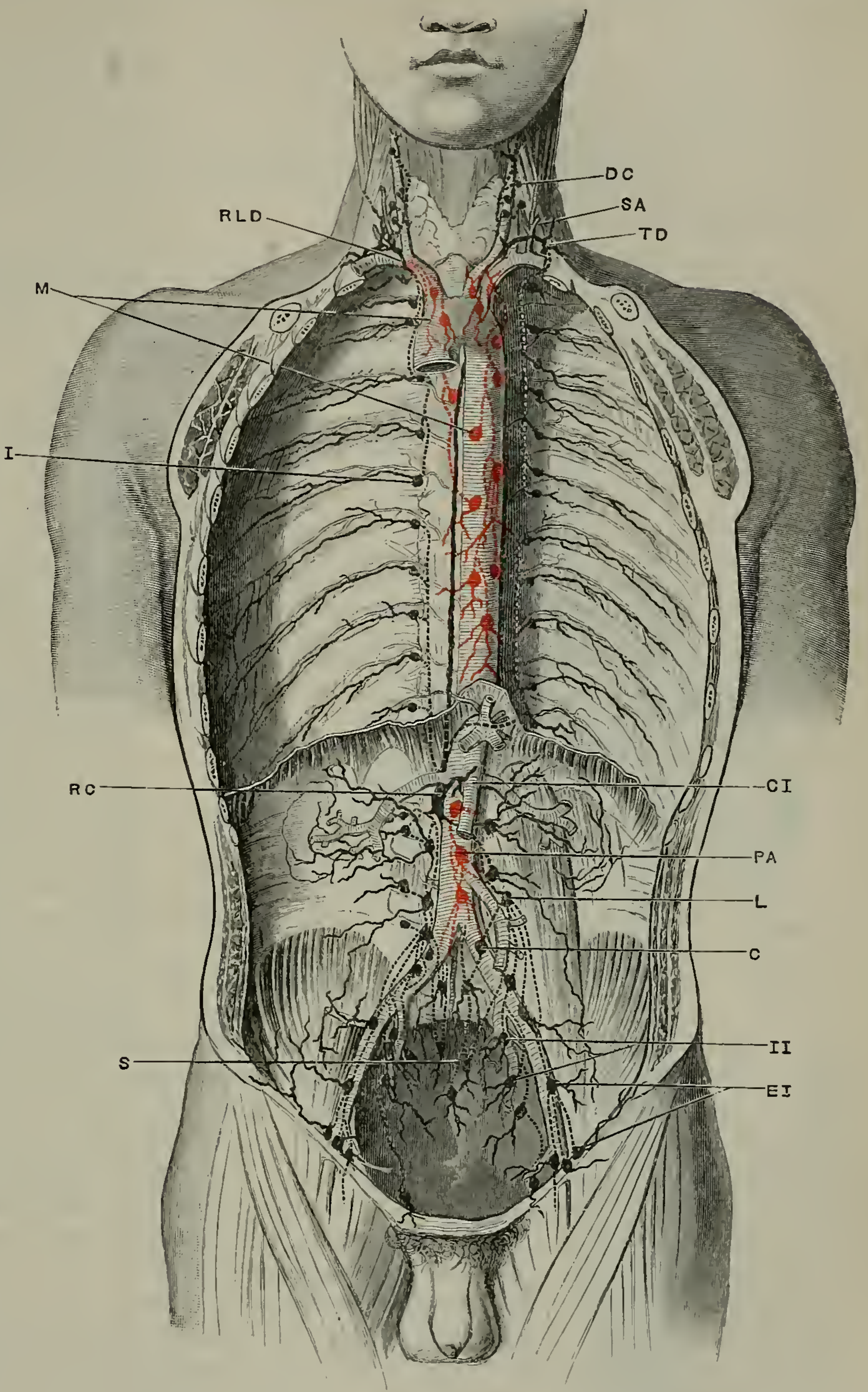

FIG. 786.—DEEP LYMPHATIC GLANDS AND VESSELS OF THE THORAX AND ABDOMEN (diagrammatic).

Afferent vessels are represented by continuous lines, and efferent and interglandular vessels by dotted lines.

C.	Common iliac glands.	M.	Mediastinal glands and vessels.
C.I.	Common intestinal trunk.	P.A.	Pre-aortic glands and vessels.
D.C.	Deep cervical glands.	R.C.	Cisterna chyli.
E.I.	External iliac glands.	R.L.D.	Right lymphatic duct.
I.	Intercostal glands and vessels.	S.	Sacral glands.
I.I.	Hypogastric glands.	S.A.	Scalenus anterior muscle.
L.	Lumbar glands.	T.D.	Thoracic duct.

(3) The **anterior mediastinal lymph glands** form two groups, a lower and an upper. The *lower group* consists of 3 or 4 glands, and is situated, posterior to the sternum, in the lower part of the anterior mediastinum. It receives *afferents* from immediately adjacent parts and from the liver and the diaphragm. Its *efferents* communicate with the upper anterior mediastinal glands, and they end, for the main part, in the broncho-mediastinal trunk.

The *upper group* consists of from 8 to 19 glands which lie posterior to the manubrium sterni and anterior to the thymus and the great vessels of the superior mediastinum. Their *afferents* are derived from the lower group of anterior mediastinal glands, from the pericardium, the heart, the thymus, the thyreoid gland, and from the sternal glands. Their *efferents* pass mainly to the broncho-mediastinal trunk, but they communicate with the medial inferior deep cervical glands and possibly also with the thoracic duct.

(4) The **posterior mediastinal lymph glands**, 8-12, lie along the descending part of the thoracic aorta and the thoracic part of the œsophagus. They receive *afferents* from the diaphragm, the pericardium, the œsophagus, and other immediately adjacent tissues. Some of their *efferents* join the thoracic duct, others the broncho-mediastinal trunk, and some pass to the bronchial glands.

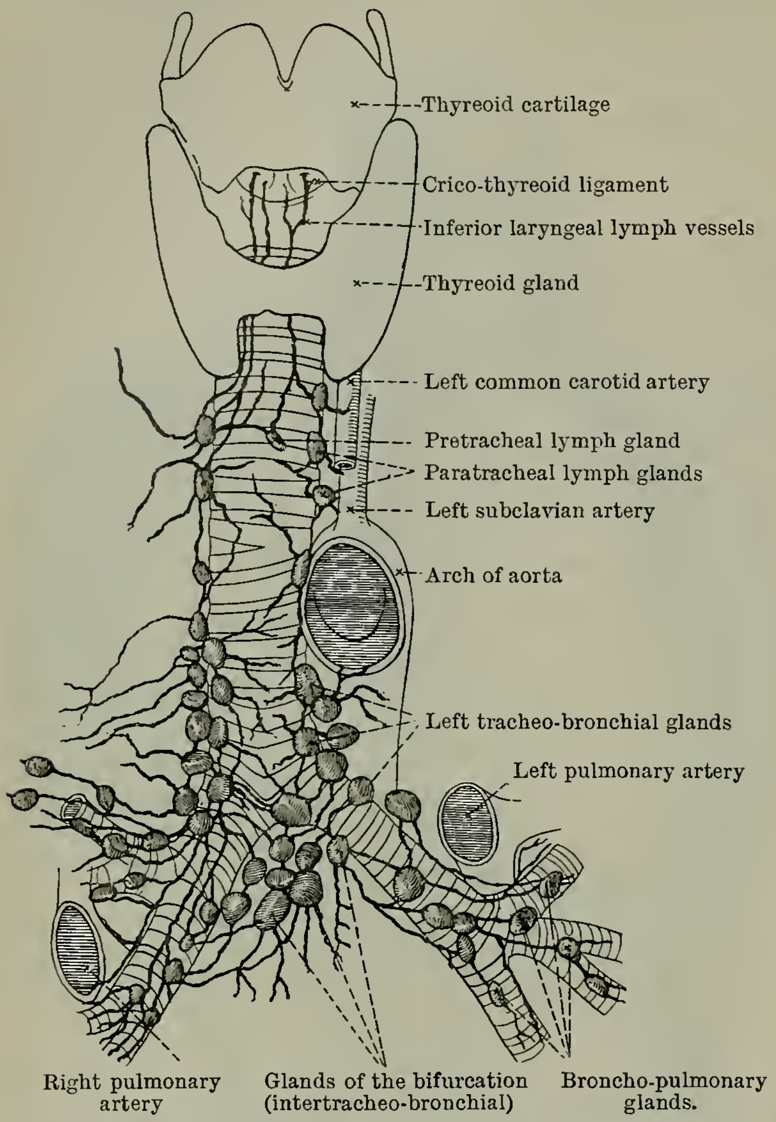
Thyreoid cartilage
Crico-thyreoid ligament
Inferior laryngeal lymph vessels
Thyreoid gland
Left common carotid artery
Pretracheal lymph gland
Paratracheal lymph glands
Left subclavian artery
Arch of aorta
Left tracheo-bronchial glands
Left pulmonary artery
Right pulmonary artery
Glands of the bifurcation (intertracheo-bronchial)
Broncho-pulmonary glands.

Fig. 787.—The Glands in Relation to the Trachea and the Main Bronchi.

(5) **Bronchial Lymph Glands.**—Under the term are included all the lymph glands which are closely associated with the walls of the intra-thoracic part of the trachea and with the main bronchi and their intra-pulmonary branches. The glands are extremely numerous, and they are conveniently classified, by Bartels, into four groups—(1) tracheo-bronchial right and left; (2) the glands of the bifurcation, also called inter-tracheo-bronchial; (3) broncho-pulmonary; (4) pulmonary. At birth and for some years afterwards they are pink in colour, but later they become blackened by the deposit of carbonaceous particles derived from the atmosphere.

(1) The **tracheo-bronchial lymph glands** are those which are situated in the lateral angle between the trachea and the bronchus, on each side. On the right side they vary in number from 5 to 9, on the left from 3 to 6. Those on the left are in close relation with the left recurrent nerve. Their *afferents* are derived from the other groups of bronchial glands and from the adjacent parts of the trachea and bronchi. They are connected with the anterior and posterior mediastinal glands. Their *efferents* pass to the broncho-mediastinal trunk and also to the inferior deep cervical glands. They are associated, also, by interglandular vessels, with the paratracheal glands.

(2) The **lymph glands of the bifurcation** (intertracheo-bronchial) lie below the trachea, in the angle between the two main bronchi. They are situated between the roots of the great vessels anteriorly and the œsophagus and the aorta posteriorly. Their *afferents* are derived from the broncho-pulmonary glands and from adjacent parts; their *efferents* terminate in the tracheo-bronchial glands. They are connected with the posterior mediastinal glands.

(3) **The Broncho-Pulmonary Lymph Glands.**—Each group of broncho-pulmonary glands, right and left, lies in the hilum of the corresponding lung, in the angles between the branches of the bronchial tube. The glands vary considerably in number, and they receive *afferents*, either directly or through the pulmonary glands, from the lung substance. They also receive afferents from the pleura; and their *efferents* pass to the tracheo-bronchial glands and to the glands of the bifurcation.

(4) The **pulmonary lymph glands** lie in the lung substance and usually in the angles between two bronchial tubes. Their *afferents* are derived from the lung substance, and their *efferents* pass to the broncho-pulmonary glands.

THE LYMPH VESSELS OF THE THORAX.

The lymph vessels of the thorax form two main groups—(*a*) the vessels of the thoracic wall, and (*b*) the vessels of the contents of the thorax.

(*a*) The **Lymph Vessels of the Thoracic Wall** are the intercostal lymph vessels and the lymph vessels of the diaphragm.

(1) The **Intercostal Lymph Vessels** receive lymph from the ribs and from the content of the intercostal spaces, and they terminate in the intercostal and sternal glands. Communications are said to exist between the intercostal vessels and the glands of the axilla.

(2) The **Lymph Vessels of the Diaphragm.**—The lymph vessels from the anterior part of the diaphragm pass to the lower sternal and anterior mediastinal glands, and those from the posterior part to the posterior mediastinal glands.

(*b*) The **Lymph Vessels of the Contents of the Thorax** are :—

(1) The **Lymph Vessels of the Heart**, which follow the courses of the coronary arteries, and pass to the anterior mediastinal glands.

(2) The **Lymph Vessels of the Pericardium**, which terminate in adjacent glands.

(3) The **Lymph Vessels of the Thymus**, some of which pass to the anterior mediastinal glands, some to the tracheo-bronchial glands, others to the medial inferior deep cervical glands.

(4) The **Lymph Vessels of the Thoracic Part of the Œsophagus**, which are separable into upper and lower groups. The upper pass to the bronchial, the posterior mediastinal, and the lower deep cervical glands. The lower group end in the glands situated at the cardiac end of the stomach. The two groups anastomose together.

(5) The **Lymph Vessels of the Pleura.**—The vessels from the apical parts of the parietal portion of the pleura pass to the adjacent lymph trunks or their tributaries. The vessels from the posterior part of the parietal pleura join the intercostal glands, and those from the anterior part end in the sternal glands.

The **Lymph Vessels of the Lungs and the Visceral Pleura** pass to the broncho-pulmonary glands.

THE LYMPH GLANDS OF THE INFERIOR EXTREMITY.

The lymph glands of the inferior extremity, like those of the superior, are separable into a superficial and a deep group.

The **superficial lymph glands** lie, almost entirely, in the subinguinal region, though occasionally one or more may be situated above the level of the inguinal ligament, and therefore in the inguinal region. On this account they are separated in the B.N.A. into inguinal and subinguinal groups. Both groups lie in the superficial fascia.

The **inguinal lymph glands**, when they exist, are merely scattered members of the subinguinal group which lie above the level of the inguinal ligament. They receive *afferents* from the lower and anterior part of the abdominal wall. Their *efferents* terminate either in the superficial or the deep subinguinal glands.

The **superficial subinguinal glands** (Figs. 784, 788) form two groups, a proximal and a distal, each of which is separable into medial and lateral parts; but the various members of the groups are intimately connected together by communicating vessels.

The *proximal group* lies along the line of the inguinal ligament. It may extend from the anterior superior spine of the ilium to the pubic tubercle. Its lateral members receive *afferents* from the lower and lateral part of the abdominal wall, from the buttock, and the proximal and lateral part of the thigh.

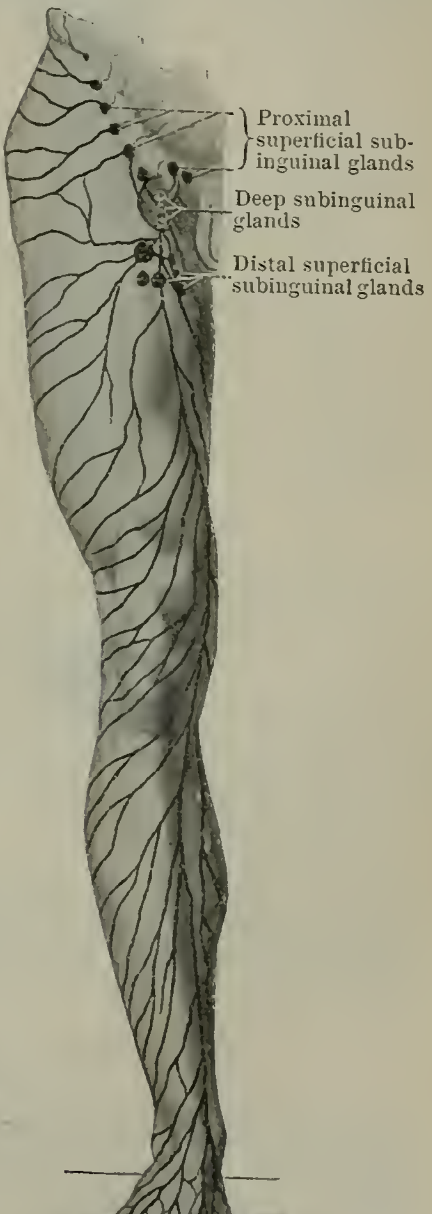
Proximal superficial subinguinal glands
Deep subinguinal glands
Distal superficial subinguinal glands

Fig. 788.—Diagram of the Lymph Vessels and Lymph Glands of the Lower Extremity.

The more medial members of the proximal group receive afferents from the anal canal, the perineum, the scrotum, the penis, and the pubic region in the male, and from the corresponding parts, including the lower part of the vagina, in the female.

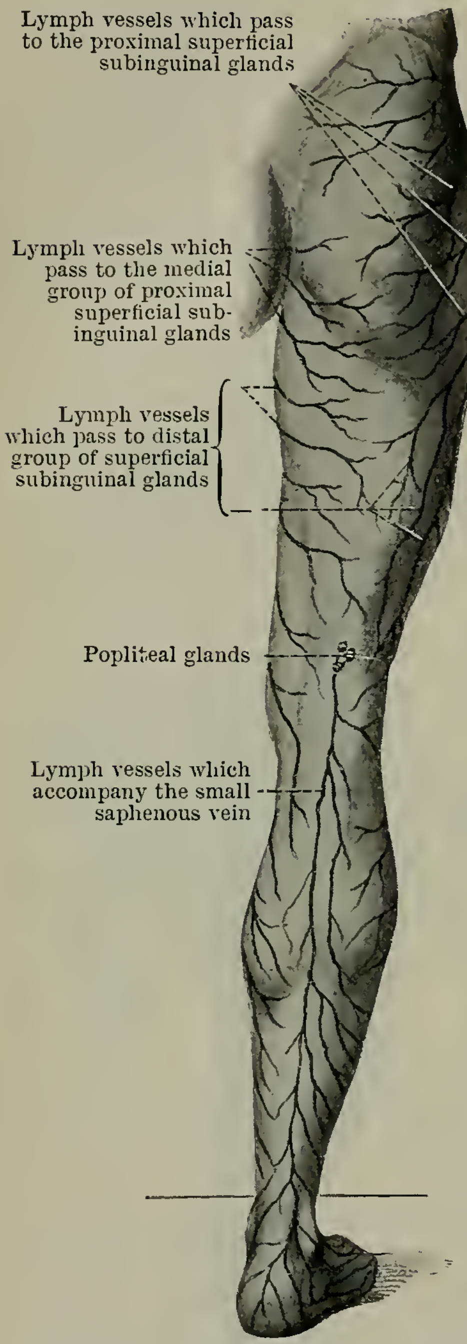
Lymph vessels which pass to the proximal superficial subinguinal glands
Lymph vessels which pass to the medial group of proximal superficial subinguinal glands
Lymph vessels which pass to distal group of superficial subinguinal glands
Popliteal glands
Lymph vessels which accompany the small saphenous vein

Fig. 789.—Diagram of the Lymph Vessels of the Posterior Part of the Lower Extremity.

The *distal group* of superficial subinguinal glands lies along the line of the proximal part of the great saphenous vein—some on its lateral and some on its medial side. They receive *afferents* bearing lymph from the superficies of the greater part of the inferior extremity, with the exception of the lateral part of the foot, the heel, and a part of the posterior aspect of the leg.

The *efferents* of both proximal and distal groups of subinguinal glands pass to the deep subinguinal glands.

The **deep lymph glands** of the inferior extremity are the popliteal and the deep subinguinal glands. Occasionally a deep gland is met with in the leg in relation with the proximal third of the anterior tibial artery.

The **popliteal lymph glands** (Fig. 789) lie in the popliteal fossa. One is usually situated, comparatively superficially, at the point where the small saphenous vein pierces the deep fascia and enters the fossa. It receives *afferents*, which accompany the small saphenous vein, from the lateral part of the foot, the heel, and the posterior part of the calf. Its *efferents* pass to the deeper glands.

The deeper glands lie in the fat around the popliteal vessels and are sometimes separated into inter-condylar and supra-condylar groups. Their *afferents* are derived from the more superficial gland and from the deeper tissues of the leg and foot. Their *efferents* pass to the deep subinguinal glands.

The **deep subinguinal glands** (Figs. 784, 788, 794) lie in the femoral trigone. They are small glands, three to seven in number, which are difficult to demonstrate. Some of them lie in the femoral canal, the most proximal being situated in or close to the femoral ring. Their *afferents* are the efferents of the other glands of the lower extremity, and, in addition, vessels from the deeper parts of the penis or the clitoris. Their *efferents* pass to the external iliac glands.

THE LYMPH VESSELS OF THE INFERIOR EXTREMITY.

The arrangement of the **superficial lymph vessels** of the toes and the foot is very similar to that met with in the fingers and the hand. From lymph plexuses on the plantar aspect vessels pass to the dorsum of the foot and toes, where they unite into a number of vessels, the majority of which accompany the great saphenous vein and terminate in the distal group of superficial subinguinal glands. Some of the lymph from the lateral part of the plantar surface and from the lateral border of the foot, and the lymph from the heel enter vessels which accompany the small saphenous vein; they end either in the more superficial gland of the popliteal fossa or in the deeper glands of that region (Fig. 789).

With the exception of the lymph vessels from the lateral and posterior part of the leg, which accompany the small saphenous vein to the popliteal glands, all the superficial lymph vessels of the leg, thigh, and buttock pass to the superficial subinguinal glands; those from the leg and thigh mainly to the glands of the distal group; those of the buttock chiefly to the lateral glands of the proximal group.

The **deep lymph vessels** of the inferior extremity accompany the deep blood-vessels. Many of the vessels from the leg and foot end in the popliteal glands, but some pass directly to the deep subinguinal glands. The deep vessels of the more proximal parts of the inferior extremity end in the deep subinguinal glands and in the hypogastric glands.

THE LYMPH GLANDS OF THE ANTERIOR ABDOMINAL WALL.

Some lymph glands are regularly, and others are occasionally present in the anterior wall of the abdomen. Those fairly regularly present are :—

The **inferior epigastric lymph glands**, 3-6, which lie along the course of the inferior epigastric artery. Their *afferents* are from the deep part of the umbilicus and their *efferents* pass to the inferior external iliac glands.

The **Pubic Gland or Glands.**—One or more small glands which lie anterior to the suspensory ligament of the penis or clitoris. Their *afferents* are vessels from the superficial parts of the penis or clitoris, and their *efferents* end in the proximal superficial subinguinal glands.

The occasional glands are :—

(1) A **superior epigastric gland** which sometimes lies in the superficial fascia of the median part of the epigastric region. Its *afferents* are from the adjacent parts and its *efferents* pass to the sternal glands. It is probably very rare.

(2) **Circumflex iliac glands**, 2-4, which lie along the course of the deep circumflex iliac artery.

(3) An **umbilical gland** which lies in the extra-peritoneal tissue below the umbilicus. When it is present it receives vessels from the umbilicus and its *efferents* go to the external iliac glands.

(4) **Supra-umbilical glands**, 1-2, small glands which lie in the extra-peritoneal tissue above the umbilicus. Its *afferents* are from the region of the umbilicus. The *efferents* probably pass to the inferior anterior mediastinal glands.

THE LYMPH VESSELS OF THE ANTERIOR WALL OF THE ABDOMEN.

The superficial lymph vessels of the upper part of the anterior wall of the abdomen go, for the most part, to the anterior or pectoral group of axillary glands; but some pierce the wall of the lower part of the thorax and end in the sternal glands.

The superficial lymph vessels of the lower part of the anterior wall of the abdomen terminate either in the inguinal glands or in the proximal group of superficial subinguinal glands.

The deep lymph vessels of the upper part of the anterior abdominal wall accompany the superior epigastric vessels and terminate in the sternal glands; but some may be connected with the supra-umbilical glands if they are present.

The deep lymph vessels of the lower part of the anterior wall of the abdomen accompany the inferior epigastric vessels, and end in the inferior external iliac glands or the inferior epigastric glands.

THE LYMPH VESSELS OF THE EXTERNAL GENITALS.

The **lymph vessels of the scrotum** in the male and of the **labia majora** in the female pass to the proximal superficial subinguinal glands, and mostly to the medial group.

The **superficial lymph vessels of the penis** go to the medial glands of the proximal subinguinal group.

The **deep lymph vessels of the penis**, including those of the penile portion of the urethra, end either in the medial glands of the proximal subinguinal group or in the deep subinguinal glands.

The termination of the **lymph vessels of the clitoris** is similar to that of the lymph vessels of the penis.

LYMPH GLANDS OF THE PELVIS AND ABDOMEN.

The lymph glands of the pelvis are separable into visceral and parietal groups.

The Visceral Glands of the Pelvis.

Vesical Lymph Glands.—The **lymph glands of the urinary bladder** form an anterior and two lateral groups.

(*a*) The anterior lymph glands of the bladder are variable in number. They lie in the retro-pubic fat and receive *afferents* from the anterior and antero-lateral parts of the bladder wall. Their *efferents* go to the external iliac glands.

(*b*) The lateral lymph glands of the bladder lie along the course of the umbilical artery on each side. Their *afferents* are derived from the upper and lateral parts of the bladder and their *efferents* end in the external iliac glands.

The **ano-rectal lymph glands** (2-8) lie in the lower part of the pelvis minor, in relation with the ampullary part of the rectum, between its muscular wall and its external fibrous coat. Their *afferents* are derived from the muscular and mucous coats of the rectum and from the upper part of the anal canal, and their *efferents* pass to the superior hæmorrhoidal glands.

The **para-uterine lymph glands** (1-6), lie at the sides of the neck of the uterus in the bases of the broad ligaments. They receive afferents from the neck of the uterus and the efferents pass to the hypogastric glands.

The **superior hæmorrhoidal lymph glands** lie along the course of the superior hæmorrhoidal artery in the pelvic meso-colon. They receive *afferents* from the walls of the rectum, and from the ano-rectal glands. Their *efferents* go to the inferior mesenteric glands.

The Parietal Lymph Glands of the Pelvis.

The **sacral lymph glands**, variable in number, lie along the anterior aspect of the sacrum, between the anterior sacral foramina. Their *afferents* are from the rectum, the prostate, and the adjacent parts of the wall of the pelvis. Their *efferents* end in the sub-aortic, the aortic, and the hypogastric glands.

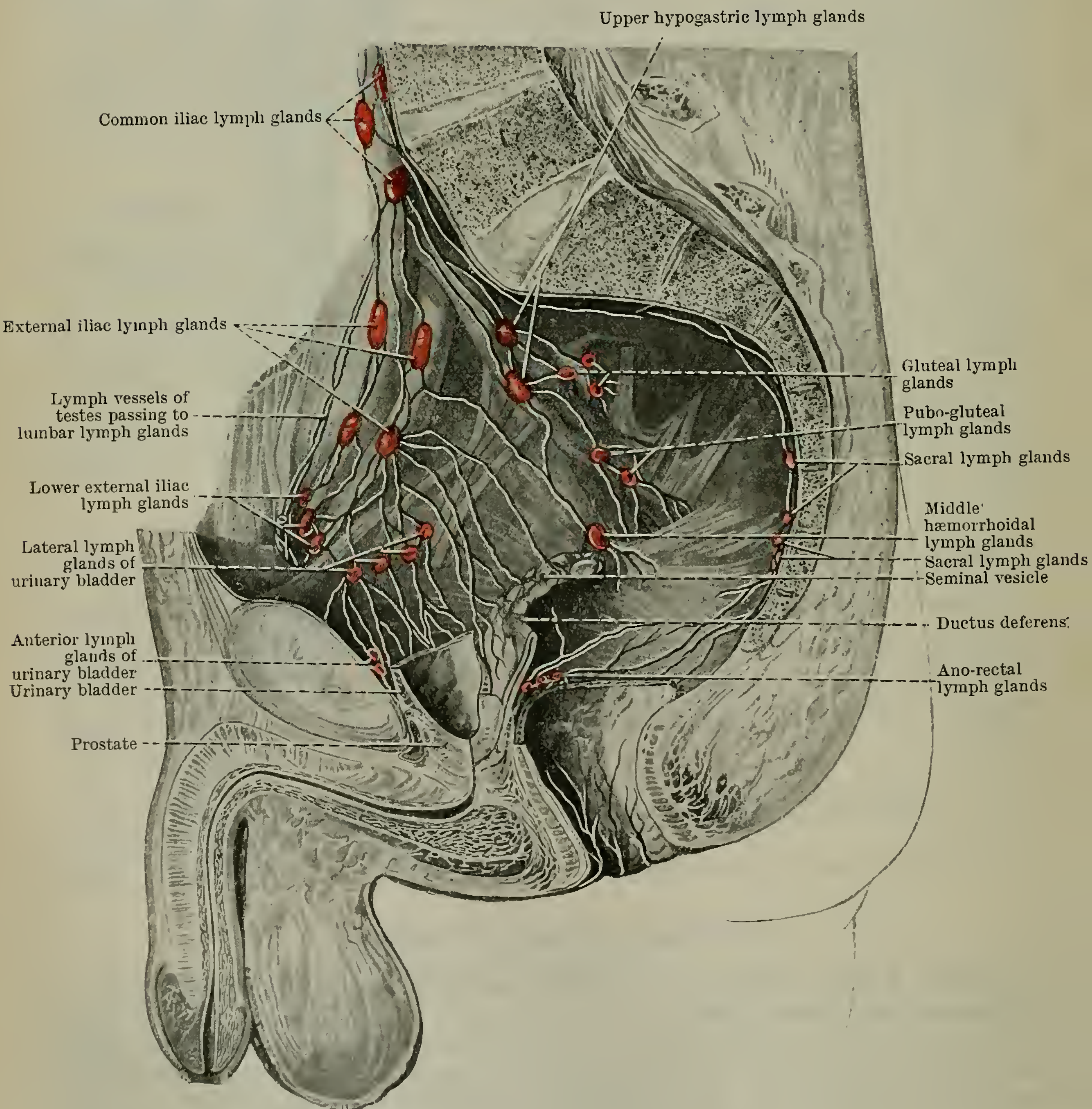
Upper hypogastric lymph glands
Common iliac lymph glands
External iliac lymph glands
Lymph vessels of testes passing to lumbar lymph glands
Lower external iliac lymph glands
Lateral lymph glands of urinary bladder
Anterior lymph glands of urinary bladder
Urinary bladder
Prostate
Gluteal lymph glands
Pubo-gluteal lymph glands
Sacral lymph glands
Middle hæmorrhoidal lymph glands
Sacral lymph glands
Seminal vesicle
Ductus deferens
Ano-rectal lymph glands

Fig. 790.—Diagram of the Lymph Glands of the Pelvis.

The **subaortic lymph glands** (1-3) lie on the anterior aspect of the fifth lumbar vertebra. Their *afferents* are from the sacral glands, the hypogastric glands, and the external iliac glands. Their *efferents* go to the aortic glands (Fig. 794).

The **Hypogastric Lymph Glands** form right and left groups, which are associated with the corresponding hypogastric vessels. As a rule they lie near the origins of the main branches of the hypogastric artery, or in the angles between the branches, and they, therefore, are separable into a number of groups.

The **Gluteal Lymph Glands** lie in relation to the superior gluteal artery and receive *afferents* from the gluteal region. Their *efferents* pass to the common iliac glands.

The **Pubo-gluteal Lymph Glands** (1-2) lie in relation to the origins of the inferior gluteal and internal pudendal arteries. They receive *afferents* from the thigh and perineum and their *efferents* end in the common iliac glands.

The **Middle Hæmorrhoidal Gland** lies more medially than the other glands of the group, close to the lateral wall of the rectum at the point where the middle hæmorrhoidal artery breaks up into its terminal branches. It receives *afferents* from the rectum and gives *efferents* to the other hypogastric and to the external iliac glands.

The **Inter-iliac Glands** lie in the angle between the external iliac and the hypogastric arteries, and cannot be clearly disassociated from the medial external iliac glands. They receive *afferents* from the lower parts of the pelvic portions of the genito-urinary organs. Their *efferents* pass to the common iliac glands.

The **Obturator Gland** lies at the inner end of the obturator canal, above the obturator vessels. It receives *afferents* from the upper and medial parts of the thigh and its *efferents* join the inter-iliac and common iliac glands.

The **Iliac Lymph Glands** are separable into a lower group, associated with the external iliac artery, **lymphoglandulæ iliacæ externæ**, and an upper group, the **lymphoglandulæ iliacæ communes.**

The External Iliac Glands.—According to Poirier and Cuneo, the external iliac lymph glands form three chains, lateral, intermediate, and medial, which lie, respectively, at the lateral side, anterior to, and at the medial side of the external iliac vessels. The three lowest members of the group, that is the lowest member of each chain, lie in close relation to the abdominal aperture of the femoral ring, and are frequently spoken of as supra-femoral glands. They receive *afferents* from the superficial subinguinal and the deep subinguinal glands, from the urethra and the deeper parts of the penis, and from the portions of the abdominal wall supplied by the deep circumflex iliac and inferior epigastric arteries. Their *efferents* end in the upper glands of the external iliac group.

The higher members of the external iliac lymph glands receive *afferents* from the membranous part of the urethra, the prostate, the bladder, the vagina, and the neck of the uterus. They are connected by anastomoses with the hypogastric glands, particularly the middle hæmorrhoidal gland, and their *efferents* pass to the common iliac glands.

The Common Iliac Lymph Glands.—The glands of the common iliac group are sometimes separated into a lateral and intermediate and a medial series. The lateral and intermediate groups are quite distinct, the former lying along the lateral margin of the artery and the latter posterior to it, but the medial group is not clearly defined from the sub-aortic group already mentioned. Indeed the sub-aortic group may be looked upon as constituted by the medial common iliac glands of opposite sides.

The common iliac glands receive *afferents* from the external iliac and the hypogastric glands, and consequently from practically the whole of the pelvic contents, except the ovaries of the female.

THE LYMPH VESSELS OF THE PELVIC VISCERA.

The Lymph Vessels of the Urethra of the Male.—It has been pointed out that the lymph vessels of the greater part of the penile portion of the urethra are said to pass to the deep subinguinal glands. The lymph vessels of the bulbar and membranous parts of the urethra have not yet been satisfactorily demonstrated, but it is stated that they pass to the hypogastric glands, to the medial supra-femoral gland of the external iliac group, and to the higher glands of the external iliac group. The lymph vessels of the prostatic part of the urethra unite with the other lymph vessels of the prostate.

The Lymph Vessels of the Prostate pass to the anterior and lateral vesical glands, to the external iliac glands, to the hypogastric glands, and to the sacral and hæmorrhoidal glands. They anastomose with the lymph vessels of the bladder and the deferent duct.

The Lymph Vessels of the Urethra of the Female have terminations corresponding with those of the vessels of the membranous and prostatic portions of the urethra of the male.

The Lymph Vessels of the Seminal Vesicle, on each side, pass to the medial glands of the external iliac group.

The Lymph Vessels of the Ductus Deferens, on each side, anastomose with those of the seminal vesicle, and they pass to the hypogastric and external iliac glands.

The Lymph Vessels of the Urinary Bladder.—Many of the lymph vessels from the antero-lateral aspect of the urinary bladder pass to the corresponding anterior and lateral vesical lymph glands and, through them, become connected with the external iliac and hypogastric glands, but some apparently pass directly to the hypogastric lymph glands.

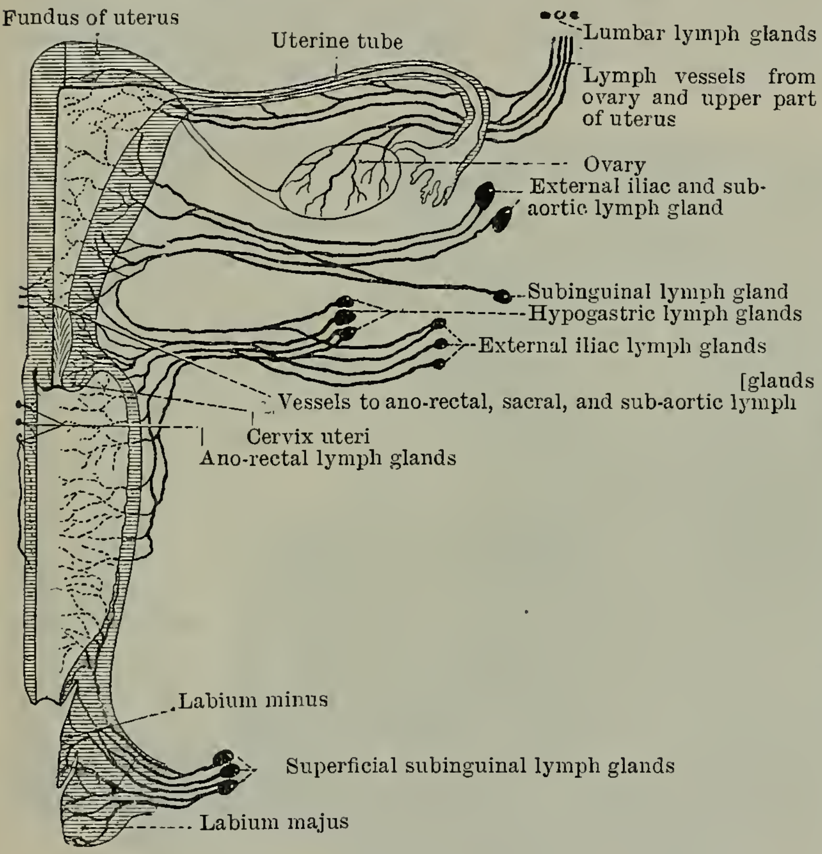
Fundus of uterus
Uterine tube
Lumbar lymph glands
Lymph vessels from ovary and upper part of uterus
Ovary
External iliac and sub-aortic lymph gland
Subinguinal lymph gland
Hypogastric lymph glands
External iliac lymph glands
[glands
Vessels to ano-rectal, sacral, and sub-aortic lymph
Cervix uteri
Ano-rectal lymph glands
Labium minus
Superficial subinguinal lymph glands
Labium majus

Fig. 791.—Diagram of Lymph Vessels of Female Genital Organs.

The lymph vessels from the superior, and many from the posterior part of the bladder, on each side, end in the external iliac and hypogastric glands, but some from the posterior part pass directly to the sub-aortic glands.

The Lymph Vessels of the Ureter.—Little is known of the lymph vessels of the ureter except that those of its lower extremity anastomose with the lymph vessels of the urinary bladder. It is suggested that the vessels pass to the nearest lymph glands.

The Lymph Vessels of the Vagina.—The lymph vessels of the lower part of the vagina anastomose with the lymph vessels of the labia minora and so transmit lymph to the superficial subinguinal glands. The lymph vessels of the upper parts of the vagina pass to the hypogastric glands and also, with the lymph vessels of the cervix uteri, to the external iliac glands. Some of the lymph vessels from the posterior wall of the vagina terminate in the ano-rectal glands.

The Lymph Vessels of the Uterus.—The Lymph Vessels of the Lower Part of the Uterus. The majority of the lymph vessels from the lower part of the uterus, including the cervix, unite with the lymph vessels of the upper part of the vagina and pass to the hypogastric glands including the inter-iliac group (p. 1025). Some pass to the external iliac glands, and others from the lower and posterior part become associated with the ano-rectal, the sacral, and the sub-aortic glands.

The Lymph Vessels of the Body of the Uterus run in several directions. The most important outflow is along the upper part of the broad ligament, below the uterine tube, to the region of the ovary where there is an anastomosis with the ovarian lymph vessels. Afterwards the lymph vessels of this stream cross the brim of the pelvis minor and ascend to the lumbar lymph glands. The accessory outflows are to the external iliac glands; to the sub-aortic glands; and, along the round ligament, to the superior group of subinguinal glands.

The Lymph Vessels of the Uterine Tube accompany the vessels of the main outflow from the body of the uterus, and those from the ovary, and pass to the lumbar lymph glands.

The Lymph Vessels of the Ovaries.—The lymph vessels of each ovary accompany the ovarian artery and some of the uterine lymph vessels, along the upper part of the broad ligament to the brim of the pelvis minor and then upwards to the lumbar lymph glands.

The Lymph Vessels of the Testis and Epididymis.—The testis and the epididymis are not normally pelvic organs in the adult, but their lymph vessels may be considered here, inasmuch as the testes correspond, morphologically, with the ovaries. The lymph vessels of each testis and its epididymis accompany the testicular arteries and ascend to the lumbar region where they terminate in the lumbar lymph glands.

The Lymph Vessels of the Rectum.—The lymph vessels of the rectum and the upper part of the anal canal pass for the most part along the middle and superior hæmorrhoidal vessels. Those which accompany the branches of the middle hæmorrhoidal artery, on each side, pass to the corresponding middle hæmorrhoidal gland of the hypogastric group; whilst the lymph vessels of the rectum which accompany the branches of the superior hæmorrhoidal artery become associated with the ano-rectal, the sacral, and the inferior mesenteric lymph glands. The lymph vessels of the lower part of the anal canal go to the medial proximal subinguinal glands.

THE LYMPH GLANDS OF THE ABDOMEN.

The lymph glands of the abdomen are separated into visceral and parietal groups. The visceral groups are those more directly associated with the lymph vessels which issue from the walls of the abdominal part of the alimentary canal, although they may lie posterior to the peritoneum in relation to the posterior wall of the abdomen. The parietal glands lie in relation with the abdominal part of the aorta and the inferior vena cava and the adjacent parts of the posterior abdominal wall.

Visceral Lymph Glands of the Abdomen.

Lymphoglandulæ Gastricæ.—The **gastric lymph glands** are arranged in two main groups, the *lymphoglandulæ superiores* which lie in association with the arteries of the smaller curvature, and the *lymphoglandulæ inferiores* associated with the greater curvature. Jamieson and Dobson have separated the superior gastric glands into several subdivisions.

Lymphoglandulæ Gastricæ Superiores.—(*a*) The **Anterior Left Gastric Glands** (lower coronary glands, J. and D.). The anterior left gastric glands lie between the layers of the lesser omentum along the course of the left gastric artery. They receive *afferents* from the greater part of the lesser curvature of the stomach and the adjacent parts of its anterior and posterior walls, and they send *efferents* to the posterior left gastric glands.

(*b*) The **Right Paracardial Glands** are essentially members of the anterior left gastric group which lie to the right of the cardiac orifice of the stomach. Their *afferents* are derived from the cardiac part of the stomach and their *efferents* go to the posterior left gastric glands.

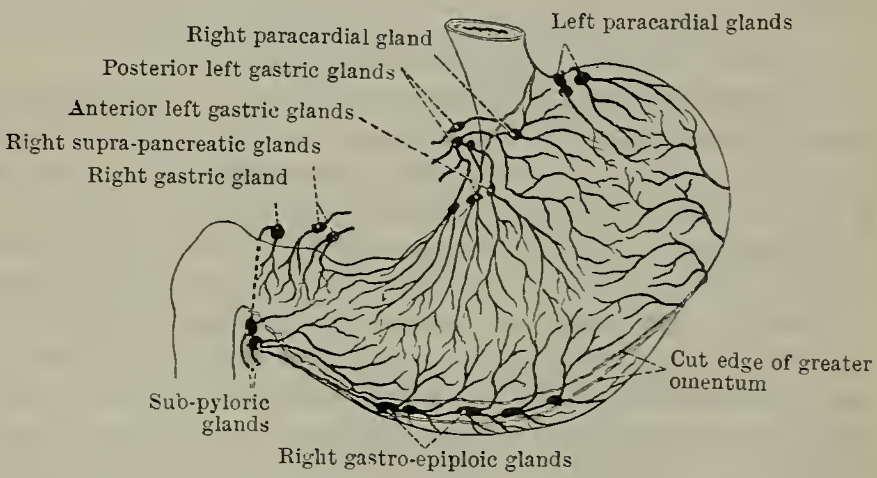
Right paracardial gland
Left paracardial glands
Posterior left gastric glands
Anterior left gastric glands
Right supra-pancreatic glands
Right gastric gland
Cut edge of greater omentum
Sub-pyloric glands
Right gastro-epiploic glands

Fig. 792.—Lymph Vessels and Glands of the Stomach. (After Jamieson and Dobson, modified.)

(*c*) The **Left Paracardial Glands** lie to the left of the œsophageal orifice. They receive *afferents* from the adjacent parts of the cardiac portion of the stomach, and their *efferents* end in the posterior left gastric glands.

(*d*) The **Posterior Paracardial Glands** lie on the posterior aspect of the stomach, between the layers of the gastro-phrenic ligament. Their *afferents* are from the neighbouring parts of the cardia and their *efferents* go to the posterior left gastric glands.

(*e*) The **Posterior Left Gastric Glands** (upper coronary, J. and D.) lie around the left gastric artery as it passes forwards through the left gastro-pancreatic fold of peritoneum. They receive *afferents* from the previously mentioned groups of gastric glands and *direct afferents* from the cardiac portion of the stomach. Their efferents pass to the middle supra-pancreatic glands of Jamieson and Dobson (cœliac glands, B.N.A.).

(*f*) The **Right Gastric Gland** (pyloric of J. and D.) is a small gland, occasionally present, which lies immediately above the pylorus or the first part of the duodenum, in association with the right gastric artery. It receives *afferents* from the pylorus, and its *efferents* end in the sub-pyloric glands.

(*g*) The **Right Gastro-epiploic Glands** lie along the lower part of the greater curvature of the stomach, in association with the right gastro-epiploic artery. Their *afferents* are from the adjacent parts of the anterior and posterior surfaces of the stomach and their *efferents* pass to the sub-pyloric glands.

(*h*) The **Left Supra-pancreatic Glands** of Jamieson and Dobson (lymphoglandulæ pancreaticolienales, B.N.A.) lie along the course of the splenic artery and in the gastro-splenic ligament: they receive *afferents* from the left part of the stomach and from the spleen. Their *efferents* pass to the middle supra-pancreatic glands.

(*i*) The **Right Supra-pancreatic Glands** (J. and D.) lie in relation with the stem of the hepatic artery as it passes through the right gastro-pancreatic fold. They receive *afferents* directly from the pyloric part of the stomach and the liver, and give off *efferents* to the middle supra-pancreatic glands.

(*j*) The **Sub-pyloric Glands** (J. and D.). The sub-pyloric lymph glands lie at the right border of the omental bursa, in the angle between the superior and descending parts of the duodenum, between the head of the pancreas posteriorly and the peritoneum of the posterior wall of the great sac anteriorly. Their *afferents* are from the right gastro-epiploic glands, the right gastric gland, and from the pyloric portion of the stomach. The *efferents* pass to the middle supra-pancreatic glands.

(*k*) The **Biliary Lymph Glands** (J. and D.) lie along the line of the bile duct. They receive *afferents* from the gall-bladder and liver. One of the lower glands of the group, which lies posterior to the head of the pancreas, close to the lower end of the bile-duct, is associated, by direct afferents, with the upper part of the pylorus. Their *efferents* pass to the right and middle supra-pancreatic glands.

The highest member of the series is associated with the cystic artery and the gall-bladder and is called the *cystic gland.*

Lymphoglandulæ Hepaticæ (B.N.A.).—The **Hepatic Lymph Glands** of the Basle nomenclature are a few small glands which lie in the region of the porta hepatis, between the layers of the lesser omentum; they receive *afferents* from the liver and give *efferents* to the right supra-pancreatic glands (J. and D.).

Lymphoglandulæ Mesentericæ (B.N.A.).—The **Mesenteric Lymph Glands** lie between the layers of the mesentery, where they form three main groups: (*a*) a series of juxta-intestinal glands which lie close to the walls of the small gut; (*b*) an intermediate series of larger glands which lie in relation with the trunks of the rami intestinales of the superior mesenteric artery; and (*c*) a terminal group of large glands which lie round the upper part of the stem of the superior mesenteric artery. They receive lymph from all parts of the small intestine, from the cæcum, the vermiform process, the ascending colon, the transverse colon, and the part of the descending colon. Their *efferents* unite to form a common intestinal trunk, which enters the cisterna chyli.

The Lymph Glands of the Cæcum and the Vermiform Process and the Terminal part of the Ileum.—The lymph glands particularly associated with the terminal part of the ileum, the cæcum and its vermiform process, according to Jamieson and Dobson, are (1) the ileal, (2) the anterior ileo-colic, (3) the posterior ileo-colic, and (4) the appendicular. All these glands give off vessels which pass to the larger ileo-colic glands which lie along the ileo-colic branch of the superior mesenteric artery.

The **Ileal Glands** lie in the lower part of the mesentery. They receive *afferents* from the lower part of the ileum and give *efferents* to the main ileo-colic glands.

An **Appendicular Lymph Gland** is sometimes met with in the mesentery of the vermiform process. When it is present it may be associated with the vessels which pass from any part of the vermiform process. Its *efferents* pass to the main ileo-colic glands.

The **Anterior Ileo-colic Glands**, 1-4, lie in the anterior ileo-colic fold of peritoneum. Their *afferents* are derived from the anterior part of the cæcum and the root of the vermiform process, and *efferents* pass to the main ileo-colic glands.

The **Posterior Ileo-colic Glands**, more numerous than the anterior, lie in the angle between the ileum and the cæcum, and in the angle between the ileum and the ascending colon. Their *afferents* are from the posterior part of the cæcum and the root of the vermiform process. Their *efferents* pass to the main ileo-colic glands.

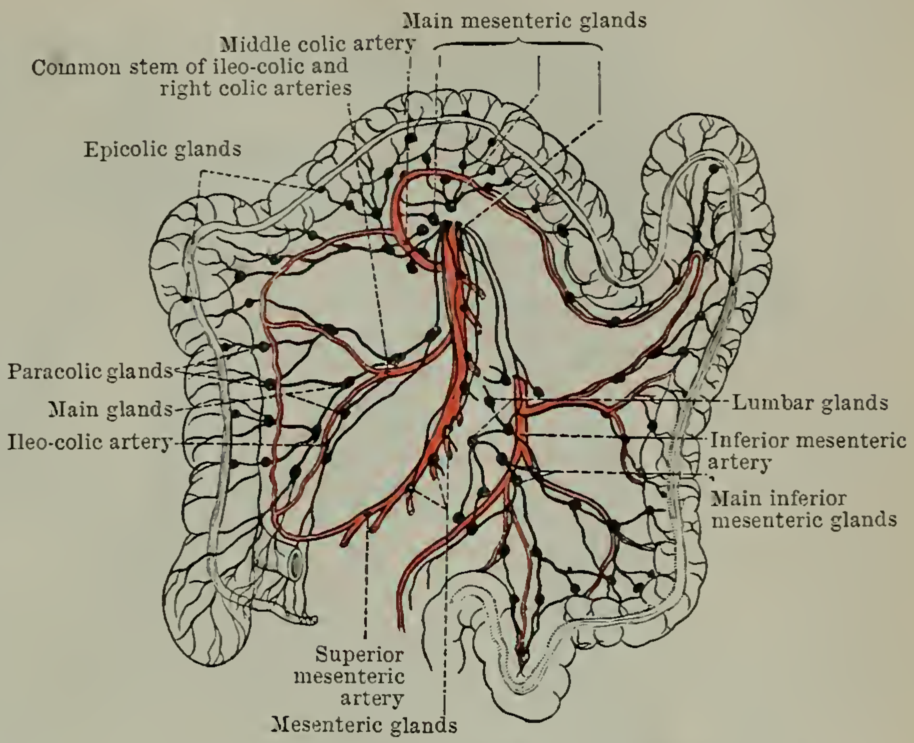
Main mesenteric glands
Middle colic artery
Common stem of ileo-colic and right colic arteries
Epicolic glands
Paracolic glands
Main glands
Ileo-colic artery
Lumbar glands
Inferior mesenteric artery
Main inferior mesenteric glands
Superior mesenteric artery
Mesenteric glands

FIG. 793.—DIAGRAM OF THE LYMPH GLANDS AND LYMPH VESSELS OF THE LARGE INTESTINE. (After Jamieson and Dobson.)

The **Lymph Glands of the Colon**, according to Jamieson and Dobson, may be considered as forming four groups, epicolic, paracolic, intermediate, and main.

The **Epicolic Glands** are small nodules which lie in the appendices epiploicæ and in relation with the wall of the gut. The **paracolic glands** lie along the medial borders of the ascending, descending, and iliac parts of the colon; along the upper border of the transverse colon, and on the mesenteric border of the pelvic colon. The intermediate glands lie along the branches of the colic arteries and the main groups are situated around the stems from which the colic arteries arise. The lymph gathered by the lymph plexuses in the walls of the gut passes through one or more of the groups of glands, and that which issues from the main group, in association with the ileo-colic and middle colic arteries, enters the main mesenteric glands which surround the upper part of the superior mesenteric artery. It is then carried by the efferents of those glands to the common intestinal lymphatic trunk. The lymph from the descending, the iliac, and the pelvic parts of the colon passes to the intermediate groups of inferior mesenteric glands and thence, for the main part, to the lumbar glands, but some of the efferents from the upper intermediate inferior mesenteric glands pass to the main group of superior mesenteric glands.

The lymph glands associated with the middle colic artery and its branches are the **lymphoglandulæ mesocolicæ** of the Basle nomenclature.

The **Main Glands of the Inferior Mesenteric Group** receive lymph from the intermediate left colic glands and transmit it to the lumbar glands through which it passes, by the lumbar lymph trunks, to the cisterna chyli; but some of the lymph from the upper intermediate left colic glands passes to the main mesenteric glands, and so to the common intestinal lymph trunk.

The **Middle Supra-pancreatic Lymph Glands** of Jamieson and Dobson correspond fairly closely with the **lymphoglandulæ cœliacæ** of the Basle terminology. They lie at the upper border of the pancreas around the cœliac artery. Their *afferents* are from the right and left supra-pancreatic glands, from the posterior left gastric glands, and from the sub-pyloric glands. They are connected by intermediate channels with the superior mesenteric glands, and they give *efferents* to the common intestinal lymph trunk and also to the common lumbar trunks.

Lymphoglandulæ Lumbales (B.N.A.).—The **Lumbar Lymph Glands** lie behind the peritoneum of the posterior wall of the abdomen, in association with the aorta, the inferior vena cava, the psoas and quadratus lumborum muscles, and the crura of the diaphragm. Those which are situated on the anterior aspect of the aorta are frequently spoken of as **pre-aortic glands** and those situated more laterally as **para-aortic glands.**

The **afferents** of the lumbar lymph glands are (1) the efferents of the common iliac glands, (2) efferents from the sub-aortic glands, (3) efferents from the sacral glands, (4) some efferents from the hypogastric glands, (5) efferents from the main inferior mesenteric glands, (6) the lymph vessels from the testes and epididymides and their coverings in the male, and from the ovaries, the uterine tubes, and the upper part of the uterus in the female, (7) lymph vessels from the kidneys, (8) lymph vessels from the suprarenal glands, (9) lymph vessels from the muscles of the back and of the posterior wall of the abdomen.

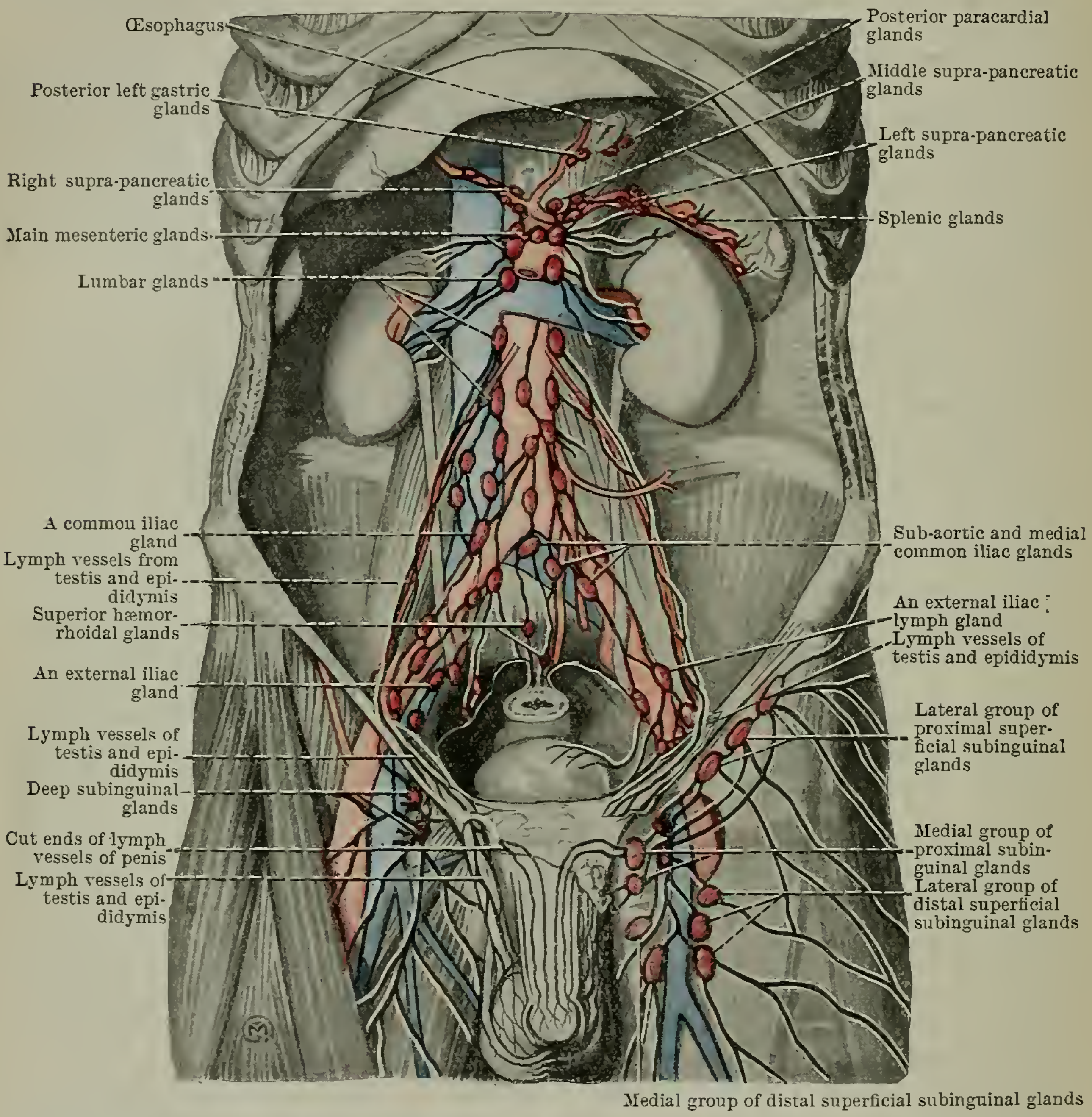
Œsophagus
Posterior left gastric glands
Right supra-pancreatic glands
Main mesenteric glands
Lumbar glands
A common iliac gland
Lymph vessels from testis and epididymis
Superior hæmorrhoidal glands
An external iliac gland
Lymph vessels of testis and epididymis
Deep subinguinal glands
Cut ends of lymph vessels of penis
Lymph vessels of testis and epididymis
Posterior paracardial glands
Middle supra-pancreatic glands
Left supra-pancreatic glands
Splenic glands
Sub-aortic and medial common iliac glands
An external iliac lymph gland
Lymph vessels of testis and epididymis
Lateral group of proximal superficial subinguinal glands
Medial group of proximal subinguinal glands
Lateral group of distal superficial subinguinal glands
Medial group of distal superficial subinguinal glands

FIG. 794.—SEMI-DIAGRAMMATIC VIEW OF THE LYMPH GLANDS AND VESSELS OF THE PROXIMAL PARTS OF THE LOWER EXTREMITIES, THE PELVIS MAJOR AND THE POSTERIOR PART OF THE ABDOMEN.

The *efferents* of the lumbar glands form two common lumbar lymph trunks, which pass to the cisterna chyli.

THE LYMPH VESSELS OF THE ABDOMINAL VISCERA AND THE SUPERIOR AND POSTERIOR WALLS OF THE ABDOMEN.

The Lymph Vessels of the Abdominal Part of the Alimentary Canal.—The lymph vessels in the walls of the alimentary canal form four plexuses: (1) a mucous plexus, in the mucous membrane, (2) a submucous plexus, in the submucous tissue, (3) a muscular plexus, between the two muscle coats, (4) a subserous plexus which lies in the areolar tissue between the peritoneal covering and the outer muscular coat. The four plexuses communicate freely with each other. The lymph is eventually collected from the subserous plexus and carried to the various groups of lymph glands. The vessels which carry away the lymph from the subserous plexuses of the various parts of the alimentary canal are spoken of in the following account as the lymph vessels of those parts.

The Lymph Vessels of the Stomach.—The lymph vessels of the stomach communicate freely with the lymph vessels of the œsophagus on the one hand and those of the duodenum on the other.

From the point of view of lymph outflow the area of each surface of the stomach may be divided into four parts. First a small right portion of the region of the pyloric canal, and, second, the remaining larger portion which is subdivided into three parts by two lines: (1) A line from the apex of the fundus to the pyloric canal along the junction of the upper and right two thirds with the left and lower third, (2) a line, parallel with the œsophagus, dividing the left and lower part into left and right portions (J. and D.). It must be understood, however, that the lymph vessels of the various areas communicate freely with one another (Fig. 792).

The Lymph Vessels of the Region of the Pyloric Canal pass (*a*) partly to the anterior left gastric glands, (*b*) partly to the right supra-pancreatic lymph glands, and (*c*) partly to the lower biliary group of lymph glands. If the right gastric gland is present some of the vessels of the upper pyloric region go to it, and in some cases vessels from the pyloric region pass directly to the posterior left gastric lymph glands.

The Lymph Vessels from the Right Upper Area of the larger portion of the stomach pass (*a*) to the anterior left gastric lymph glands, (*b*) to the posterior left gastric lymph glands, (*c*) to the paracardial lymph glands.

The Lymph Vessels from the Left Section of the Left and Lower Portion of the stomach pass along the gastro-splenic ligament to the splenic glands, which are occasionally present near the hilum of the spleen, and partly to the left supra-pancreatic lymph glands.

The Lymph Vessels from the Right Part of the Lower and Left Area follow the course of the right gastro-epiploic artery and terminate in the sub-pyloric glands.

The Lymph Vessels of the Duodenum are apparently few and difficult to inject; they communicate with those of the stomach above and the jejunum below, and the collecting vessels which pass from the subserous plexus end in the biliary, the sub-pyloric, and the mesenteric lymph glands.

The Lymph Vessels of the Jejunum and Ileum, with the exception of those from the terminal part of the ileum, pass to the mesenteric lymph glands. The lymph vessels from the terminal part of the ileum go to the ileo-colic lymph glands.

The Lymph Vessels of the Cæcum, the Vermiform Process, and the Ascending Colon pass to the ileo-colic lymph glands, either directly or after having traversed glands which lie nearer to the walls of the various parts of the gut.

The Lymph Vessels of the Right Colic Flexure and the Transverse Colon pass to the meso-colic and the superior mesenteric lymph glands.

The Lymph Vessels of the Left Colic Flexure, the Descending Colon, the Iliac Colon, and the Pelvic Colon pass to the inferior mesenteric lymph glands. From those glands the greater part of the lymph is conveyed to the lumbar lymph glands, but part passes to the mesenteric lymph glands and part to the common intestinal lymph trunk.

The Lymph Vessels of the Liver.—The lymph vessels of the liver are described as forming superficial and deep groups. The superficial vessels pass to subserous plexuses from which collecting vessels arise.

The collecting vessels from the superior, anterior, and right lateral surfaces converge to a series of posterior and anterior efferent trunks.

The Posterior Collecting Trunks form three groups: (1) a right group, which runs through the right triangular ligament of the liver and then downwards and medially on the posterior wall of the abdomen, to the middle supra-pancreatic lymph glands; (2) the middle group runs towards the inferior vena cava, passes with it through the diaphragm, and ends in the posterior mediastinal lymph glands; (3) the left group passes through the left triangular ligament to the posterior left gastric glands and the posterior paracardial glands.

The Anterior Collecting Trunks are inferior and superior. The inferior pass from the anterior part of the right lobe, turn round the lower border, and end in the hepatic lymph glands. The superior group pass to the falciform ligament. Some turn posteriorly towards the inferior vena cava, pass through the diaphragm with it and end in the posterior mediastinal lymph glands; others turn forwards and downwards to the round ligament, which they accompany to the porta hepatis where they join the hepatic glands. The remaining vessels pass upwards to the anterior part of the diaphragm which they perforate, and they end in the anterior mediastinal glands.

The superficial collecting vessels of the inferior surface of the right lobe pass (*a*) backwards to the inferior vena cava and along that vessel to the posterior mediastinal glands, (*b*) to the cystic gland of the biliary chain. The collecting vessels of the lower part of the left lobe end in the hepatic glands. The collecting vessels of the caudate lobe pass partly to the posterior mediastinal glands, along the inferior vena cava; and partly to the hepatic lymph glands in the porta hepatis.

The Deep Lymph Vessels of the Liver pass to ascending and descending collecting trunks. The ascending trunks follow the hepatic veins and the inferior vena cava and end in the posterior mediastinal lymph glands. The descending collectors accompany the bile-ducts, the branches of the portal vein, and the branches of the hepatic artery, and terminate in the hepatic lymph glands.

The Lymph Vessels of the Gall Bladder.—The lymph vessels from the gall bladder terminate chiefly in the cystic gland but some pass to other members of the biliary chain.

The Lymph Vessels of the Pancreas.—The efferent vessels from the pancreas end in the adjacent glands, that is, some pass to the sub-pyloric, some to the supra-pancreatic, some to the mesenteric glands, and some to the posterior left gastric lymph glands.

The Lymph Vessels of the Spleen.—The collecting vessels from the spleen pass to the splenic lymph glands which occasionally lie near the hilum of the spleen and the left supra-pancreatic lymph glands.

The Lymph Vessels of the Kidneys.—The lymph vessels of each kidney run along the renal blood-vessels and terminate in the lumbar glands, especially in the pre- and para-aortic lymph glands.

The Lymph Vessels of the Ureters.—The lymph vessels from the abdominal part of each ureter pass to the lumbar and the common iliac and the sub-aortic lymph glands.

The Lymph Vessels of the Suprarenal Glands anastomose with the vessels of the kidneys and pass to the lumbar and to the posterior mediastinal lymph glands.

The Lymph Vessels of the Diaphragm.—The collecting lymph vessels from the diaphragm pass to the thoracic lymph glands, that is, to the anterior and posterior mediastinal lymph glands, and lower sternal glands.

The Lymph Vessels of the Posterior Wall of the Abdomen terminate in the lumbar lymph glands.

ABNORMALITIES OF THE LYMPH VESSELS.

Variations of the glands and smaller vessels of the lymphatic system are so common that they can hardly be regarded as abnormalities; variations of the larger vessels, however, are comparatively rare. This is especially the case with respect to the two terminal trunks, the thoracic duct and the right lymph duct, the abnormalities of which are interesting and important.

When the arch of the aorta is on the right side instead of on the left side, the thoracic duct terminates usually in the right innominate vein, in which case it receives the tributaries which usually open into the right lymph duct, whilst the corresponding area on the left side is drained by lymph vessels terminating in a left lymph duct which opens into the commencement of the left innominate vein. A similar arrangement of the terminal lymph trunks sometimes occurs even when the arch of the aorta is in its normal position on the left side. In either case the thoracic duct may commence in the usual way, and after reaching the level of the fifth thoracic vertebra continue upwards on the right side, instead of crossing to the left side of the vertebral column; more rarely it commences on the left side and crosses over to the right at a higher level.

In one case in which the thoracic duct opened into the right innominate vein, instead of the left, no trace of a lymph duct was discovered on the left side.

Occasionally the thoracic duct commences and terminates in the usual manner, but crosses the vertebral column immediately after its origin and ascends on the left side.

Not uncommonly there is no distinct cisterna chyli, in which case the terminal lymph vessels of the abdomen merely unite to form a larger vessel which does not present any obvious dilatation, and from which the thoracic duct is continued. The terminal lymph trunk may open into the internal jugular vein, previous to its junction with the subclavian, instead of into the commencement of the innominate vein.

Occasionally the thoracic duct is double, either in the whole or in part of its extent, and sometimes it breaks up into a plexus of vessels which may reunite into a single trunk in the upper part of the thorax. Both the thoracic duct and the right lymph duct may, before terminating, divide into branches which, though sometimes reuniting on each side into a single trunk, not infrequently open separately into the great veins at the root of the neck.

As a rule the thoracic duct joins the commencement of the left innominate vein, but it may end in the internal jugular, vertebral, or subclavian veins of the left side; whilst very rarely, it opens into the vena azygos.

DEVELOPMENT OF THE BLOOD-VASCULAR SYSTEM.

The Arteries and the Heart.

In the general account of the development of the zygote (pp. 71-74) it has been pointed out that the primitive vascular system, from which the main blood-vessels of the adult are derived, consists of—

(1) A tubular heart, separated by constrictions into five parts named, from the caudal to the cranial end, the sinus venosus, the atrium, the ventricle, the cardiac bulb, and the aortic trunk.

(2) Two ventral aortæ.

(3) Two dorsal aortæ fused in parts of their extents to form a median descending aorta.

(4) Six pairs of aortic arches, of which four pairs, the first to the fourth, connect the ventral aortæ with the unfused portions of the dorsal aortæ; one pair, the fifth, connects the ventral aortæ, for a short time, with the dorsal parts of the sixth arches; and the remaining pair, the sixth, connects the aortic trunk of the heart with the unfused parts of the dorsal aorta.

(5) Seven pairs of venous trunks, the vitelline, the umbilical, the precardinal, the post-cardinal, the ducts of Cuvier, the subcardinals, and the supracardinals, of which only three pairs, the vitelline veins, the umbilical veins, and the ducts of Cuvier, open directly into the venous sinus of the heart (Figs. 795, 796).

It was also noted (*a*) that the dorsal aortæ gave off a series of paired branches through which blood passed from the aortæ to networks of capillary vessels from which it was collected into the veins; (*b*) that the venous trunks were connected with their fellows of the opposite side, across the median plane, by transverse anastomoses; and (*c*) that anastomoses were formed between the post-, the sub-, and the supra-cardinal veins (p. 74).

The further changes by which the heart and the blood-vessels of the embryo are converted into the heart and the blood-vessels of the adult have now to be considered.

The Development of the Heart.—During the period in which the embryo increases in length from 1·3 mm. to 2·6 mm. the heart is formed, in the septum transversum and the dorsal wall of the pericardium, by the fusion of the caudal parts of the ventral aortæ (Fig. 796).

The sinus venosus lies for a time in the septum transversum. There it receives the ducts of Cuvier, the vitelline veins, and the umbilical veins, and after a short period it is projected out of the septum transversum into the dorsal part of the pericardium.

After its formation the heart elongates more rapidly than the pericardium and, therefore, bends into the form of a loop, of which the cranial limb is formed by the aortic trunk and the bulbus cordis, the apex, which lies ventrally, by the ventricle, and the caudal limb by the atrium and the sinus venosus (Fig. 802), whilst the interval between the cranial and caudal limbs is filled by a fold of the lining pericardium which constitutes the mesocardium.

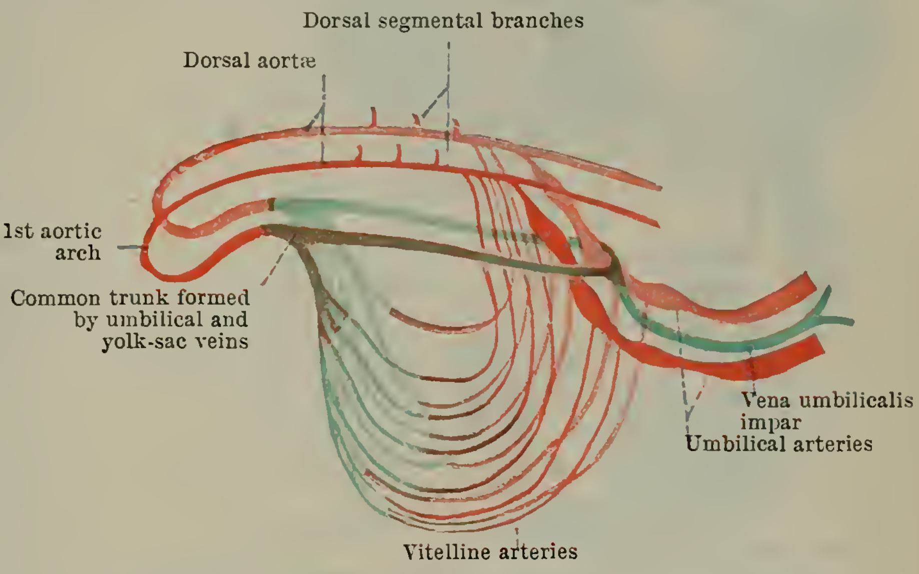

Fig. 795.—Schema of Circulation of an Embryo, 1·35 mm. long, with Six Somites. (After Felix, modified.)

As the heart folds longitudinally it is also bent in the transverse plane, so that, for a time, the more cranial part of the ventricle with the bulbus cordis and the aortic trunk lie towards the right of the more caudal part of the ventricle and the atrium and sinus venosus, and the atrio-ventricular orifice enters what, for a period, is the left limb of the ventricle (Fig. 797).

Afterwards, as the ventricle enlarges mainly ventrally, laterally, and cranialwards, the atrio-ventricular orifice is transposed to the middle of its dorsal wall, the right segment of the sinus venosus is absorbed into the atrium, and the atrium, thus reinforced, expands round the sides of the bulbus cordis and the aortic trunk (Fig. 797).

Subsequently the bulbus cordis is absorbed, partly into the ventricle and partly into the aortic trunk, and, thereafter, the aortic trunk is divided into the stem of the pulmonary artery and the ascending part of the aorta, whilst the mesocardium, which lay in the angle between the aortic trunk and the atrium, disappears, leaving an aperture, the transverse sinus of the pericardium, through which the right and left halves of the pericardial cavity communicate with one another dorsally and cranially to the ventricle, dorsally to the ascending aorta and the pulmonary artery, and ventrally to the atrium.

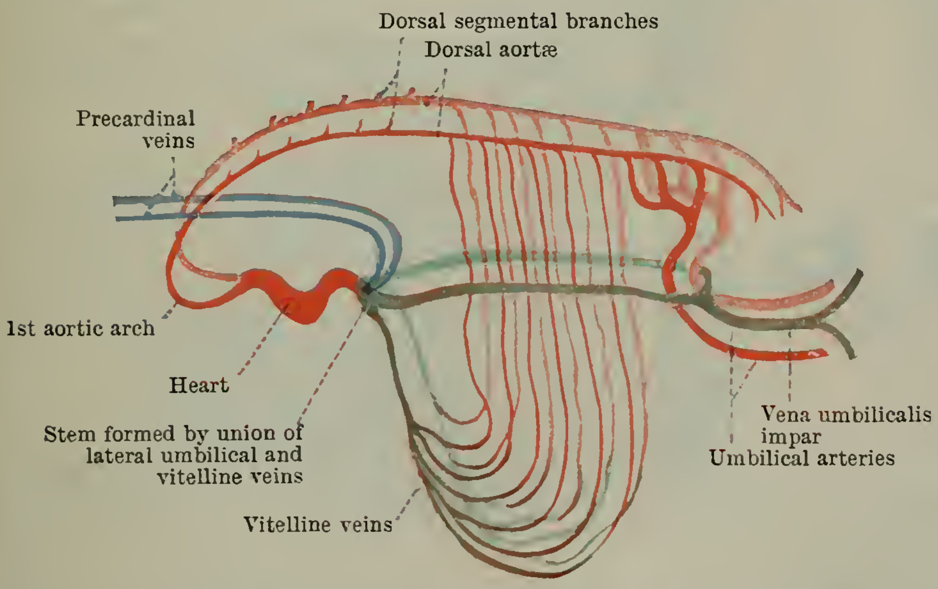

Fig. 796.—Schema of Vascular System of an Embryo, 2·6 mm. long, with Fourteen Somites. (Arteries after Felix, modified.)

Whilst the changes in position and shape of the heart, the disappearance of the mesocardium, and the division of the aortic trunk are taking place, the cavities of the atrium, the atrio-ventricular canal, which is the constricted part of the heart through which the atrium communicates with the ventricle, and the cavity of the ventricle, are all being divided into right and left halves by means of septa, which it is convenient to consider separately although they are formed simultaneously and fuse with one another in parts of their extents.

The Division of the Atrio-ventricular Canal.—After the longitudinal folding of the primitive cardiac tube has occurred the atrio-ventricular canal runs dorso-ventrally (from behind forwards in the erect posture) from the atrium to the ventricle. At first it is cylindrical in form, but, gradually, its cranial and caudal walls are thickened to form *endocardial cushions*, which project into the lumen of the canal, except at its right and left margins, and convert it into a cleft (Figs. 798, 800). Finally the cushions fuse, forming an atrio-ventricular septum but leaving the right and left margins of the canal intact as the *right* and *left atrio-ventricular orifices*; the right orifice forming a communication from the part of the atrium which afterwards becomes the right atrium to the part of the common ventricle which becomes later the right ventricle, whilst the left orifice connects the part of the common atrium which will become the left atrium with the part of the common ventricle which will become the left ventricle.

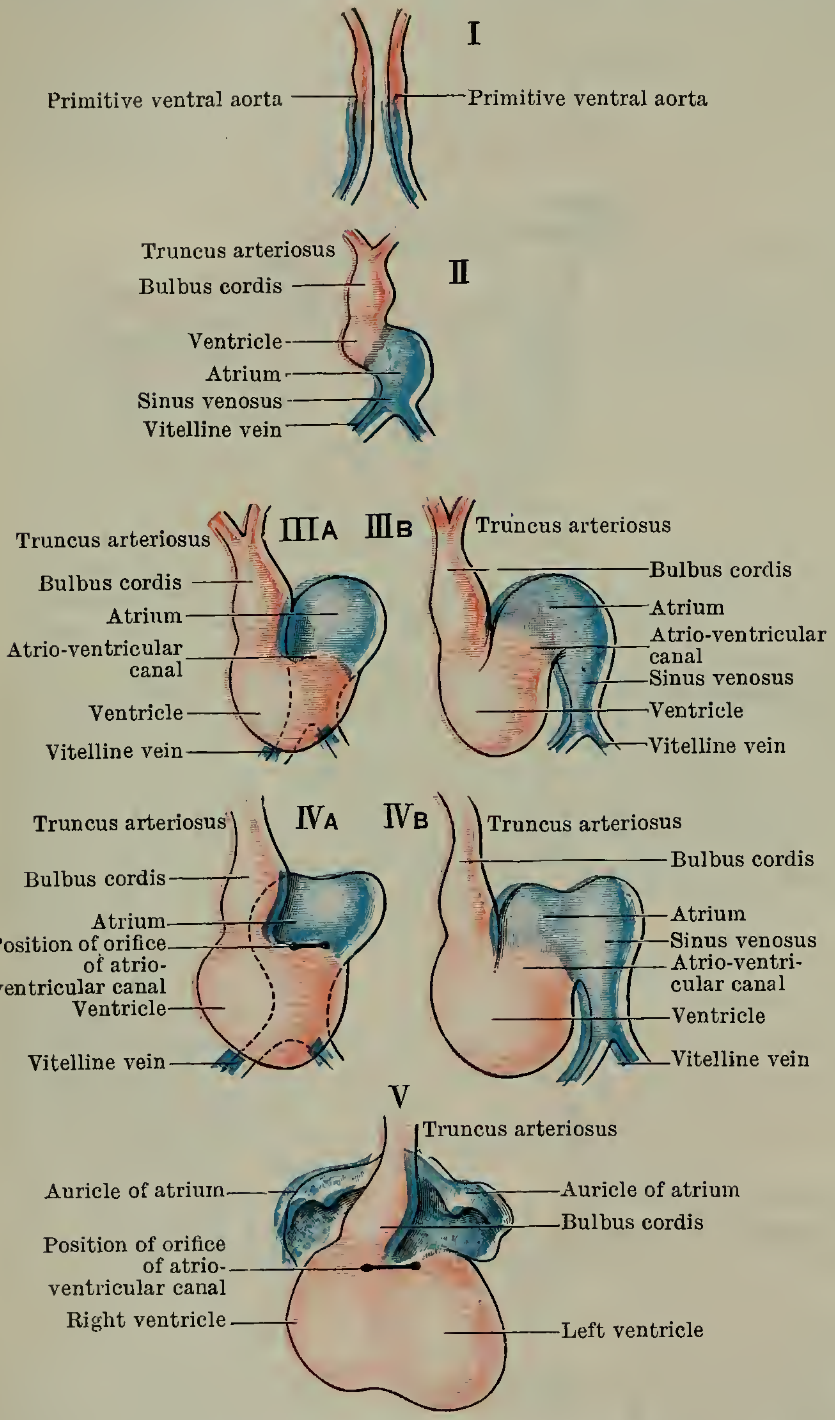

Fig. 797.—Development of the Heart.

Diagram showing the changes of form and external appearances at different stages. Modified from His's models. III.B and IV.B are side views; the other figures represent the heart as seen from the front.

Later, partly by invagination into the ventricle and partly by the growth of the margins of the atrio-ventricular orifices into the ventricles the cusps of the atrio-ventricular valves are formed (Fig. 798).

Occasionally the atrio-ventricular cushions obliterate not only the middle of the lumen of the atrio-ventricular canal but also one of its margins. In such cases only a single atrio-ventricular orifice is found in the later stages, right or left as the case may be. When such an abnormality occurs it is usually associated with incomplete formation of the interatrial and interventricular septa.

The Division of the Atrium.—The division of the primitive atrium into right and left atria is brought about by the formation and fusion of two septa, the *septum primum* and the *septum secundum*, and the fusion of both with the atrial end of the septum of the atrio-ventricular canal.

The septum primum is so called because it appears and partially disappears before the septum secundum is developed. It grows ventrally from the dorsal and cranial walls of the atrium until it meets and fuses with the septum of the atrio-ventricular canal, and, as it grows, the area of communication between the right and left parts of the atrium is gradually reduced. The aperture which is thus contracted is called the *primary foramen ovale* (Fig. 798). It is obliterated when the septum primum fuses with the septum of the atrio-ventricular canal, but before that fusion occurs an aperture called the *secondary foramen ovale* appears in the dorsal and caudal part of the septum primum (Fig. 798).

The septum secundum grows from the cranial and ventral walls of the atrium, immediately to the right of the septum primum.

When the growth of the septum secundum has caused its dorsal margin to pass dorsally beyond the dorsal margin of the secondary foramen ovale the latter margin acts as a flap valve, which permits blood to pass through the secondary foramen ovale, from the right to the left atrium, but prevents its return. That condition is retained until a short time after birth, when the right surface of the septum primum fuses with the left surface of the septum secundum and the orifice is permanently closed.

As a result of incomplete development the interatrial septum may be absent and the common atrium then communicates with both ventricles. In other cases the septum is incompletely formed and one, or other, or both of the interatrial foramina persist to adult life.

If the ventral end of the septum primum fails to fuse with the septum of the atrio-ventricular canal the primary foramen ovale persists, and is found as an aperture which lies between and immediately dorsal (posterior in the erect posture) to the atrio-ventricular apertures.

If the right surface of the septum primum fails to fuse with the left surface of the septum secundum a more or less reduced foramen ovale secundum persists. Such a condition is found in 10 per cent of adults examined in the post-mortem room.

The Division of the Truncus Arteriosus and the Cranial Part of the Bulbus Cordis.—It has already been noted that the bulbus cordis is absorbed partly into the arterial trunk and partly into the ventricular segment of the heart. As the absorption proceeds endocardial cushions develop in the arterial trunk and pass spirally along its inner wall into the ventricle.

At the apex of the arterial trunk, where it gives off the ventral aortæ and the sixth aortic arches, four endocardial cushions are found. They are placed ventrally, dorsally, and right and left.

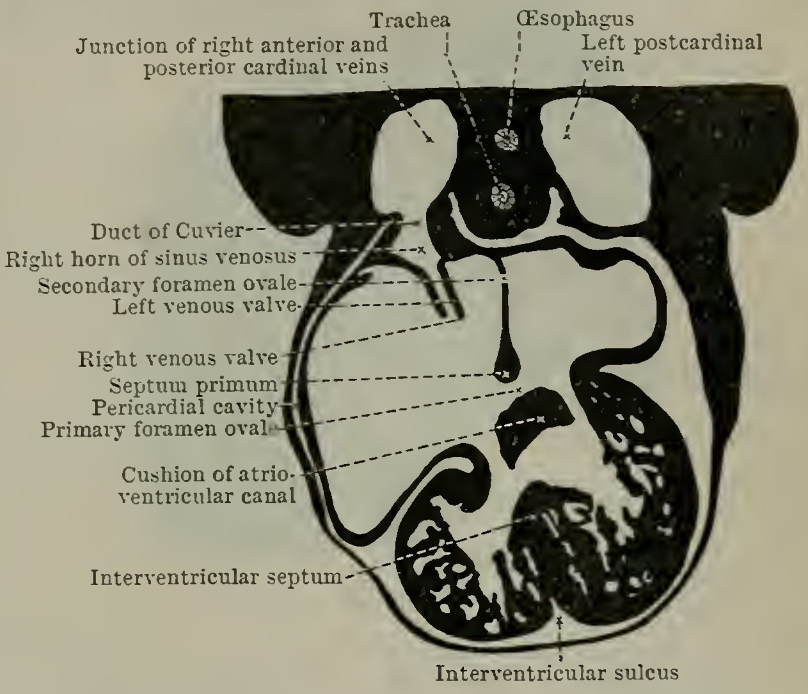

FIG. 798.—SECTION OF THE HEART OF A HUMAN EMBRYO. (Edinburgh University collection.)

The ventral and dorsal cushions disappear, in normal cases, but the right and left cushions pass spirally along the arterial trunk into the ventricle, and they fuse together to form a septum which divides the lumen of the arterial trunk into two segments.

At the apex of the arterial trunk, where the cushions were right and left, the septum divides the arterial trunk into a ventro-cranial (anterior in the erect posture) or aortic section, which communicates with the ventral aortæ, and a dorso-caudal or pulmonary section which remains continuous with the sixth aortic arches which become parts of the pulmonary arteries.

At the apex of the arterial trunk the septum has ventro-cranial and dorso-caudal surfaces and right and left borders. As it passes towards the ventricle it twists like a right-handed spiral, its right border first becoming dorsal, next left lateral, and finally ventral; consequently the surface which was originally dorso-caudal becomes ventro-cranial, and, as a result, when the ventricular end of the septum passes into the ventricle the blood from the right or ventro-cranial part of that chamber is directed into the sixth aortic arches, which become parts of the pulmonary arteries, and that from the left and more caudal part into the ventral aortæ and the four anterior aortic arches which help to form the main arterial trunks of the head, neck, and superior extremities of the adult.

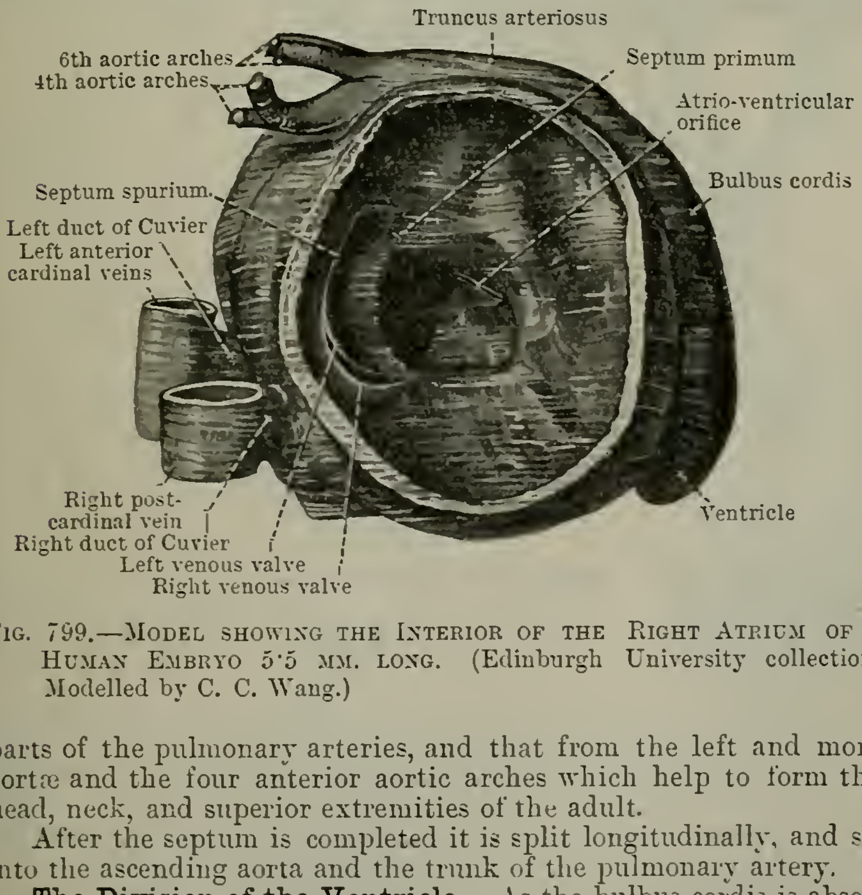

FIG. 799.—MODEL SHOWING THE INTERIOR OF THE RIGHT ATRIUM OF A HUMAN EMBRYO 5·5 MM. LONG. (Edinburgh University collection. Modelled by C. C. Wang.)

After the septum is completed it is split longitudinally, and so the arterial trunk is divided into the ascending aorta and the trunk of the pulmonary artery.

The Division of the Ventricle.—As the bulbus cordis is absorbed into the ventricle and the arterial trunk, and the cavities of the arterial trunk and the atrium are divided by the formation of septa, the septum which divides the ventricle into right and left parts also appears.

It commences as a fold of the ventricle wall, immediately to the right of its most ventral point, and its position is indicated on the surface by a sulcus (Fig. 798), which sometimes remains evident in the adult, producing a bifid apex of the heart. The fold, which consists of the muscular substance as well as the endocardial lining, projects into the cavity, not only from its ventral but also from its cranial and caudal walls, hence the septum, in the early stages, is semilunar in form.

The cranial horn of the semilune advances along the cranial wall of the ventricle until it meets the cranial margin of the ventricular part of the septum of the aortic trunk, with which it fuses. The caudal margin travels along the caudal wall of the ventricle until it meets and fuses with the septum of the atrio-ventricular canal (Fig. 801). The concave margin of the semilunar septum lies ventral to the aperture into the arterial trunk, therefore, for a time, there exists an aperture, ventral to the arterial trunk, through which the right and left ventricles communicate with one another. The aperture is closed by the extension of the septum of the arterial trunk into the ventricular area until it meets and fuses with the dorsal concave margin of the interventricular septum.

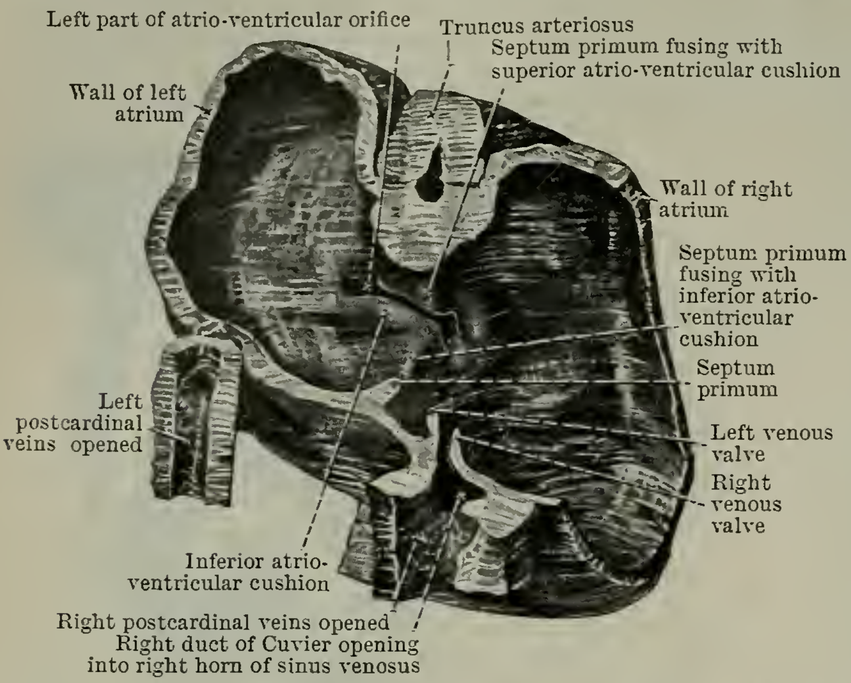
Left part of atrio-ventricular orifice
Truncus arteriosus
Septum primum fusing with superior atrio-ventricular cushion
Wall of left atrium
Wall of right atrium
Septum primum fusing with inferior atrio-ventricular cushion
Septum primum
Left postcardinal veins opened
Left venous valve
Right venous valve
Inferior atrio-ventricular cushion
Right postcardinal veins opened
Right duct of Cuvier opening into right horn of sinus venosus

FIG. 800.—VIEW OF THE INTERIORS OF THE RIGHT AND LEFT ATRIA OF A HUMAN EMBRYO 5·5 MM. LONG. (Edinburgh University collection. Modelled by C. C. Wang.)

The interventricular septum of the adult consists, therefore, of two parts—a ventral and larger muscular part, formed from the wall of the ventricle, and a dorsal and smaller membranous part (pars membranacea), formed from the ventral extension of the septum of the arterial trunk.

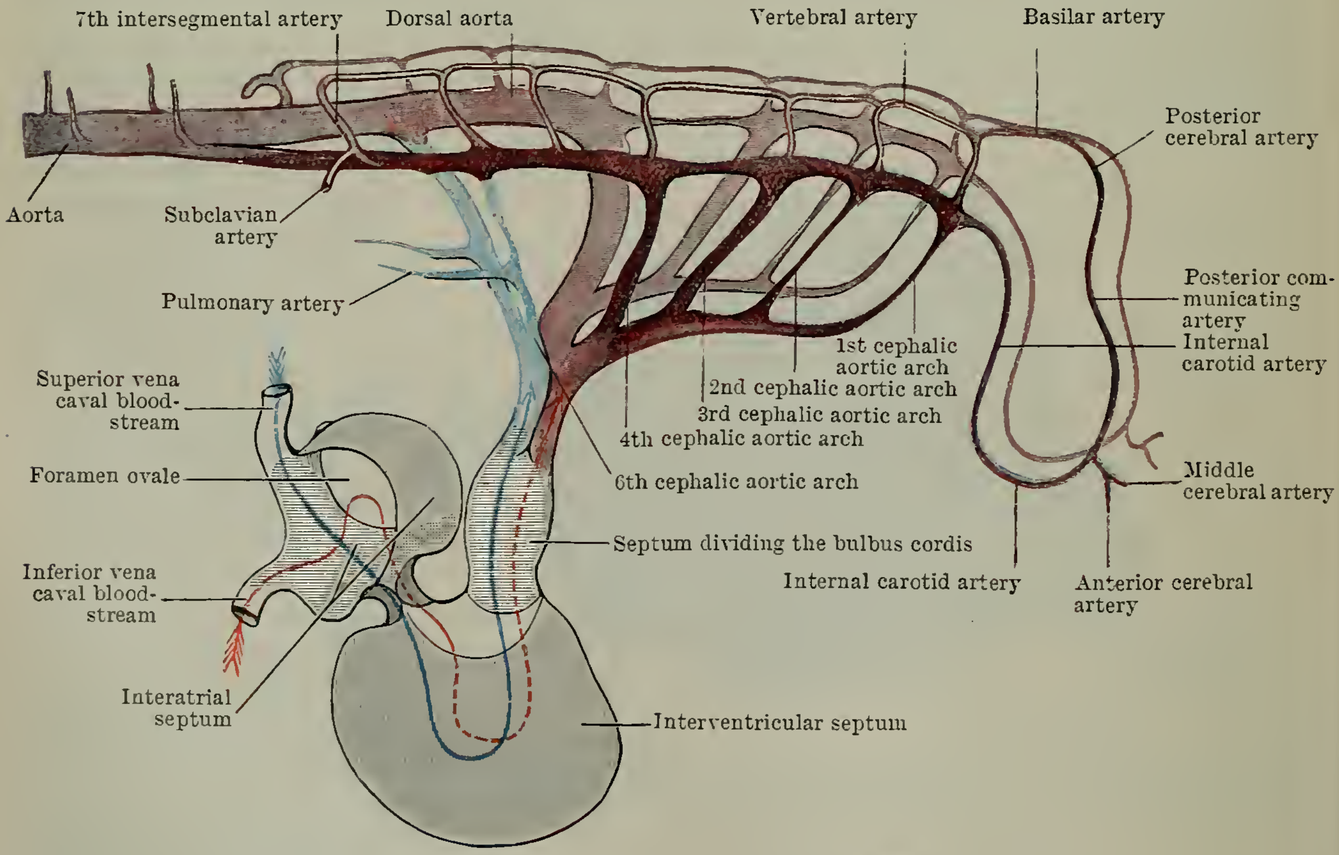

FIG. 801.—DEVELOPMENT OF THE HEART AND THE MAIN ARTERIES.

Diagram of the heart, showing the formation of its septa, and of the cephalic portion of the arterial system.

The more common abnormalities which result from the non-completion or the modification of the developmental processes in the ventricular area :—

(1) The septum of the arterial trunk may fail to descend into the ventricular area, in which

case the pars membranacea septi is absent and an interventricular foramen exists through which the cavities of the two ventricles communicate with one another, and each ventricle opens into both the aorta and the pulmonary artery.

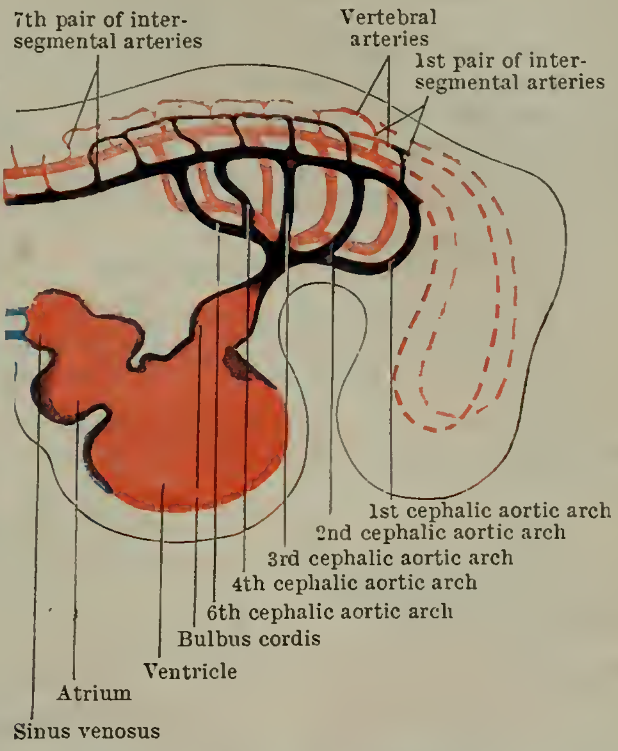

Fig. 802.—Schema of the Stage of Five Aortic Arches. The cardinal veins and ducts of Cuvier are not shown.

(2) The muscular part of the interventricular septum may be absent. There is then only one ventricular cavity which receives blood from both atria and projects it into both the pulmonary artery and the aorta.

(3) The septum of the arterial trunk may form a left-handed instead of a right-handed spiral, with the result that the pulmonary communicates with the left and the aorta with the right ventricle.

(4) The spiral twist of the septum of the arterial trunk may be incomplete, so that its ventral margin meets the dorsal margin of the ventricular septum more or less at right angles, then the pulmonary artery and the aorta both communicate with each of the ventricles.

Many other abnormalities, due to interference with or alterations of the ordinary processes of development, occur ; for accounts of them readers who are interested must consult monographs on malformations of the heart.

The Fate of the Sinus Venosus.—The sinus venosus, which constituted the most caudal part of the primitive heart, was formed, in the septum transversum, by the fusion of the terminal parts of the common vitello-umbilical trunk veins, to form a single chamber which consists of right and left cornua and an intermediate section.

Each cornu, at that time, receives a duct of Cuvier, a vitelline and an umbilical vein. Later, as the longitudinal folding of the cardiac tube occurs, the sinus venosus emerges from the septum transversum and is transposed into the caudal part of the pericardium. There it lies dorsal to the atrium into which its right cornu opens, through an orifice guarded by right and left venous valves (Fig. 798) which fuse with one another at their cranial and caudal ends.

As development proceeds, the right cornu of the sinus venosus is absorbed into the right atrium, the whole of the left and the cranial part of the right venous valves disappearing, whilst the caudal part of the right valve becomes the valve of the inferior vena cava, which is the modified termination of the right vitelline vein (see Development of the Portal System, p. 1042).

The left cornu of the sinus venosus remains as the coronary sinus of the fully developed heart, and the dorsal wall of the intermediate section is projected ventrally towards the right atrium, to form the valve of the coronary sinus, which lies at the right margin of the opening through which the coronary sinus communicates with the right atrium (Fig. 724).

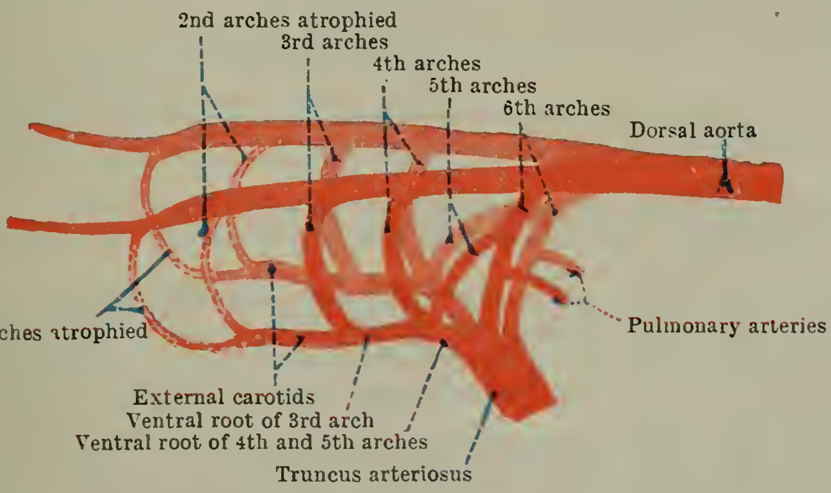

Fig. 803.—Schema of Aortic Arches of an Embryo, 9 mm. long. (After Tandler, modified.) The second and third arches have atrophied and the transitory fifth has appeared.

The Fate of the Ventral Aortæ, the Aortic Arches, and the Unfused Parts of the Dorsal Aortæ.—It has already been pointed out (see p. 73) that when the embryo is 5 mm. long it possesses five pairs of aortic arches, of which the first and second pairs connect the ventral aortæ with the unfused parts of the dorsal aortæ, whilst the third, fourth, and sixth pairs, which also pass to the unfused parts of the dorsal aortæ, arise from a common stem which springs from the apex of the truncus arteriosus (Fig. 802).

As the embryo increases from 5 mm. to 9 mm. in length, (1) the third and fourth pairs of arches are transferred to the ventral aortæ ; (2) a transitory fifth pair of arches appears and for a time connects the ventral aortæ with the dorsal parts of the sixth arches ; (3) the first two pairs of arches have begun to disappear; and (4) the right and left pulmonary arteries have grown from the corresponding sixth arches into the rudiments of the lungs (Fig. 803).

As soon as two or more arches arise from the ventral aortæ it is customary, for convenience of description, to speak of the parts of the ventral aortæ which lie caudal to the various arches as the ventral roots of those arches, and the corresponding parts of the dorsal aortæ are called the dorsal roots of the arches; therefore, at the 9 mm. stage, if the fifth pair of arches are left out of consideration on account of their very transitory and unimportant nature, it may be said that first four pairs of arches have ventral roots. The sixth arches spring from the apex of the truncus arteriosus, and therefore are devoid of ventral roots; but all the arches have dorsal roots, and the dorsal roots of the sixth arches end in the descending aorta which was formed by the fusion of the more caudal portions of the primitive dorsal aortæ.

The main events of the subsequent changes which occur before the embryo is 15 mm. long may be summarised as follows:—

(1) The following parts have disappeared:—

(*a*) The dorsal roots of the third arches.
(*b*) The dorsal roots of the right fourth and sixth arches.
(*c*) The dorsal part of the right sixth arch.

(2) In the meantime the truncus arteriosus has been divided into the ascending aorta, which passes from the left ventricle to the ventral roots of the fourth pair of arches, and the pulmonary stem which connects the right ventricle with the sixth arches.

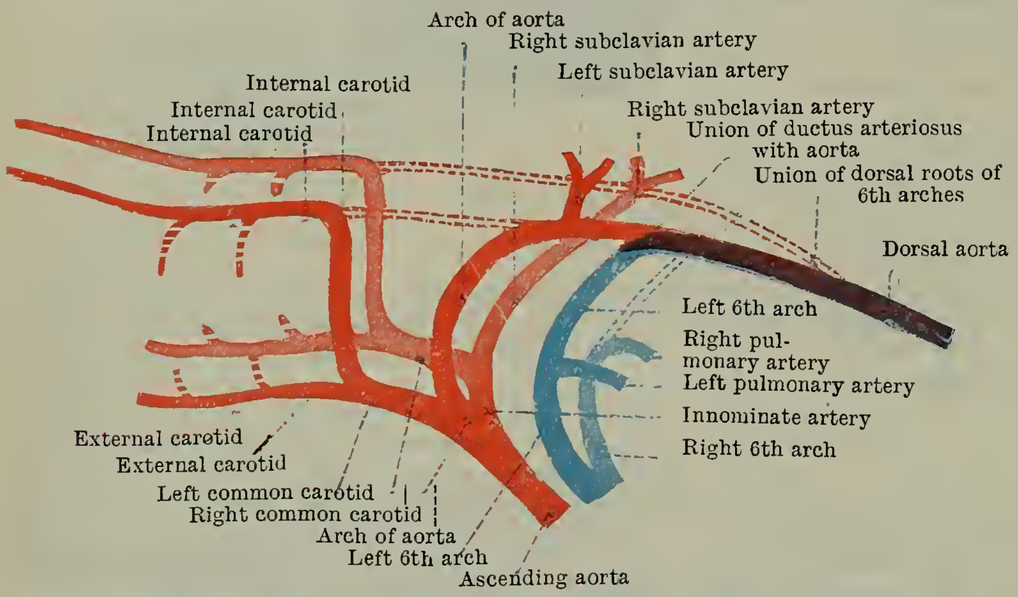

Fig. 804.—Schema of Part of the Arterial System of a Fœtus seen from the Left Side. Parts of the first and second arches, the dorsal roots of the third arches, the dorsal part of the right sixth arch, and the dorsal roots of the right fourth and fifth arches have atrophied. The position of the fifth arch is not indicated; see Fig. 803.

(3) The ventral root of the right fourth arch has become the innominate artery.

(4) The ventral root of the left fourth arch and the fourth arch itself have been converted into the arch of the aorta.

(5) The right fourth arch has become the right subclavian artery.

(6) The ventral roots of the third arches have become the common carotid arteries.

(7) The ventral roots of the first and second arches have become the external carotid arteries.

(8) The third arches and the dorsal roots of the first and second arches have formed the internal carotid arteries.

(9) The dorsal root of the left fourth arch has become part of the arch of the aorta.

(10) The dorsal root of the left sixth arch has become the cranial part of the descending aorta.

(11) The dorsal part of the left sixth arch has become the ductus arteriosus, through which blood, which has passed from the right ventricle into the pulmonary artery, is transmitted into the aortic arch until birth. Then the dorsal part of the left sixth arch becomes the ligamentum arteriosum, and the blood which passes into the pulmonary artery runs through the lungs to the pulmonary veins, and so to the left atrium.

Many variations of the main stems of the adult arterial system are the result of modifications of the ordinary developmental changes which have been noted. Parts which usually disappear may remain, parts which usually remain may disappear, and fusions and absorptions of parts which usually remain distinct may occur.

If the dorsal roots of the right fourth and sixth arches persist, in addition to the persistence of the same parts of the left side, both right and left aortic arches are formed, and the more cranial part of the descending aorta is doubled, a condition which persists in adult reptiles.

If the dorsal roots of the right fourth and sixth arches persist and the corresponding parts on the left side disappear, the arch of the aorta is transposed from the left to the right side. This is the regular occurrence in birds.

If the right fourth arch disappears, and the dorsal roots of the right fourth and sixth arches persist, a not uncommon variation, then the right subclavian artery arises from the descending aorta caudal to the origin of the left subclavian artery.

If the ventral roots of the fourth arches of opposite sides fuse, a common stem is formed, which arises from the arch of the aorta and gives origin to the right subclavian and both common carotid arteries.

If the ventral roots of the third and fourth arches of opposite sides fuse, a common stem is formed, which springs from the arch of the aorta; it gives off the right subclavian artery and the external and internal carotid arteries of both sides.

High division of the common carotid, on either side, may be due to the disappearance of the third arch, and the dorsal roots of the second and third arches, and the persistence of the second arch.

The Branches of the External Carotid Artery.—All the typical branches of the external carotid artery are present in embryos 15·5 mm. long; little is known, however, regarding the details of their development. It is probable that the internal maxillary artery and its branches are evolved partly from the ventral part of the first aortic arch and partly from an anastomosis with the branches of a temporary *stapedial artery*, which develops from the dorsal end of the second arch; but it is not known whether the other branches of the external carotid spring as offsets from the ventral roots of the first or second arches or from the ventral parts of the arches themselves.

The Descending Aorta.—The greater part of the descending aorta is formed by the fusion of the primitive dorsal aortæ. In embryos about 2·6 mm. long, possessing twenty-three mesodermal somites, the primitive dorsal aortæ are fused together from the tenth to the sixteenth segment (Fig. 796). At a later period the fusion is continued caudalwards to the twenty-third body segment—the level of the fourth lumbar vertebra—where the common iliac arteries arise. Still later the small terminal portions of the primitive dorsal aortæ fuse together to form the unpaired middle sacral artery, which terminates at the extremity of the coccygeal region.

If the three somites which lie nearest the head-end, in embryos possessing twenty-three somites, are cephalic somites, then the point of commencement of the median aorta would be situated at the level of the seventh body somite, that is, at the situation of the future seventh cervical vertebra. The position of the anterior point of fusion of the primitive dorsal aortæ is indicated in the adult by the origin of the abnormal right subclavian artery, and is situated at the level of the fifth thoracic vertebra; therefore the anterior end of that part of the descending aorta which is formed by the process of the primitive dorsal aortæ must move caudalwards during the developmental period.

The Branches of the Dorsal Aortæ.—The branches given off from the primitive dorsal aortæ are dorsal, lateral, and ventral.

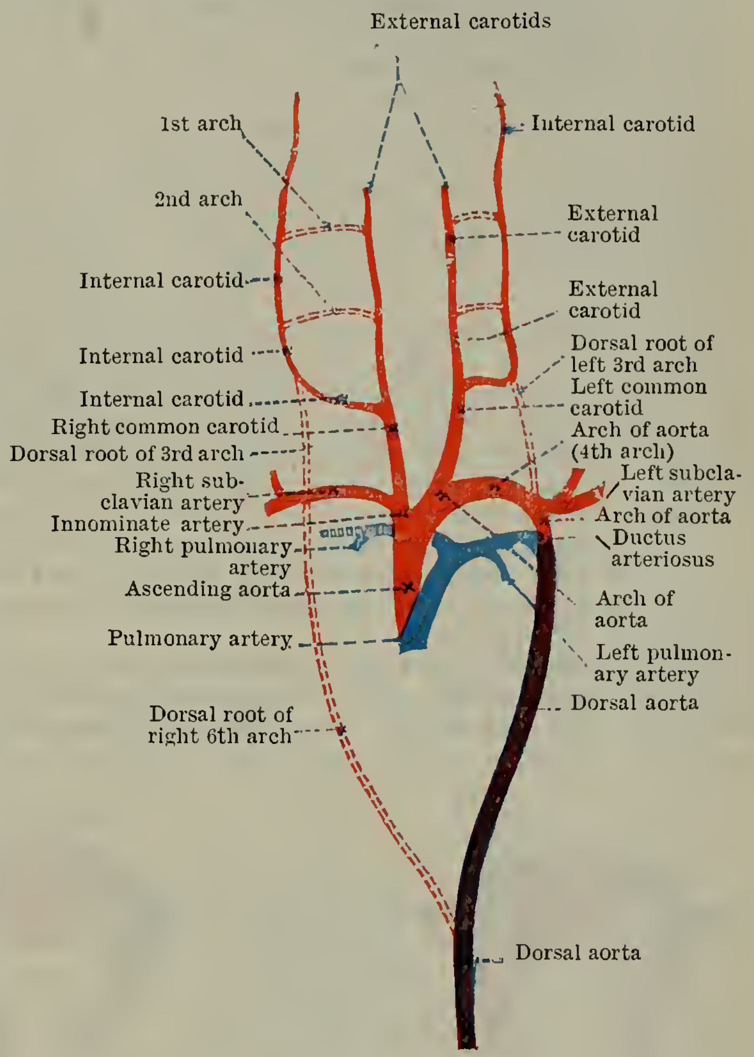

FIG. 805.—SCHEMA OF PART OF THE VASCULAR SYSTEM OF A FŒTUS SEEN FROM THE FRONT. The origin of the positions of the first and second arches, the dorsal roots of the third arches on both sides, and the dorsal roots of the fourth and fifth arches on the right side are shown in dotted lines. The positions of the fifth arches are not shown.

The dorsal branches arise either in the head region, cranial to the point where the first mesodermal somite is formed, and hence are presegmental, or more caudally in the head, and in the neck and body regions, where they lie opposite the intervals between the mesodermal somites, and are therefore intersegmental.

They supply the neural tube and its surroundings, the tissues of the head and neck, the body wall and the extremities, but they do not send branches to the viscera, therefore they are somitic arteries.

They anastomose with each other by a series of longitudinal channels which lie ventral and dorsal to the dorsal portions of the costal elements of the skeleton, and dorsal to the transverse processes of the vertebræ.

An account of their branches and anastomoses and the transformations which affect them, and more especially of those which result in the formation of the vertebral arteries and the arteries of the extremities, is given in the description of the morphology of the vascular system (see pp. 1052, 1059); but it may be stated here that the main arteries of the adult, which are derived from the dorsal branches of the primitive dorsal aortæ and their anastomoses and branches, are: (1) The intercostal and lumbar arteries and their posterior or dorsal rami; (2) parts of the subclavian arteries; (3) the axillary arteries and their continuations in the upper extremities;

(4) the vertebral arteries; (5) the spinal arteries; (6) the basilar artery; (7) the superior intercostal arteries; (8) the internal mammary and the superior and inferior epigastric arteries.

As a rule, the dorsal branches of the primitive dorsal aortæ remain separate from each other, even in the regions where the primitive dorsal aortæ themselves fuse, but occasionally in the thoracic and lumbar regions they fuse, with the result that intercostal and lumbar arteries of opposite sides arise from common stems.

The Lateral Branches of the Dorsal Aortæ are distributed to organs developed from the intermediate cell tracts—that is, to the temporary and permanent urinary organs, the pronephri and mesonephri (Wolffian bodies), which disappear; and to the metanephri, which become the permanent kidneys; and also to the suprarenal and genital glands. They become the renal, internal testicular, and ovarian arteries.

The Ventral Branches of the Primitive Dorsal Aortæ.—The vessels of this group are neither definitely segmental nor intersegmental. They pass to the walls of the entodermal portion of the alimentary canal and its diverticula, and also, in the early stages of development, to the walls of the yolk sac and the chorion and its placental derivative. They are connected together by longitudinal anastomosing channels which lie in the dorsal mesentery of the gut and also upon the wall of the gut itself. As the yolk sac atrophies the prolongations of the ventral branches which pass to its walls disappear and, simultaneously, the portions of the corresponding vessels of opposite sides, which lie in the mesentery, dorsal to the gut, and the longitudinal anastomoses which connect them, fuse together to form unpaired stem-trunks from which the three great vessels of the abdominal part of the alimentary canal are derived, namely, the cœliac, the superior mesenteric, and the inferior mesenteric arteries; but the original stem of each of these three important vessels is not that which eventually forms its origin from the abdominal part of the aorta, for the cœliac artery, which originally arose opposite the seventh cervical segment, wanders caudalwards to the twelfth thoracic segment as the roots of origin of the ventral vessels which are situated nearer the head disappear; and in the same manner the superior mesenteric is transposed from the level of the second thoracic to the level of the first lumbar segment, and the inferior mesenteric wanders from the twelfth thoracic to the third lumbar segment.

Of the three arteries mentioned the superior mesenteric retains longest its connection with the yolk sac, and it occasionally happens that a fibrous strand representing the original channel extends from one of the intestinal branches of the superior mesenteric past the side of the intestine to the umbilicus.

The Umbilical and Iliac Arteries.—It was pointed out, in the account of general features of embryology, that the umbilical arteries which carry blood to the placental area of the chorion arise, in a human embryo about 1·38 mm. long, about the level where the fourth cervical mesodermal somite will be developed at a later stage. They spring from plexuses formed, on the lateral walls of the caudal part of the primitive gut, by the anastomosis of some of the most caudally situated ventral or vitelline branches of the primitive dorsal aorta. The origins of the arteries are gradually moved caudally as the embryo grows, until, eventually, they spring from the primitive dorsal aorta, opposite the twenty-third body somite, that is the fourth lumbar segment. As each umbilical artery passes from its origin on the ventral wall of the primitive dorsal aorta to the body-stalk it lies to the medial side of the pronephric duct. The ventral origin is, however, but temporary; for, by the time the embryo has attained a length of 5 mm., and the primitive dorsal aortæ have fused to form the permanent descending aorta, a new vessel has arisen, on each side, from the lateral part of the caudal end of the aorta. This new vessel passes ventrally, to the lateral side of the Wolffian duct, and then unites, on a plane ventral to the aorta, with the primitive umbilical artery of the same side. After the union has taken place the ventral origin of the umbilical artery disappears, and the primitive umbilical artery then arises from the side of the caudal end of the aorta. From the newly formed vessel, which now constitutes the only origin of the umbilical artery, the inferior gluteal artery, which is the primitive main artery of the lower limb, arises. At a later period, and at a more dorsal level, a second branch arises from the dorsal root of origin of the umbilical artery; this is the second main vessel of the lower extremity, which becomes the **external iliac** and the **femoral arteries** of the adult. As soon as the external iliac artery is formed that portion of the umbilical stem which lies dorsal to it becomes the **common iliac artery**, and the more ventral part, which descends into the pelvis minor, becomes the **hypogastric artery**. But that portion of the original umbilical artery which runs along the side of the pelvis minor to the ventral wall of the abdomen, then cephalwards to the umbilicus and through the umbilicus to the placenta, is still called the umbilical artery. After birth, when the placental circulation ceases, the greater part of the intra-abdominal portion of the umbilical artery atrophies and

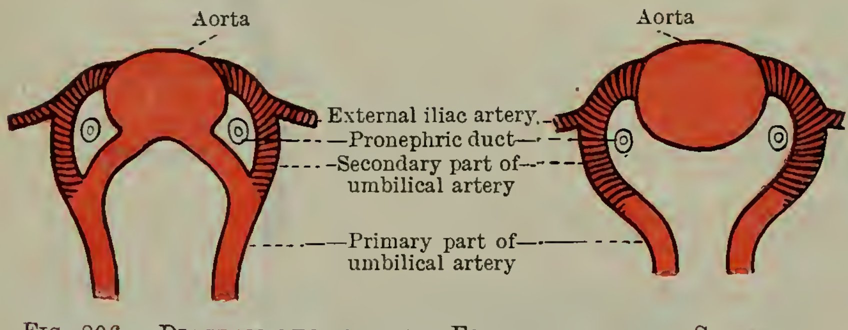
Aorta
Aorta
External iliac artery
Pronephric duct
Secondary part of umbilical artery
Primary part of umbilical artery

Fig. 806.—Diagram showing the Formation of the Secondary Part of the Primitive Umbilical Artery.

becomes converted into the **lateral umbilical ligament**, but a portion of the part which lies in the pelvis minor remains pervious and from it springs the **superior vesical artery**.

The Blood-Vessels of the Superior Extremities.—It appears probable that, in the earliest stages of development, a number of branches arise from the sides of the primitive dorsal aortæ and pass to the rudiments of the superior extremities, where they end in vascular plexuses which are drained into the precardinal veins.

At a later period the number of connexions with the aorta, on each side, is reduced to one, and that is transferred from the aorta to the ventral branch of the seventh intersegmental artery, whilst, at the same time, the original plexus in the limb is reduced to a single trunk, which is divisible into subclavian, axillary, brachial, and volar interosseous segments. At a later period a median branch arises from the volar interosseous artery, and still later radial and ulnar branches are formed, the portion of the ulnar artery which lies between the bifurcation of the brachial and the origin of its volar interosseous branch being part of the original stem vessel.

In the early phases the blood is returned from the superior extremity by two superficial vessels, the cephalic and basilic veins, which unite at the root of the neck to form the subclavian vein, which ends in the precardinal vein. For a time the cephalic vein communicates across the front of the rudiment of the clavicle with the external jugular vein.

The deep veins which accompany the arteries are developed later.

The Blood-Vessels of the Inferior Extremities.—The development of the arteries of the inferior extremities has recently been investigated by Senior, and readers who wish to follow the details of an intricate process, or those who desire to understand the evolution of the arterial variations met with in the inferior extremities, should refer to Senior's *Communications*[1]; only a general outline of the phenomena can be given here.

It is not possible from the knowledge so far attained to assign to the arteries of the inferior extremities any segmental or intersegmental relationship.

In the first place, a primary axial artery is developed. It springs from the secondary umbilical artery, leaves the pelvis through the greater sciatic foramen, descends through the thigh, between the rudiments of the hamstrings and the adductor muscles, passes through the popliteal fossa, where its distal part lies anterior to the rudiment of the popliteus muscle, and descends along the interosseous membrane to the foot, where it terminates in a capillary plexus.

The remnants of the primitive axial artery usually present in the adult are—the inferior gluteal artery and its sciatic branch, the proximal or femoral part of the popliteal artery, and the distal part of the peroneal artery.

After the axial artery is established, a new branch springs from the secondary umbilical artery above the origin of the axial artery. The new vessel runs along the margin of the upper aperture of the pelvis minor, passes above the superior ramus of the pubis, and enters the front part of the thigh, where it divides into two branches.

The two branches end in a capillary plexus which is joined distally by a recurrent branch of the axial artery which pierces the rudiment of the adductor magnus.

That part of the new vessel which lies in the abdomen becomes the external iliac artery. The part which lies in the thigh, with one of its branches, part of the capillary plexus and the recurrent branch of the axial artery, is converted into the femoral artery of the adult.

The other terminal branch and the remainder of the capillary plexus disappear, or they are utilised in the formation of some of the branches of the femoral artery.

All the vessels of the leg and foot of the adult, except the distal part of the peroneal artery, are formed either by rami of the primitive axial artery, or their branches, or anastomosing channels, or by combinations of some of the three groups of vessels.

DEVELOPMENT OF THE VEINS.

Simultaneously, or almost simultaneously, with the formation of the arteries by which blood is distributed to all parts of the zygote, and in an essentially similar manner, a series of vessels is developed by which the blood is returned to the heart of the embryo. These vessels are the primitive veins. They form two groups which make their appearance at different periods.

The first group includes (1) the vitelline veins (right and left), which return blood from the yolk sac, and (2) the umbilical veins (impar, right, and left), by which blood is returned from the chorion and the placenta.

All the vessels of this group are partly extra-embryonic and partly intra-embryonic, and they are largely transitory.

The intra-embryonic portions of the vitelline veins take part in the formation of the cardiac end of the inferior vena cava, the hepatic veins, the capillary blood plexus in the liver, and the portal vein and its right and left branches. The extra-embryonic portions disappear.

The umbilical veins are essentially associated with the period of intra-uterine life, and they are represented in the adult body only by a fibrous cord, the round ligament of the liver, which is a remnant of the left umbilical vein.

The second group placed in their order of appearance consists of (1) the precardinal veins, (2) the postcardinal veins, (3) the ducts of Cuvier, (4) the subcardinal veins, (5) the supracardinal veins. It is mainly from these veins that the permanent veins of the head, neck, and body are evolved (for the development of the veins of the limbs see above and p. 1058).

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[1] H. D. Senior, *Amer. Jour. of Anat.* vol. xxv. No. 1, Jan. 1919; *Anat. Rec.* vol. xvii. No. 5, 1920.

All the above-named veins are paired, right and left, and between the vessels of opposite sides, in the case of each pair, there are transverse anastomoses, whilst anastomoses also exist between the post-, sub-, and the supra-cardinal veins.

The precardinal veins, and a transverse anastomosis between them situated in the more cranial or upper part of the thoracic region, are transformed into (1) the cavernous sinuses of the cranium, (2) the internal jugular veins, (3) the innominate veins, (4) the extra-pericardial part of the superior vena cava, and (5) the upper or more cranial part of the left superior intercostal vein.

The other venous channels of the cranium, head and neck, and the superior extremities are later formations.

The right duct of Cuvier becomes the intra-pericardial part of the superior vena cava, and the left duct of Cuvier is converted into the oblique vein of the left atrium.

From the postcardinal veins are derived the hypogastric and common iliac veins, the inferior end of the inferior vena cava, and the terminal part of the vena azygos (Fig. 813).

The right subcardinal vein takes part in the formation of the inferior vena cava, and an anastomosis between the right and left subcardinal veins forms the major part of the left renal vein.

From the supracardinal veins are evolved part of the inferior vena cava, the greater part of the azygos vein, the hemiazygos vein, and the accessory hemiazygos vein.

The alterations, enlargements, and suppressions which occur during the transformation of the primitive into permanent veins must now be considered in detail.

The Vitelline and Umbilical Veins and their Association with the Formation of the Portal Vein, the Hepatic Capillary Plexus, the Hepatic Veins, and the Cardiac End of the Inferior Vena Cava.—In the early stages of development the vitelline veins, right and left, convey blood from the yolk-sac part of the entodermal vesicle first to the caudal ends of the corresponding primitive ventral aortæ, and next, after the caudal parts of the primitive ventral aortæ have fused to form the heart, to the sinus venosus of the primitive heart.

After the entodermal vesicle of the zygote is separated into the entodermal part of the alimentary canal of the embryo, the yolk sac, and the vitello-intestinal duct which connects the alimentary canal and the yolk sac together, each vitelline vein passes along the vitello-intestinal duct to the corresponding border of the cranial margin of the umbilical orifice where it enters the embryo, passing at once into a mass of mesoderm called the septum transversum; there it unites, for a time, with the cardiac end of the corresponding umbilical vein to form a common vitello-umbilical trunk, which terminates in the sinus venosus. At this period the sinus venosus is also situated in the septum transversum.

Subsequently, as the sinus venosus leaves the septum transversum and passes into the pericardial cavity, the common vitello-umbilical trunk is absorbed into it, and each vein thus requires its own separate termination into the sinus.

The septum transversum is a mass of mesoderm which intervenes between the pericardium and the cranial end of the ventral portion of the abdominal cavity along the line of the cranial border of the umbilical orifice. From it are derived the caudal (lower) wall of the pericardium, the ventral part of the central portion and the lateral parts of the diaphragm, the falciform ligament of the liver, the connective tissue and vascular parts of the liver, and the lesser omentum.

As the liver is developed from the mingling of the rami of a diverticulum from the ventral wall of the duodenum with the mesoderm of part of the septum transversum, the portions of the vitelline and umbilical veins which lie in the liver area of the septum transversum are expanded and, at the same time, broken up into a great number of anastomosing channels, which form for a period the main part of the liver substance and which constitute what is called **sinusoidal tissue.**

The sinusoidal tissue consists of relatively wide anastomosing blood-vessels whose walls are formed by endothelium surrounded by young connective tissue, and intervening between the channels of adjacent sinuses, spreading through the connective tissue, are ramifying strands of liver cells, which multiply and increase in size until the sinusoidal blood spaces are, for the main part, reduced to blood capillaries and the liver becomes a comparatively solid organ.

Whilst the formation of the sinusoidal spaces is taking place in the liver area the parts of the foregut are defined, and as the duodenal and stomach areas recede from the liver the lesser omentum is evolved from the caudal part of the septum transversum. Then, as the duodenum is deliminated the vitelline veins pass along its sides, on their way to the liver, and become connected around it by three transverse anastomoses, two of which lie ventral and one dorsal to the duodenum. Cranialwards of these anastomoses each vitelline vein is broken up into a caudal part, the **vena advehens**, which enters the liver substance, an area of sinusoidal channels, and a cranial part, the **vena revehens**, which passes from the liver to the heart. After a time the left vena revehens loses its direct connexion with the heart, moves across towards the right, and opens into the cranial end of the right vena revehens. When this change has occurred all the blood passing to the liver by the vitelline veins reaches the heart by the cranial extremity of the right vena revehens, which now becomes the upper end of the inferior vena cava. This also receives the ductus venosus—a new channel, which is evolved from the sinusoidal spaces, and which carries the major part of the blood from the left lateral umbilical vein to the upper end of the inferior vena cava.

In the meantime degeneration takes place in the ventral and caudal parts of the vitelline veins and the loops formed by the three transverse anastomoses between them. The ventral parts of the veins disappear with the degeneration of the yolk sac, and the right half of the caudalward and the left part of the more cranialward situated loops also disappear. Simultaneously the superior mesenteric vein, which has been evolved in association with the formation of the intestine from the mid-gut, opens into the left vitelline vein, caudal to the dorsal transverse anastomosis, and, a little later, the splenic vein enters at the same point. The final result is the formation of the permanent **vena portæ**, which is formed from (1) the cephalic end of the left limb of the caudal loop between the vitelline veins; (2) the dorsal anastomosis between the vitelline veins; (3) the right limb of the cephalic loop formed by the vitelline veins. The right branch of the portal vein is the right vena advehens. The left branch of the portal vein is formed from the left vena advehens, and the more cranial of the two ventral anastomoses between the vitelline veins. It is connected with the ligamentum teres of the liver, because the left lateral umbilical vein, which opened at one time into the left horn of the sinus venosus of the heart, and afterwards into the sinusoids of the liver, finally becomes connected with the left vena advehens, at the level of the cranialward ventral anastomosis between the two vitelline veins; and it is connected with the ductus venosus so that a channel may exist by which the blood from the placenta can pass to the right vena revehens without much admixture with the venous blood passing to the liver through the left branch of the portal vein and the left vena advehens. Therefore the ductus venosus is developed from the sinusoidal spaces of the liver when the left lateral umbilical vein is transferred to the left vitelline vein.

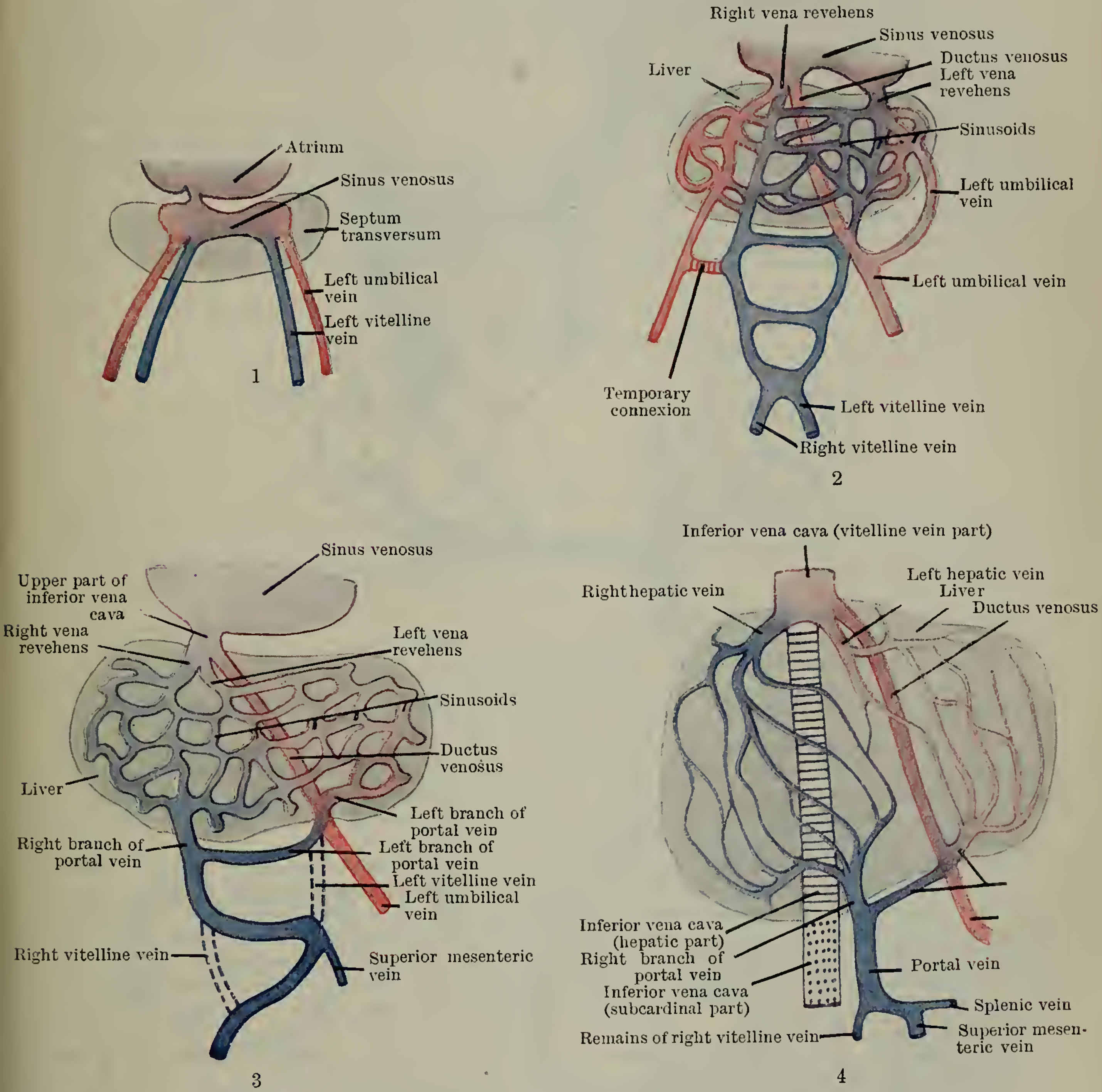

FIG. 807.—SCHEMATA, showing four stages of the development of the portal system and parts of the inferior vena cava.

The venæ revehentes, which transfer the blood from the liver to the heart, are the cranial ends of the primitive vitelline veins. The left vena revehens, as already stated, eventually loses its connexion with the heart and ends in the right vena revehens, which receives the ductus venosus also. The right vena revehens thus becomes the only channel by which blood is returned to the heart from the alimentary canal and from the placenta: that is, it becomes the upper or cranial end of the inferior vena cava. The intra-hepatic part of the stem of the right vena revehens becomes the right hepatic vein, and the left vena revehens becomes the left hepatic vein, which are the two vessels which pour, into the inferior vena cava, the blood which was carried from the alimentary canal to the liver by the portal vein and its branches.

The sinusoidal spaces, as already stated, become reduced to the blood capillaries of the liver, and the ductus venosus which, during fœtal life, conveyed the greater part of the placental blood to the inferior vena cava becomes reduced, after birth, to the *ligamentum venosum*, which connects the left branch of the portal vein with the upper end of the inferior vena cava.

As the cranial part of the right vitelline vein is transformed from the right vena revehens into the upper end of the inferior vena cava, an outgrowth passes caudally from it, along the dorsal aspect of the liver; this becomes connected, at its caudal end, with the right subcardinal vein, and it forms that part of the inferior vena cava which lies in the groove on the dorsal aspect of the right lobe of the liver.

The Umbilical Veins.—In the earliest stages of development there are three umbilical veins, the vena umbilicalis impar and the left and right lateral umbilical veins. The vena umbilicalis impar and the left lateral vein persist until birth, and a remnant of the latter is found, in the adult, as the ligamentum teres of the liver; the right lateral vein disappears entirely at an early stage of development.

The vena umbilicalis impar passes from the placenta to the caudal boundary of the umbilical orifice, where it terminates in the left and right lateral umbilical veins. Each of the latter unites, for a time, with the corresponding vitelline vein in the septum transversum; then it becomes directly connected with the corresponding cornu of the sinus venosus of the heart, and still later with sinusoidal spaces of the liver. The right lateral umbilical vein has also a temporary secondary connexion with the right vitelline vein, but at an early period it undergoes atrophy and all parts of it completely disappear.

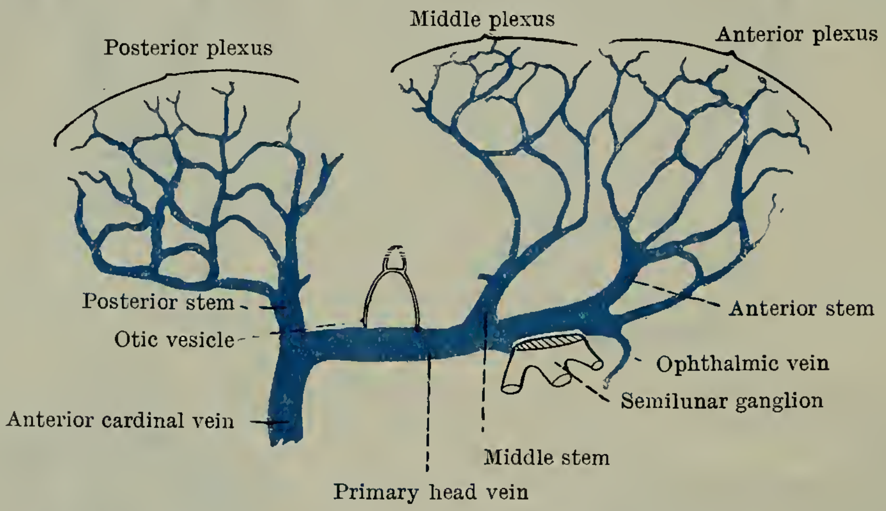

Fig. 808.—Diagram of the Primary Head Vein and its Tributaries. (After Streeter.)

The left lateral umbilical vein, which is connected first with the left vitelline vein, next with the heart, still later with the liver, and finally with the left vitelline again, at the point where the latter becomes the left vena advehens, persists until birth, and, after the disappearance of the right lateral umbilical vein, it conveys the blood from the placenta to the liver, where part of the placental blood passes into the left vena advehens and so through the left vena revehens to the inferior vena cava, and part passes into the ductus venosus, by which it reaches that portion of the cranial part of the right vena revehens which becomes the cranial or upper end of the permanent inferior vena cava.

After birth when the placental circulation ceases the left lateral umbilical vein becomes the ligamentum teres of the liver.

The Ductus Venosus.—The ductus venosus is developed as the left lateral umbilical vein loses its direct connexion with the liver and becomes united to the left vena advehens. It is formed from the sinusoidal spaces of the rudimentary liver and connects the commencement of the left vena advehens with the cranial part of the right vena revehens. It forms the more direct channel by which blood from the placenta is passed to the heart through that part of the right vena revehens which becomes the upper end of the inferior vena cava. After birth it is converted into the fibrous ligamentum venosum, which connects the left branch of the portal vein with the upper end of the inferior vena cava.

The Precardinal Veins.—The precardinal veins are the veins by which the blood is returned to the heart from the head and neck and, ultimately, from the superior extremities also, although the primitive veins of the superior extremities are, in the first place, tributaries of the postcardinal veins.

Each precardinal vein may be separated into two parts—the intra-cranial and the extra-cranial.

In the majority of vertebrates the portion of each precardinal vein which is situated in the head region, and which afterwards becomes intra-cranial, lies to the medial side of the otic vesicle and the 5th, 7th, 8th, 9th, 10th, and 11th cerebral nerves.

At a later period that portion of the vein which lay medial to the otic vesicle and the 7th, 8th, 9th, 10th, and 11th cerebral nerves has disappeared and has been replaced by a new channel, which is placed lateral to the otic vesicle and the 7th, 8th, 9th, 10th, and 11th cerebral nerves.

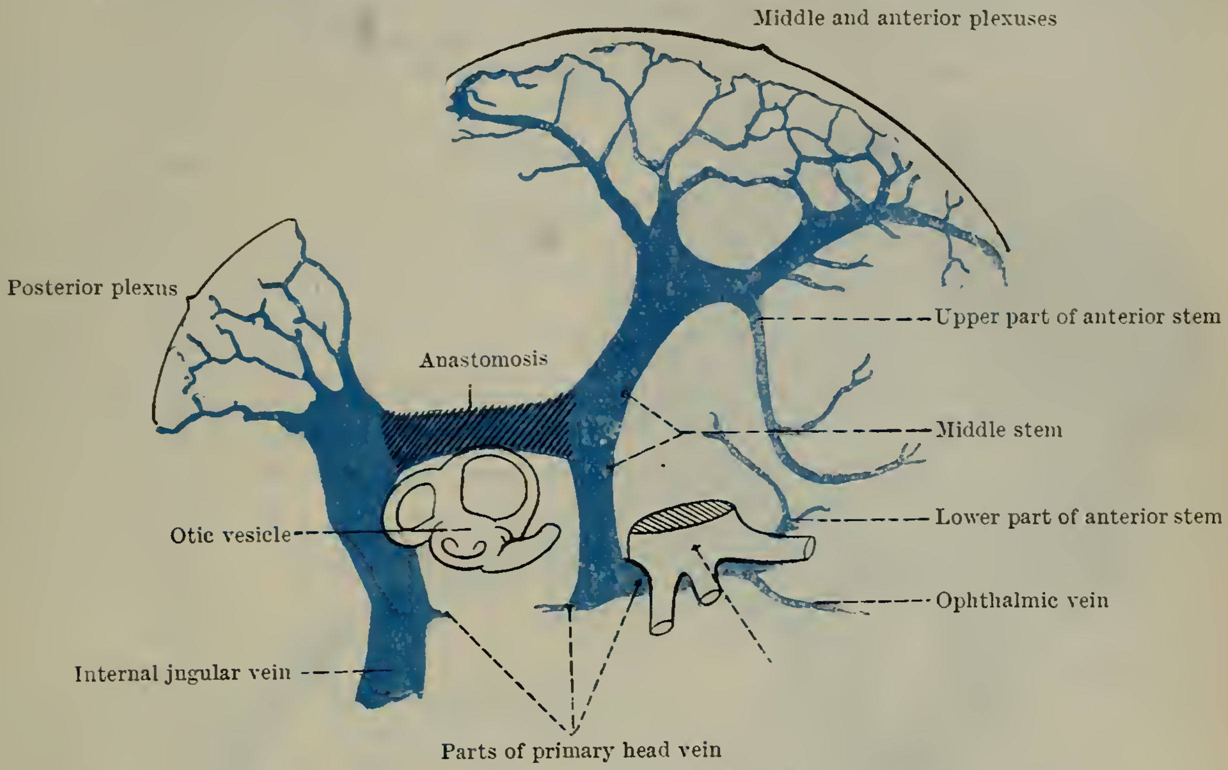
Middle and anterior plexuses
Posterior plexus
Upper part of anterior stem
Anastomosis
Middle stem
Lower part of anterior stem
Otic vesicle
Ophthalmic vein
Internal jugular vein
Parts of primary head vein

Fig. 809.—Diagram of the Head Veins of a 21 mm. Embryo. (After Streeter.)

The new channel extends from the semilunar ganglion of the trigeminal nerve to the upper end of the extra-cranial part of the precardinal vein, that is, to the upper end of the internal jugular vein. This secondary vessel follows the course of the facial nerve and in part of its extent it is extra-cranial.

In the human embryo the stage in which the primitive stem vein lies to the medial side of the otic vesicle and the 7th, 8th, 9th, 10th, and 11th nerves does not seem to occur. At all events in a 3 mm. embryo in the Edinburgh University Collection, and in a 4 mm. embryo in the Collection of the Carnegie Institution of Washington (Streeter), the second stage, in which the posterior part of the cranial portion of the primitive vein lies lateral to the otic vesicle and the 7th, 8th, 9th, 10th, and 11th cerebral nerves, is already present and there is no indication of a vein medial to the otic vesicle.

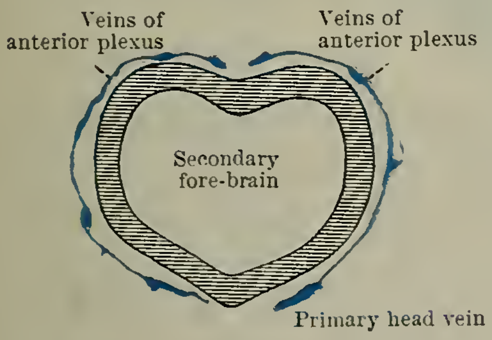

Fig. 810 a.—Diagram of a Transverse Section of the Secondary Fore-brain and the Venous Plexuses.

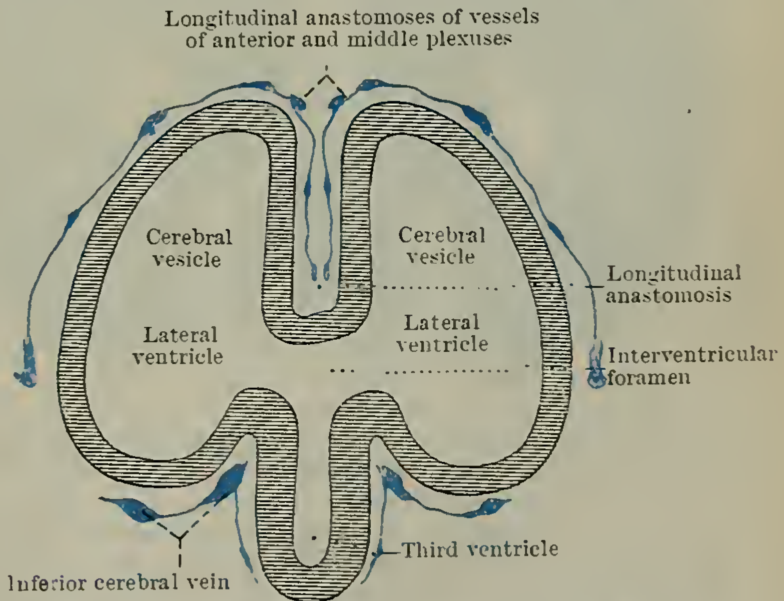

Fig. 810 b.—Diagram of a Transverse Section of the Brain showing the Folding of the Upper Parts of the Plexuses between the Cerebral Hemispheres.

In the human embryo, therefore, the primitive venous stem in the head region, on each side, consists of an anterior portion medial to the semilunar ganglion of the trigeminal nerve, and a posterior portion lateral to the otic vesicle and the 7th, 8th, 9th, 10th, and 11th cerebral nerves; for this stem Streeter has suggested the convenient term "primary head vein" (Fig. 808).

The most anterior tributaries of the primary head vein are derived from the region of the optic vesicle and remnants of them become converted into the ophthalmic vein, but in addition to the anterior tributaries there are numerous dorsal or upper tributaries which become arranged in three main groups: an anterior plexus associated with the regions of the fore-brain and the mid-brain; a middle plexus associated with the cerebellar region of the hind-brain; and a posterior plexus associated with the region of the medulla oblongata (Fig. 809).

The vessels of each plexus tend to run together as they approach the stem of the primary head vein and so three stems are formed, the anterior, middle, and posterior; they were described by Mall in 1904 (Fig. 809). This condition persists until the embryo attains a length of about 18 mm. when an anastomosis forms, above the otic vesicle, between the stems from the middle and posterior plexuses (Fig. 812), and at the same time that part of the primary head vein which lay lateral to the otic vesicle and the 7th, 8th, 9th, 10th, and 11th cerebral nerves disappears.

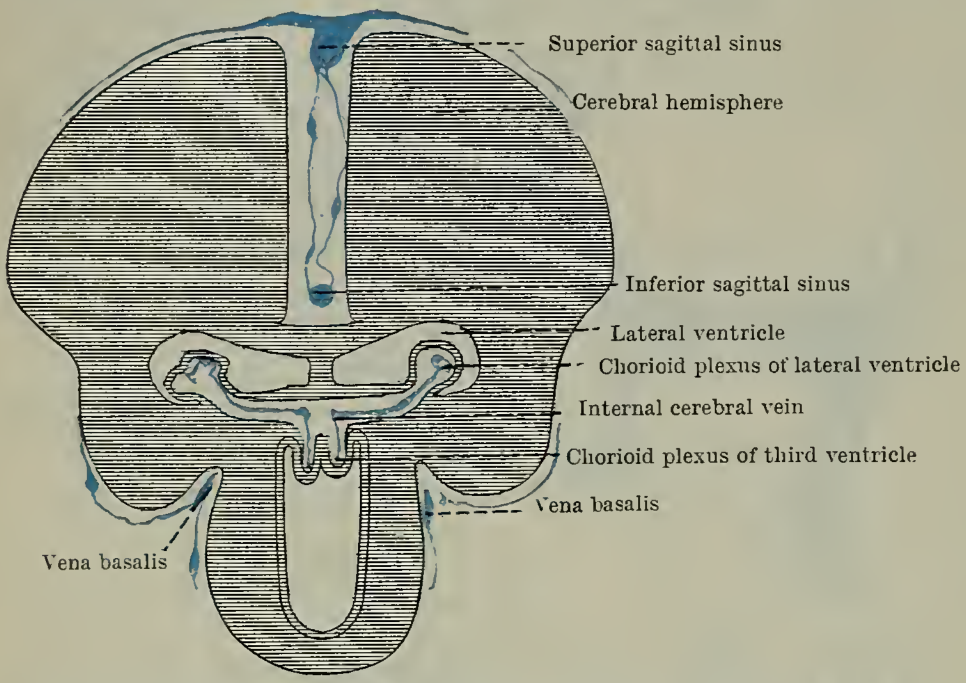

Fig. 811 A.—Diagram of a Transverse Section of the Brain showing Sagittal Sinuses still connected by Remains of the Plexuses.

By the time the embryo has become 21 mm. long the anastomosis mentioned has become very important, and a separation has occurred between the lower and the upper portions of the anterior stem tributary; therefore, at that period, the blood from the eye region flows backwards to the anterior end of the primary head vein, then upwards along what was the lower part of the middle stem tributary, next backwards along the anastomosis above the otic region to the posterior stem tributary, down which it passes to the upper part of the extra-cranial portion of the precardinal vein which has now become the internal jugular vein (Fig. 812). At this time the blood from the anterior and middle plexuses reaches the supra-otic anastomosis through the upper or dorsal part of the middle stem tributary (Fig. 812).

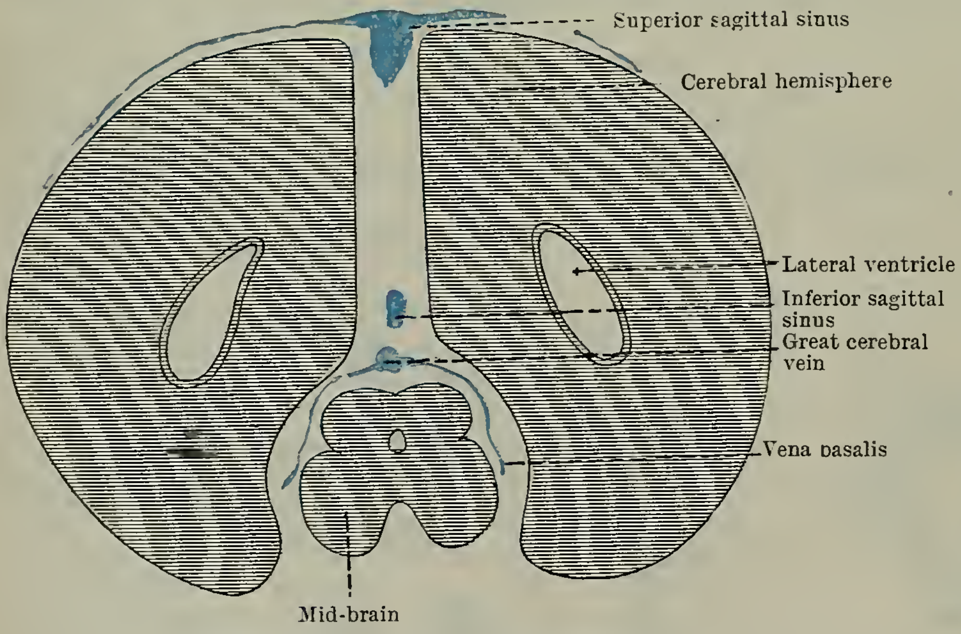

Fig. 811 B.—Diagram of a Transverse Section of the Brain after Completion of the Sagittal Sinuses.

In the meantime the subdural and subarachnoid spaces have been forming, and with the formation of those spaces the main parts of the venous plexuses are carried away from the brain, with the membrane which will be transformed into the dura mater, but in part the plexuses still retain their connexions with the pia mater on the brain surface, and they afterwards establish new connexions with the veins which appear on the surfaces of the developing cerebral hemispheres. In the meantime on each side the upper or dorsal tributaries of the anterior and the middle plexus anastomose together (Fig. 811).

When the cerebral hemispheres increase in size the dura-matral tissue is compressed between them, and between the cerebral hemispheres above and the mid- and hind-brain below, in the form of folds (Figs. 811 A and B). As the folds are formed the conjoined anterior and middle plexuses of one side are carried into relation with those of the opposite side in the median plane of the head; there the vessels of opposite sides unite together and are finally resolved into the superior and inferior sagittal sinuses and the straight sinus (Figs. 811 A and B), and at the same time some of the smaller vessels of the plexuses which retain their connexion with the pia mater are transformed into the internal cerebral veins and the great cerebral vein; and from some of the lower or ventral tributaries, on each side, is produced the inferior cerebral vein of the embryo which probably becomes the vena basalis of the adult (Figs. 811 B, 812).

Whilst the changes last mentioned are taking place the growth of the hemispheres forces the upper part of the middle stem tributary on each side backwards and then downwards until it becomes the horizontal part of the transverse sinus (Fig. 812), whilst the anastomosis above the otic region and the posterior stem tributary are converted into the sigmoid portion of the transverse sinus (Fig. 812).

By the time this stage is attained the anterior portion of the primary head vein which lies to the medial side of the semilunar ganglion has become the cavernous sinus, and the lower or ventral part of the middle stem tributary has been converted into the superior petrosal sinus (Fig. 812).

The inferior petrosal sinus appears to be an independently formed anastomosis which connects the posterior end of the cavernous sinus with the upper end of the internal jugular vein across the medial side of the otic region (Fig. 812).

The extra-cranial parts of the precardinal veins become connected together, in the upper or cephalic part of the thoracic region, by a transverse anastomosis which becomes the greater part of the left innominate vein. A short distance cranialwards to this transverse connexion, the primitive vein of each upper limb ultimately opens into the corresponding precardinal vein. The portion of the precardinal vein of the right side, which lies between the entrance of the limb vein and the transverse anastomosis, becomes the **right innominate vein** (Fig. 813), and the corresponding part on the left side forms the commencement of the **left innominate vein.**

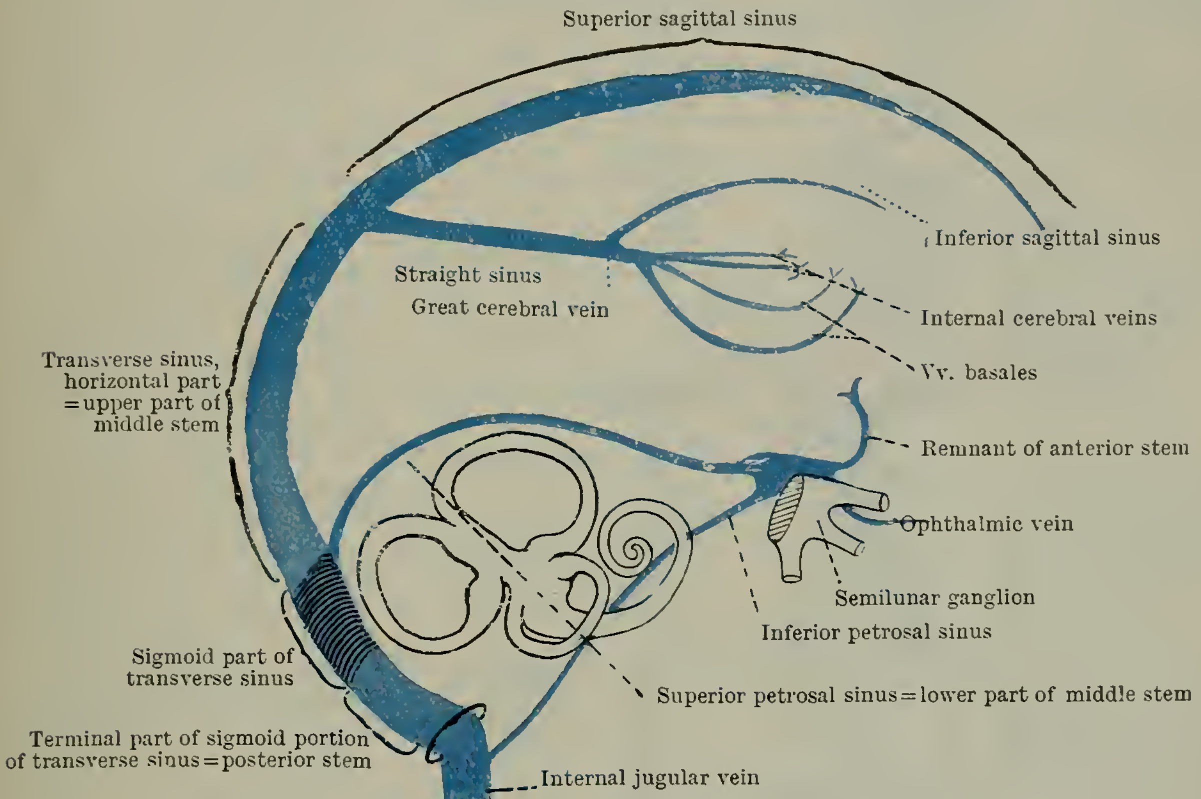

FIG. 812.—DIAGRAM OF THE VENOUS SINUSES. (Only one transverse sinus is shown.)

The part of the extra-cranial portion of each precardinal vein which lies cephalwards of the entrance of the limb vein forms the **internal jugular vein**; and the part of the right precardinal vein which lies caudalwards of the transverse anastomosis becomes the upper or cephalic part of the **superior vena cava**, whilst the corresponding portion of the left vein is converted into the upper or more cranial part of the **left superior intercostal vein** (Fig. 813).

The **external jugular vein** is a new formation which receives for a time the cephalic vein of the upper extremity; but the cephalic vein, which is a secondary vessel, is eventually transposed to the axillary vein, which is a part of the primitive upper limb vein.

The Postcardinal Veins, the Subcardinal Veins, the Supracardinal Veins, and the Inferior Vena Cava.—The Postcardinal Veins which appear shortly after the precardinals lie dorsal to the mesonephri and extend from the pelvic region to the thorax, where they join the precardinals to form the ducts of Cuvier. They return blood from the inferior extremities, the pelvic region, the mesonephri, and the body wall of the abdominal region and the greater part of the thoracic region. In the pelvic region they receive the external iliac and hypogastric veins, and they communicate with one another by transverse anastomoses.

In the adult only portions of them are found in the thoracic and abdominal regions. In the thorax they are represented by the most cranial part of the azygos vein, and the more caudal part of the left superior intercostal vein, and in the abdomen by the hypogastric veins, the common iliac veins, and the commencement of the inferior vena cava, a considerable part of the left common iliac vein being derived from a transverse anastomosis.

The Subcardinal Veins appear in the abdominal region ventro-medial to the mesonephri. Each commences caudally and ends cranialwards in the corresponding postcardinal with which it has also numerous anastomoses medial to the mesonephros, and the two subcardinal veins anastomose across the median plane with each other.

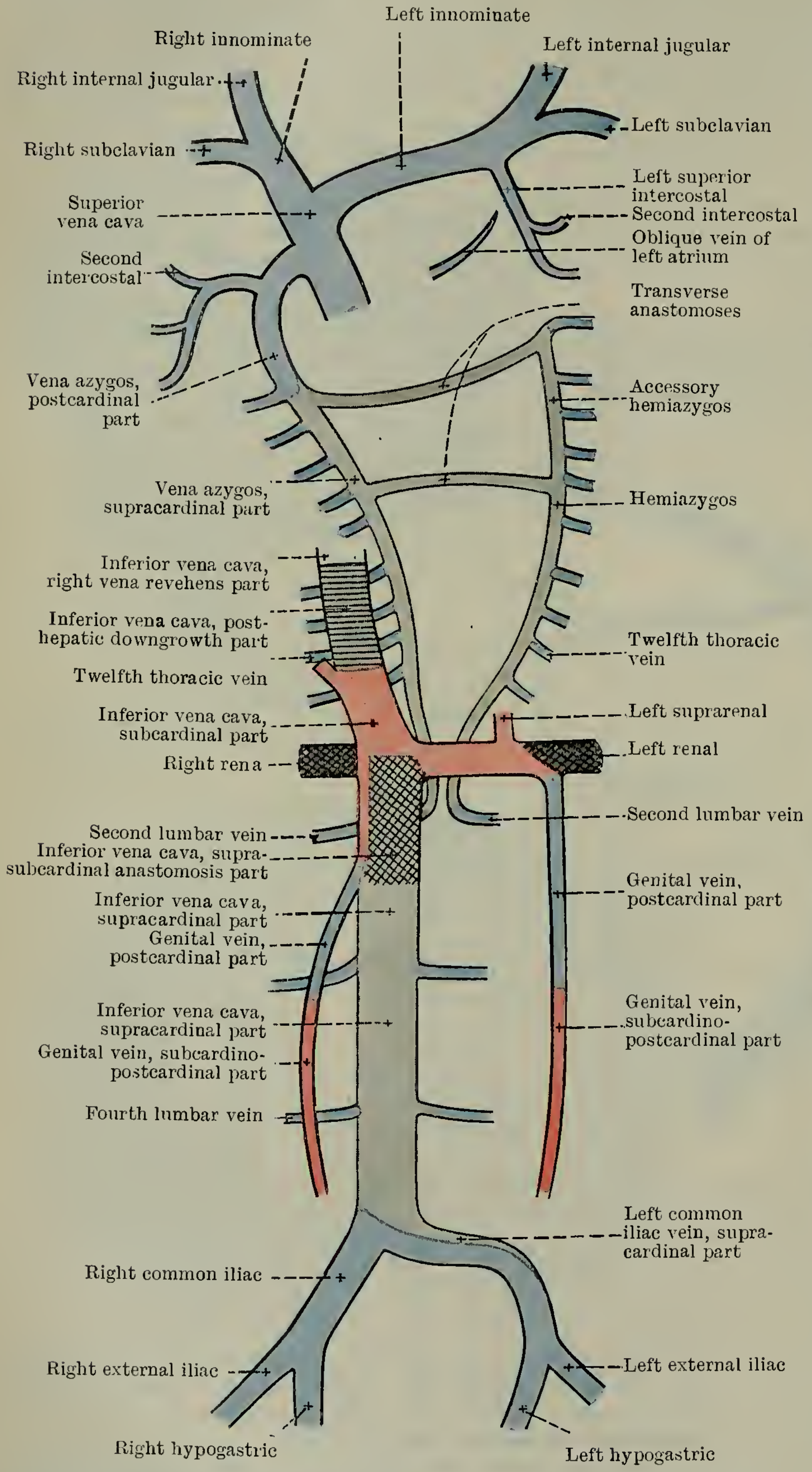
Left innominate
Right innominate
Left internal jugular
Right internal jugular
Left subclavian
Right subclavian
Left superior intercostal
Superior vena cava
Second intercostal
Oblique vein of left atrium
Second intercostal
Transverse anastomoses
Vena azygos, postcardinal part
Accessory hemiazygos
Vena azygos, supracardinal part
Hemiazygos
Inferior vena cava, right vena revehens part
Inferior vena cava, post-hepatic downgrowth part
Twelfth thoracic vein
Twelfth thoracic vein
Left suprarenal
Inferior vena cava, subcardinal part
Left renal
Right rena
Second lumbar vein
Second lumbar vein
Inferior vena cava, supra-subcardinal anastomosis part
Genital vein, postcardinal part
Inferior vena cava, supracardinal part
Genital vein, postcardinal part
Genital vein, subcardino-postcardinal part
Inferior vena cava, supracardinal part
Genital vein, subcardino-postcardinal part
Fourth lumbar vein
Left common iliac vein, supra-cardinal part
Right common iliac
Left external iliac
Right external iliac
Right hypogastric
Left hypogastric

Fig. 813.—Diagram of the Component Parts of the Main Venous Trunks, showing their Derivation. (After Huntington and M'Clure.)

Blue = Precardinal and postcardinal system.
Red = Subcardinal system.
Grey = Supra-cardinal system.
Cross-patching = Supra-subcardinal anastomosis and renal veins.

The subcardinal veins receive blood from the mesonephri, the genital glands, and the suprarenal glands.

After the subcardinals are established, a downgrowth from the cardiac end of the right vitelline vein occurs.

It is produced chiefly by a modification of the sinusoidal tissue of the dorsal part of the liver, to the right of the median plane, and it becomes the hepatic part of the inferior vena cava of the adult. Its caudal end establishes a communication with the right subcardinal vein caudal to the point where the latter receives the veins from the suprarenal gland, and at the same time a transverse anastomosis between the subcardinal veins which lies immediately caudal to the origin of the superior mesenteric artery becomes enlarged.

The result of these alterations is a great change in the venous circulation, for the blood, which previously passed from the inferior extremities and the abdominal region to the heart by way of the postcardinal veins, is short-circuited to the caudal end of the right atrium, and the thoracic parts of the postcardinal veins become relatively less important and smaller.

The enlarged anastomosis between the subcardinal veins ultimately forms part of the left renal vein, though renal veins at the stage under discussion are not existent, but at this period three parts of the permanent inferior vena cava are established: the *supra-hepatic part*, derived from the cardiac end of the right vitelline vein; the *post-hepatic part*, evolved from the sinusoidal tissue of the liver; and the *prerenal infra-hepatic part*, which is an enlarged portion of the right subcardinal vein.

After the post-hepatic portion of the inferior vena cava has joined the right subcardinal vein, the part of the latter which lies cranial to the union becomes the right suprarenal vein, and the part of the left subcardinal which lies cranial to the enlarged intersubcardinal anastomosis becomes the left suprarenal vein.

About the same time the part of each subcardinal vein which lies caudal to the enlarged intersubcardinal anastomosis disappears, and the blood from the corresponding genital gland now passes to the corresponding postcardinal vein through what was a subcardino-postcardinal anastomosis.

The Supracardinal Veins.—There now appears in the thoracic and abdominal regions another pair of longitudinal venous channels, the supracardinal veins, which lie dorso-lateral to the descending aorta and which anastomose with each other through transverse channels. They communicate at their cranial ends, in the thoracic region, and at their caudal ends, in the abdominal region, with the corresponding postcardinals, and at the level of the enlarged intersubcardinal anastomosis with the enlarged postcardinal subcardinal anastomoses by which blood is conveyed from the right postcardinal vein to the inferior vena caval part of the right subcardinal vein, and from the left postcardinal vein to the enlarged intersubcardinal anastomosis.

By this time the kidneys have attained their abdominal positions, and the renal veins open into the postcardinal-subcardinal anastomosing channels, formed around the aorta at the level of the cranial ends of the kidneys.

Thus a venous ring is formed around the aorta at the level of the kidneys, and it plays a part in the formation of the permanent veins. A detailed statement of the changes by which the postcardinals, the subcardinals, the supracardinals, and the venous interrenal circumaortic venous ring become transformed into permanent venous stems would occupy more space than is available in a Text-Book of Anatomy, but the student who is interested in the process and in the explanation of the anomalies which may result from modifications of them can consult a paper in which they are described and upon which the account here given is based;[1] here only a summary of the ordinary results can be given.

(1) The caudal parts of the postcardinals remain and are represented by the hypogastric veins, the common iliac veins; the right also enters into the formation of the caudal end of the inferior vena cava, and the interpostcardinal anastomosis at the level of the fifth lumbar vertebra takes part in the formation of the left common iliac vein.

(2) It has already been noted that after the post-hepatic part of the inferior vena cava joins the right subcardinal vein, the postcardinals cranial to that level almost entirely disappear, remnants of them persisting in the adult as the terminal part of the vena azygos and the caudal part of the right superior intercostal vein.

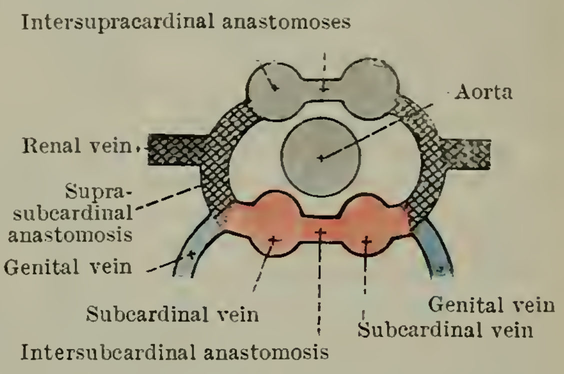
Intersupracardinal anastomoses
Aorta
Renal vein
Supra-subcardinal anastomosis
Genital vein
Subcardinal vein
Intersubcardinal anastomosis
Genital vein
Subcardinal vein

Fig. 814.—Diagram of the Circumaortic Venous Collar. (After Huntington and M'Clure.)

In the abdominal region between the caudal end of the inferior vena cava and the entrances of the genital veins into the postcardinals, the postcardinals disappear, but a small part of each postcardinal cranial to the entrance of the genital vein persists, and forms with the genital vein the testicular or ovarian vein in the adult.

(3) The postcardinal-subcardinal anastomosis which lies at the level of the main intersubcardinal anastomosis persists. On the right side it takes part in the formation of the inferior vena cava, and on the left side it forms part of the left renal vein.

(4) The persistent parts of the right subcardinal are the part of the inferior vena cava from the renal vein to the liver and the right suprarenal vein, whilst the persistent part of the left subcardinal is the left suprarenal vein.

(5) The intersubcardinal anastomosis immediately caudal to the superior mesenteric artery becomes part of the left renal vein; the other intersubcardinal anastomoses disappear.

(6) The right supracardinal-subcardinal anastomosis takes part in the formation of the inferior vena cava; the left disappears.

(7) Parts of the supracardinals persist both in the thoracic and abdominal regions.

In the thoracic and the cranial part of the abdominal region, on the right side the supracardinal becomes the azygos vein, and on the left side the hemiazygos and the accessory hemiazygos, whilst two of the thoracic intersupracardinal anastomoses persist as those sections of the hemiazygos veins which cross the front of the vertebral column on their way to join the azygos vein.

In the abdominal region the supracardinals fuse together and form that part of the vena cava inferior which lies caudal to the entrance of the right spermatic or ovarian vein, fusing at the level of the inferior fifth lumbar vertebræ with the part of the right postcardinal vein which enters into the formation of the inferior vena cava and the part of the interpostcardinal anastomosis which takes part in the formation of the left common iliac vein.

(8) The right renal vein is the efferent vein passing from the kidney to the right suprasubcardinal anastomosis.

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[1] The development of the veins in the domestic cat, with special reference to the share taken by the supracardinal veins in the development of the postcava and the azygos vessels, and to the interpretation of the variant conditions, etc., *Anat. Rec.* vol. xx. No. 1, Dec. 1920.

The left renal vein is a composite structure in which the efferent vessels of the kidney, a postsubcardinal anastomosis and the intersubcardinal anastomosis immediately caudal to the superior mesenteric artery take part.

(9) The testicular or ovarian vein is a vein from the genital gland plus part of a postcardinal vein.

(10) **The inferior vena cava** has a multiple origin. Its component parts from its cardiac to its caudal end are (1) the right vitelline vein ; (2) the posthepatic section derived from the sinusoids of the liver ; (3) the right subcardinal section from the liver to the renal veins ; (4) the section extending from the renal veins to the right testicular or ovarian vein which is formed by the fusion of a postcardinal anastomosis united with the right supra-subcardinal anastomosis ; (5) the section extending from the entrance of the right testicular or ovarian vein to the fifth lumbar vertebra formed from the fused supracardinal veins ; (6) the caudal end formed partly by the right postcardinal.

THE DEVELOPMENT OF THE LYMPH VASCULAR SYSTEM.

Very little is known regarding the origin of the vessels of the lymph vascular system in man, but during recent years numerous investigations have been made with the object of discovering the various phases of the development of the lymph vascular system in other mammals ; some of the main points are, however, still subjects of dispute.

It is generally admitted that the terminal parts of the great lymph vessels, that is, the terminal part of the thoracic duct and the right lymphatic duct, are derived from venous channels, which, for a time, lose their connexion with the larger veins and become modified into terminal lymph sacs which obtained a secondary union with the great veins at the root of the neck ; but regarding the origin of the thoracic duct and the cisterna chyli and the peripheral lymph vessels there is, as yet, no agreement. According to Florence Sabin, and those who agree with her, the peripheral lymph vessels are outgrowths from a series of lymph sacs, themselves of venous origin, and from veins. Of the lymph sacs the two cervical, a retro-peritoneal, a cisterna chyli, and two posterior sacs, lying along the inferior gluteal veins, are recognised in human embryos of about 24 mm. length. The origin of these sacs, in the human embryos, has not been proved, but it appears probable that the cervical sacs are derived as in other mammals from venous capillary vessels. There is no agreement, however, concerning the origin of the other sacs, for whilst, on the one hand, Florence Sabin appears to believe that they have an origin like that of the jugular lymph sacs and that the thoracic duct is developed in the same manner, Huntington, on the other hand, believes that, with the exception of the jugular or cervical lymph sacs, all the other lymph vessels, including the thoracic duct, are developed neither as outgrowths from lymph sacs nor by the modification of venous capillaries, but by the formation of endothelial lined spaces in the mesodermal tissues. The spaces are at first entirely closed but afterwards attain union with one another and with the terminal lymph vessels.

According to the view upheld by Florence Sabin and her supporters, the lymph vessels are outgrowths from the venous system, and are therefore lined with endothelium which is genetically the same as that in the veins. According to Huntington this is not the case ; for his observations lead him to believe that the endothelium of the lymph vessels is formed, *in situ*, from the mesodermal cells, and it has therefore no direct genetic connexion with the endothelium of the veins, which is derived from the original hæmohistoblastic tissue. The evidence brought forward by the supporters of the opposite views is interesting and instructive upon many points, but the question must still be regarded as an open one.

The Development of Lymph Glands.—Lymph glands are developed from plexuses of lymph vessels. The transformation is brought about by the aggregation of numerous lymphocytes in the connective tissue strands of the plexuses and the transformation of the lumina of the vessels into the peripheral and central portions of the lymph sinus. The stroma, the capsule, and the proper substance of a lymph gland are therefore formed from the fibro-cellular reticulum of the lymphatic plexus, and the cavity of the lymph sinus is formed from the lumina of lymph capillaries. The rudimentary lymph glands possess blood vascular as well as lymphatic capillary networks, and if the blood vascular network preponderates over the lymph vascula the developing gland has a reddish appearance and is known as a hæmal gland. Such glands are found in man as well as in other mammals, and it would appear from the observations of H. S. Harrison and Swale Vincent that hæmal glands are merely rudimentary forms of true lymph glands (*Jour. of Anat. and Phys.* vol. 31).

THE FŒTAL CIRCULATION.

During the period of fœtal life food and oxygen are transmitted from the maternal blood to the fœtal blood in the placenta, where the maternal blood flows in near relation to the walls of the fœtal blood-vessels ; and the effete products produced by the action of the cells of the fœtal tissues, including carbonic acid, are passed from the fœtal to the maternal blood in the same place.

Lungs are present in the fœtus, but they do not function as respiratory organs until birth ; therefore, although the blood-vessels necessary for pulmonary respiration are present, the only blood that flows through them is that which is necessary for their nutrition and growth.

It is because there is no necessity for a pulmonary circulation before birth, and because there is necessity that the blood which will pass through the lungs after birth shall be transmitted elsewhere before birth, that the foramen ovale in the interatrial septum and the ductus venosus which connects the left branch of the pulmonary artery with the aorta remain patent until birth.

Moreover, as it is necessary that food and oxygen shall be obtained from the mother's blood in the placenta, and that effete products of the fœtus shall be transferred from the fœtal to the maternal blood also in the placenta, the umbilical branches of the hypogastric arteries, which carry fœtal blood to the placenta, and the left umbilical vein, which returns it from the placenta to the fœtus, persist until birth. As a consequence, the course of the circulation before and after birth is different.

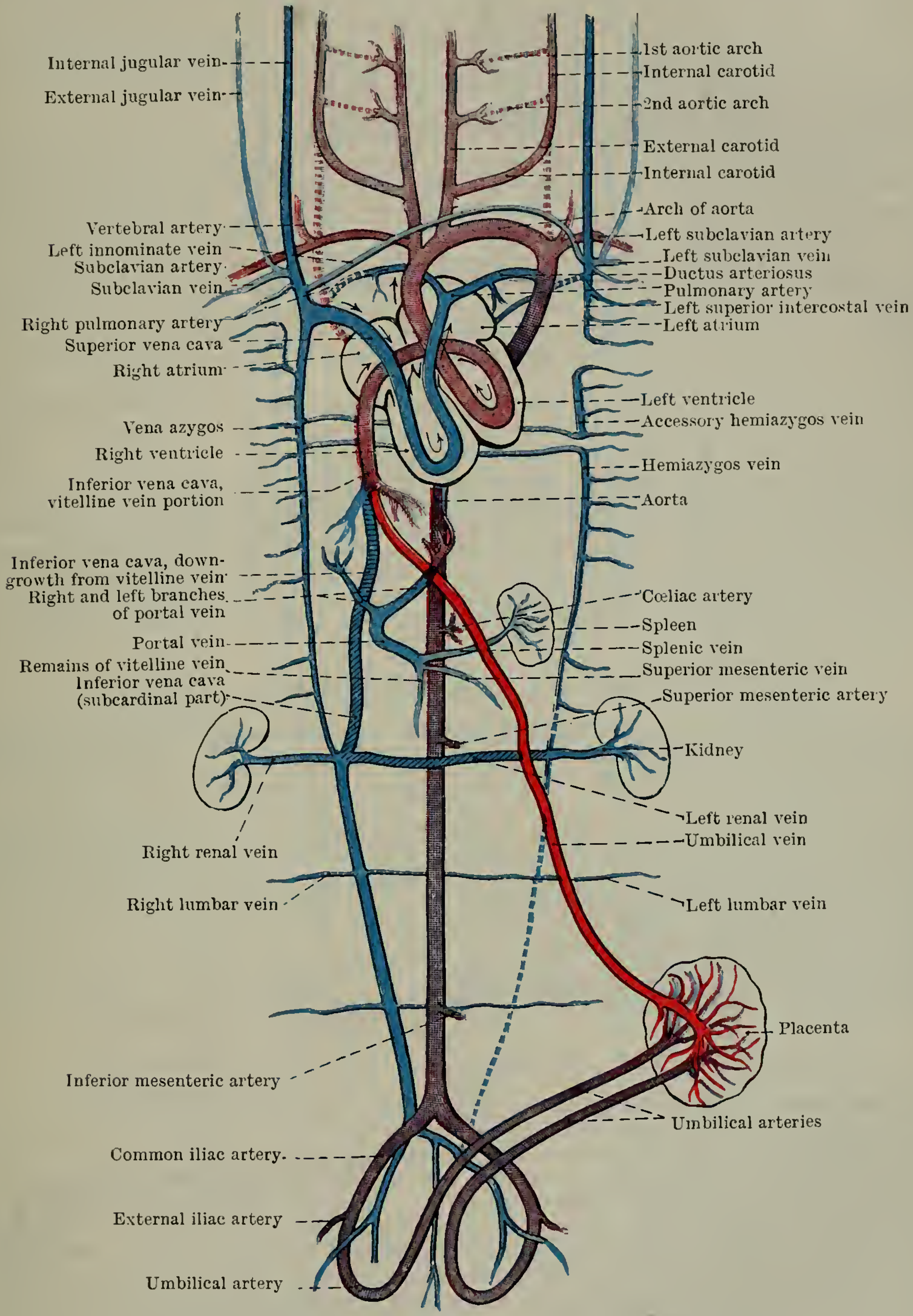

Fig. 815.—Diagram of the Course of the Fœtal Circulation.

After birth blood passes from the body generally into the right atrium, which passes it on into the right ventricle, whence it is forced, through the lungs, to the left atrium, and thence to the left ventricle, by which it is propelled through the systemic vessels back to the right atrium.

In the fœtus, on the other hand, food- and oxygen-laden blood passes from the placenta to the inferior vena cava, partly directly by the left umbilical vein and the ductus venosus, and partly indirectly by the left umbilical vein to the liver and thence to the inferior vena cava. In the inferior vena cava it mixes with venous blood returning from the inferior extremities and the lower parts of the body walls, the renal organs, and the genital glands, and so it becomes mixed blood. The mixed stream passes from the inferior vena cava through the right atrium and the foramen ovale to the left atrium, thence to the left ventricle, which forces it through the aorta into all parts of the body and limbs.

The blood from the head and neck, the superior extremities, and the upper parts of the body wall returns by the superior vena cava to the right atrium, through which it passes into the right ventricle, which ejects it, through the pulmonary artery and the ductus arteriosus, into the aorta, beyond the origin of the left subclavian artery, where it mixes with the blood from the left ventricle; a minute quantity only enters the lungs.

In the fœtus, therefore, pure oxygenated blood is only found from the umbilicus to the inferior vena cava, in the left umbilical vein and the ductus venosus. In the upper part of the inferior vena cava the blood becomes a mixture by blending with the blood returning from the lower limbs and the lower part of the body. The mixed stream, which may be termed the less venous stream, directed by the valve of the inferior vena cava, passes through the right into the left atrium, thence through the left ventricle into the aorta. From the aorta some of it passes into the head and neck and the superior extremities, the remainder passes into the descending aorta and becomes the more venous stream because it is joined, beyond the origin of the left subclavian artery, by the venous stream from the head and neck and the superior extremities, which has passed from the superior vena cava through the right atrium, the right ventricle, the pulmonary artery, and the ductus arteriosus.

From the descending aorta part of the more venous stream passes to the walls of the thorax, to the abdomen and its contents, and to the inferior extremities; the remainder passes through the hypogastric arteries and their umbilical branches to the placenta.

It is obvious, from what has been stated, that the blood in the descending aorta, which is supplied to the lower part of the trunk and the lower limbs, contains relatively less oxygen and food material and more effete matters than that in the ascending aorta and the arch of the aorta, which is transmitted to the head and neck and the superior extremities, and, as a consequence, the growth of the head, neck, and superior extremities is more rapid than that of the inferior extremities. The liver, on the other hand, which receives purer blood than any other part of the fœtus, grows with extreme rapidity and attains a relatively very large size.

MORPHOLOGY OF THE VASCULAR SYSTEM.

In conformity with the general plan of the vertebrate body, the vascular system is essentially segmental in character. The segmental character of the intercostal and lumbar vessels is obvious; that of the vessels of the head, neck, and pelvis is less obvious but is still distinguishable in the vessels of the head.

The intersegmental arteries and veins form a series of bilaterally symmetrical vessels, each of which is united to the vessels of adjacent segments by segmental channels, which anastomose with one another, through the portions of the intersegmental vessels which they connect together, and thus form longitudinal trunks. The longitudinal trunks are mainly, though not exclusively, segmental. From them the main stem vessels of the individual are formed, and from or to these latter the intersegmental vessels appear to proceed as branches or tributaries.

In the course of development the longitudinal trunks become the most important trunks in the individual, and they are formed before the branches and tributaries make their appearance.

THE SEGMENTAL ARTERIES AND THEIR ANASTOMOSES.

The main longitudinal trunks are the primitive aortæ. The descending aorta is formed, in the greater part of its extent, by the fusion of the dorsal parts of the primitive aortæ, and from it the intersegmental, lateral, and ventral arteries arise in pairs.

In a typical portion of the body of the embryo there are three arteries on each side. One arises from the dorsal surface of the primitive dorsal aorta, *i.e.* from the dorsal longitudinal trunk, and runs laterally and ventrally in the tissues developed from the somatic mesoderm; it is distributed to the body wall, including the vertebral column and its contents, and is termed a **somatic intersegmental artery.** A second vessel arises from the side of the primitive dorsal aorta; it is distributed to the structures developed from the intermediate cell mass, viz., the suprarenal gland, the kidney, and the ovary or the testis, and it is accordingly termed a **lateral** or an **intermediate visceral artery.** The third artery, which is known as the **splanchnic artery,** springs from the ventral surface of the aorta. It runs in the tissues developed from the splanchnic mesoderm, and supplies the wall of the alimentary canal.

The **somatic intersegmental arteries** form, in the early embryo, a regular series of paired vessels throughout the cervical, thoracic, lumbar, and sacral regions. It is, however, only in the thoracic and lumbar regions that their original characters are retained. The paired vessels pass dorsally, by the sides of the vertebræ, and divide into dorsal and ventral branches which accompany the corresponding anterior and posterior divisions of the spinal nerves.

The **ventral branches** run ventro-laterally, between the ribs, in the thoracic region, and in corresponding positions in the lumbar region, and together with the stems they form the main parts or trunks of the vessels in the thoracic and lumbar regions. They are connected together, near their commencements, by a series of pre-costal anastomoses which pass in front of the necks of the ribs, and they are also connected together, near their terminations, by ventral anastomosing channels which run, in the thoracic region, behind the costal cartilages, and in the lumbar region behind or in the substance of the rectus abdominis muscle. Each ventral branch gives off a lateral offset which is distributed like the lateral cutaneous branch of a spinal nerve, and the ventral branch together with the stem of the intersegmental artery forms the trunk of an intercostal or lumbar artery in the adult.

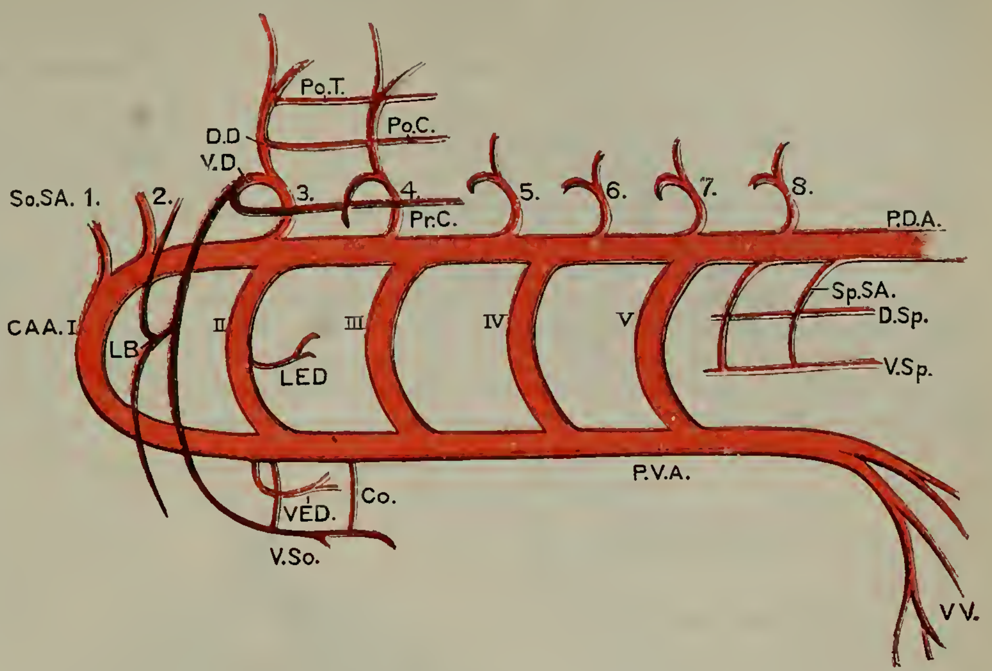

Fig. 816.—Diagram of the Cephalic Aortic Arches, and of the Segmental and Intersegmental Arteries in the Region in front of the Umbilicus.

C.A.A.	I, II, III, IV, V. The cephalic aortic arches.
Co.	Anastomosing vessel between the primitive ventral aorta and the ventral somatic anastomosis.
D.D.	Dorsal division of a somatic intersegmental artery.
D.Sp.	Dorsal splanchnic anastomosis.
L.B.	Lateral branch of ventral division of somatic intersegmental artery.
L.E.D.	Branch to lateral enteric diverticulum.
P.D.A.	Primitive dorsal aorta.
Po.C.	Post-costal anastomosis.
Po.T.	Post-transverse anastomosis.
Pr.C.	Pre-costal anastomosis.
P.V.A.	Primitive ventral aorta.
So.S.A.	1, 2, 3, 4, 5, 6, 7, 8. Somatic intersegmental arteries.
Sp.S.A.	Splanchnic arteries.
V.D.	Ventral division of a somatic intersegmental artery.
V.E.D.	Branch to ventral enteric diverticulum.
V.V.	Vitelline vessels.
V.So.	Ventral somatic anastomosis.
V.Sp.	Ventral splanchnic anastomosis.

The **dorsal branches**, which are present before the ventral branches, run dorsally between the transverse processes of the vertebræ, and form the posterior branches of the intercostal arteries and the dorsal branches of the lumbar arteries of the adult; they are connected, behind the necks of the ribs, by post-costal anastomoses, and again, behind the transverse processes of the vertebræ, by post-transverse anastomosing channels. Moreover, each dorsal branch, as it passes by the corresponding intervertebral foramen, gives off a spinal offset which enters the spinal canal, along the corresponding nerve-root, and divides into a dorsal, a ventral, and a neural branch. The dorsal branches of these spinal arteries are connected together along the ventral surfaces of the laminæ by pre-laminar anastomoses, and the ventral branches are united on the dorsal surfaces of the vertebral bodies (or centra) with their fellows above and below by post-central anastomoses; they are also united with their fellows of the opposite side by transverse communicating channels. The neural branches of the spinal arteries divide similarly into dorsal and ventral branches; the dorsal branches of each side are connected together by post-neural anastomoses, which form the posterior spinal arteries; and the ventral branches unite, in the median line, both with their fellows above and below and with those of the opposite side, forming a single longitudinal pre-neural trunk, the anterior spinal artery.

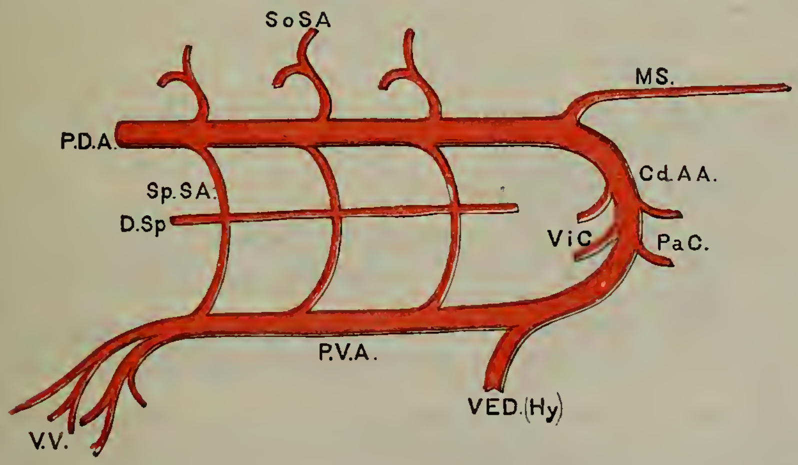

Fig. 817.—Diagram of the Arteries in the Region caudal to the Umbilicus.

Cd.A.A.	Caudal aortic arch.
D.Sp.	Dorsal splanchnic anastomosis.
M.S.	Middle sacral artery.
Pa.C.	Parietal branch from caudal arch.
P.D.A.	Primitive dorsal aorta.
P.V.A.	Primitive ventral aorta.
So.S.A.	Somatic intersegmental arteries.
Sp.S.A.	Splanchnic arteries.
V.E.D.	(Hy). Branch to a ventral enteric diverticulum.
Vi.C.	Visceral branch from the caudal arch.
V.V.	Vitelline vessels.

In the thoracic and lumbar regions of the body the somatic intersegmental arteries persist, and form the intercostal and lumbar arteries. These vessels spring from the dorsal aspect of the descending aorta, usually in pairs. The corresponding vessels of opposite sides, however, occasionally fuse together at their origins, simultaneously with the fusion of the dorsal longitudinal trunks to form the descending aorta, and then the arteries of opposite sides arise by common stems.

The pre-costal anastomoses between the ventral branches of the somatic intersegmental arteries are only represented in the thoracic region by the superior intercostal arteries; in the lumbar region they disappear entirely. The anastomoses between the anterior ends of the ventral branches of the somatic intersegmental arteries persist as the internal mammary and superior and inferior epigastric arteries.

The lateral offsets of the ventral branches are represented by the cutaneous arteries which accompany the lateral cutaneous branches of the spinal nerves, and the lateral branch of the seventh somatic intersegmental artery forms the greater part of the arterial stem of the upper limb.

The post-costal and post-transverse anastomoses usually disappear in the thoracic and lumbar regions, but the post-costal anastomoses occasionally persist in the upper thoracic region, and take part in the formation of the vertebral artery, which in such cases arises from the first or second intercostal artery. In some carnivora the post-costal longitudinal vessels persist in the upper thoracic region, and form, on each side, a trunk which is connected with the first aortic intercostal, and which supplies the first five intercostal spaces.

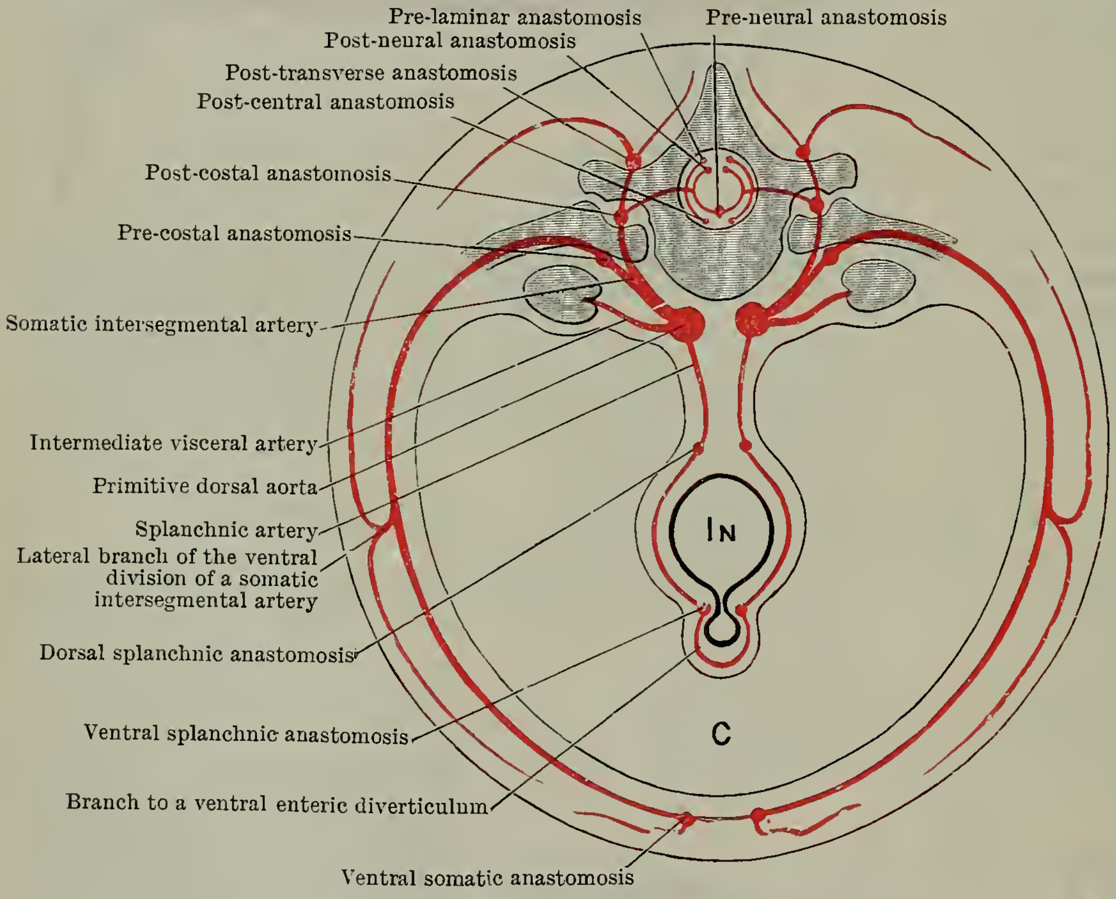
Pre-laminar anastomosis
Pre-neural anastomosis
Post-neural anastomosis
Post-transverse anastomosis
Post-central anastomosis
Post-costal anastomosis
Pre-costal anastomosis
Somatic intersegmental artery
Intermediate visceral artery
Primitive dorsal aorta
Splanchnic artery
Lateral branch of the ventral division of a somatic intersegmental artery
Dorsal splanchnic anastomosis
Ventral splanchnic anastomosis
Branch to a ventral enteric diverticulum
Ventral somatic anastomosis
IN
C

Fig. 818.—Diagram showing the Arrangement and Communications of the Segmental and Intersegmental Arteries at an early Stage of Development.

C, Cœlom; In, Intestine.

The pre-laminar, the post-central, and the pre- and post-neural anastomoses persist, the latter two aiding in the formation of the thoracic and lumbar portions of the anterior and posterior spinal arteries respectively.

It is in the cervical region, however, that the most interesting changes occur. The first six pairs of somatic intersegmental arteries lose their connexions with the dorsal roots of the aortic arches, *i.e.*, in other words, with the longitudinal anastomosing channels in that region. The seventh pair, however, persist in their entirety; and from them are formed, on the right side, a portion of the subclavian trunk, and on the left side the whole of the subclavian stem from its commencement up to the origin of the vertebral artery. On each side the ventral branch of the seventh intersegmental artery forms that portion of the subclavian artery which lies between the origins of the vertebral and internal mammary arteries, and also the trunk of the internal mammary artery as far as the upper border of the first costal cartilage. The remainder of the internal mammary artery represents the ventral longitudinal anastomoses between the ventral branches of the seventh and the following somatic intersegmental arteries. The continuation of the subclavian artery, beyond the inner margin of the first rib, is the persistent and enlarged lateral offset of the ventral branch of the seventh somatic intersegmental artery, which is continued into the upper limb, caudal or postaxial to the shoulder girdle. The thyreo-cervical trunk and the superior intercostal artery, both branches of the subclavian artery, are persistent pre-costal anastomoses, and the ascending cervical artery belongs to the same series of vessels. The vertebral artery, which appears as a branch of the subclavian in the adult, is, morphologically, somewhat complex. The first part represents the dorsal branch of the seventh somatic intersegmental artery; the second part, that passing through the cervical transverse processes, consists of the persistent post-costal anastomoses between the dorsal branches of the first seven intersegmental arteries; a third part, that lying on the arch of the atlas, is the spinal branch of the first somatic intersegmental artery and its neural continuation; whilst finally the upper part of the vertebral artery, the part in the cranial cavity, appears to represent a prolongation of the pre-neural anastomoses, which still farther upwards are probably represented by the basilar artery. As already stated, the post-costal anastomoses below the seventh intersegmental artery occasionally persist, and in such cases the vertebral may lose its connexion with the subclavian, and spring from one or other of the posterior branches of the upper intercostal arteries.

The profunda cervicis artery is to be regarded as a remnant of the post-transverse longitudinal anastomoses.

The origin of the seventh somatic intersegmental artery from the dorsal longitudinal trunk is, at first, some distance caudal to the sixth aortic arch, but, simultaneously with the elongation of the neck and the retraction of the heart into the thoracic region, it is shifted cranialwards until it is opposite the dorsal end of the fourth aortic arch.

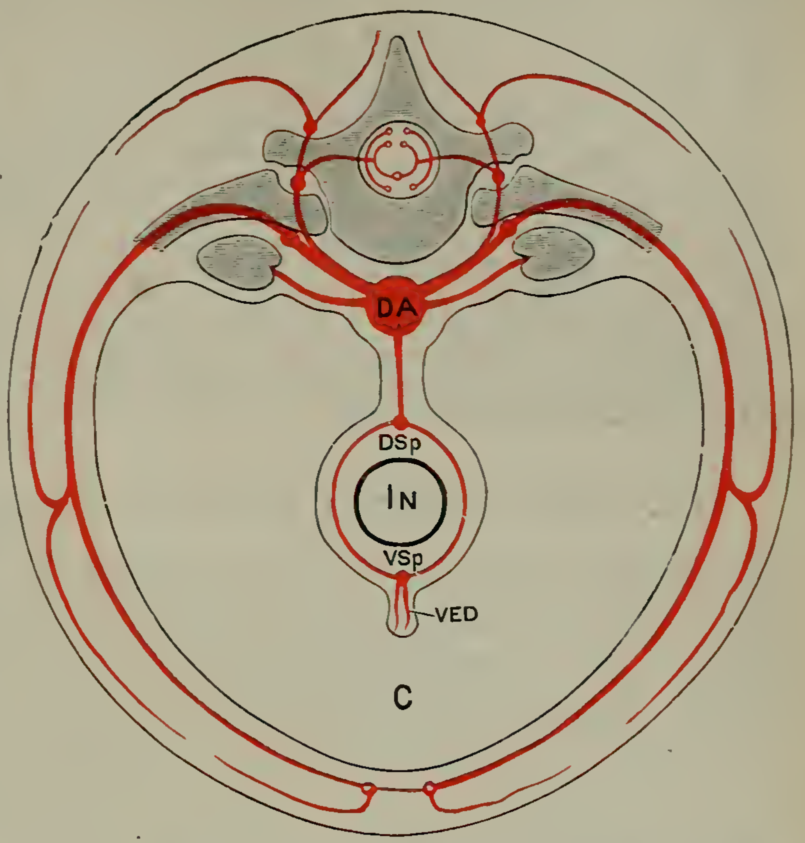

FIG. 819.—DIAGRAM OF THE SEGMENTAL AND INTERSEGMENTAL ARTERIES AT A LATER PERIOD OF DEVELOPMENT THAN IN FIG. 818.

C, Cœlom; D.A, Dorsal aorta; D.Sp, Dorsal splanchnic anastomosis; IN, Intestine; V.E.D, Branch to ventral enteric diverticulum; V.Sp, Ventral splanchnic anastomosis.

The middle sacral artery is formed by the fusion of two vessels, each of which springs from the dorsal surface of the aorta. It is regarded as the direct continuation of the descending aorta.

The **lateral** or **intermediate visceral arteries** supply the organs derived from the intermediate cell mass. They form a somewhat irregular series of vessels in the adult, but presumably in the primitive condition there was a pair in each segment of the body; many of these disappear, however, and the series is only represented in the adult by the suprarenal, the right renal, part of the left renal, and the testicular or ovarian arteries—possibly, also, by some of the branches of the hypogastric arteries.

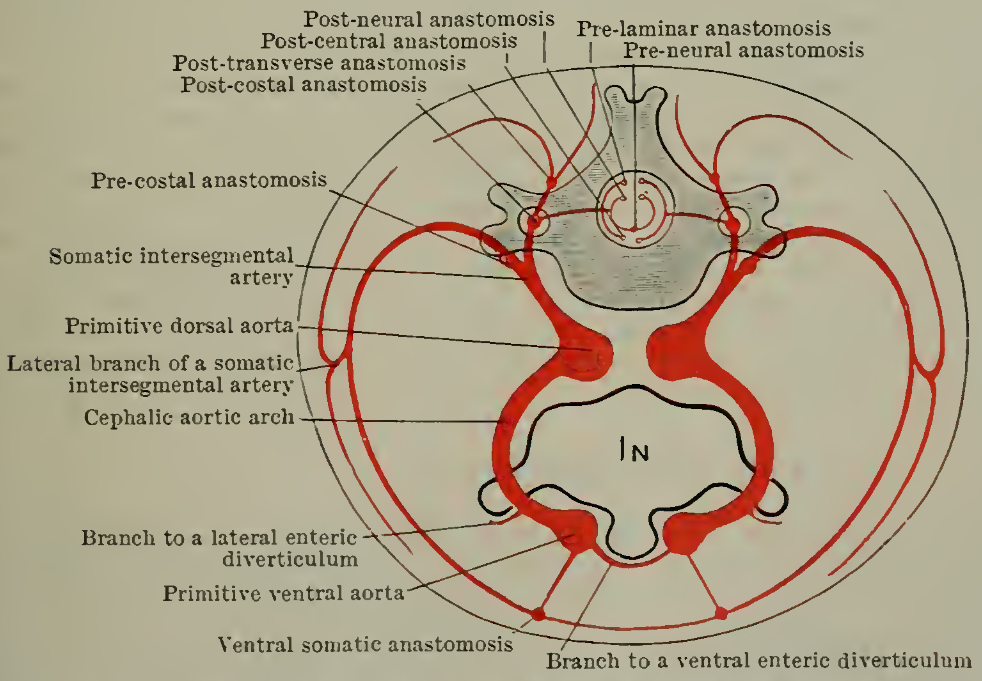
Post-neural anastomosis
Post-central anastomosis
Post-transverse anastomosis
Post-costal anastomosis
Pre-laminar anastomosis
Pre-neural anastomosis
Pre-costal anastomosis
Somatic intersegmental artery
Primitive dorsal aorta
Lateral branch of a somatic intersegmental artery
Cephalic aortic arch
IN
Branch to a lateral enteric diverticulum
Primitive ventral aorta
Ventral somatic anastomosis
Branch to a ventral enteric diverticulum

FIG 820.—DIAGRAM SHOWING THE ARRANGEMENT AND COMMUNICATIONS OF THE SEGMENTAL ARTERIES IN THE REGION OF THE CEPHALIC AORTIC ARCHES.
IN, Intestine.

The **splanchnic arteries** arise in the embryo from the ventral aspects of the primitive dorsal aortæ, and are not strictly either segmental or intersegmental in arrangement. They are distributed to the walls of the alimentary canal. Each anastomoses with its immediate neighbours on the dorsal wall and the ventral walls of the gut.

After the fusion of the dorsal longitudinal trunks to form the descending aorta, the roots of each pair of the splanchnic arteries fuse into a common stem, or either the right or left artery altogether disappears, whilst at a later period the majority of the splanchnic arteries lose their direct connexion with the descending aorta; those which retain their connexion are the cœliac artery and the superior and inferior mesenteric arteries.

The bronchial and œsophageal arteries are later formations. They appear to correspond morphologically with the more primitive splanchnic arteries, but the developmental history is not known.

The left gastric branch of the cœliac artery, as it passes from its origin to the small curvature of the stomach, represents a right splanchnic artery; the remainder of the left gastric artery and the right gastric branch of the hepatic are remnants of the ventral anastomoses between the splanchnic arteries cephalwards of the umbilicus.

The splenic artery is a branch given off from a splanchnic artery to an organ developed in the mesogastrium, and the hepatic is a branch from the ventral splanchnic anastomoses to the hepatic diverticulum from the wall of the duodenal portion of the fore-gut.

The superior and inferior mesenteric arteries represent at their origins splanchnic branches, and in the remainder of their extent they represent the dorsal anastomoses on the gut wall.

The Aorta, Pulmonary Artery, and other Chief Stem Vessels.

The heart and the majority of the great arterial trunks of the body, including the aorta, the innominate, part of the right subclavian, the common, external, and greater parts of the internal carotids, and the pulmonary arteries, are all modified portions either of the primitive aortæ or of the aortic arches. The developmental changes, which result in the formation of the vessels named, are described in the preceding chapter, and the morphology of these vessels is obviously the same as that of the trunks from which they are derived.

It will be sufficient, therefore, to point out that the primitive aortæ may be regarded as the greatly enlarged pre-central or pre-vertebral longitudinal anastomoses between the successive intersegmental arteries of each side; obviously, therefore, each primitive aorta, like the rest of the longitudinal anastomoses, consists chiefly of segmental elements. The origins of the intersegmental vessels enter into its formation only in so far as they connect the segmental vessels together, and so complete the longitudinal anastomoses.

The first cephalic aortic arches are simply portions of the primitive aortæ. The other aortic arches have possibly a different morphological significance, but their exact nature is not definitely settled.

The second, third, fourth, fifth, and sixth cephalic aortic arches of each side are developed in the undivided mesoderm of the head region, caudal to the first arch. They spring from the part of the primitive aorta which, after the head fold is formed, lies on the ventral aspect of the fore-gut, and they extend, at the side of the pharyngeal part of the fore-gut, to the dorsal aorta. Thus in some respects they may be looked upon as segmental vessels. In addition to the vessels already mentioned, there are given off from the ventral aortæ and the aortic arches a series of branches which supply ventral and lateral diverticula from the alimentary canal; these are represented in the adult by the superior thyreoid, the thyreoidea ima.

Iliac Arteries and their Branches.—The common iliac arteries are formed from the secondary roots of the umbilical arteries, and their exact morphological position is uncertain. The true morphological position of the hypogastric arteries is not yet defined. They also are parts of the secondary roots of the umbilical arteries, and they give off both somatic and splanchnic branches; therefore they do not correspond either with somatic intersegmental or with splanchnic arteries. The branches of the hypogastric artery are arranged in two groups—(1) a visceral set which supplies the walls of the hind-gut and the genital organs, and (2) a parietal set which is distributed to the body wall and to the hind-limbs. The branches distributed to the gut probably represent the splanchnic vessels, more or less homologous with ordinary splanchnic branches of the primitive aortæ, and the parietal branches are possibly the homologues of intersegmental arteries.

The Limb Arteries.

In all probability the vessels of both the upper and the lower limbs are derived originally from several somatic intersegmental arteries, the majority of which, however, have atrophied. The upper limb is supplied in man by the lateral offset from the ventral branch of the seventh somatic intersegmental artery. It passes into the extremity caudal to the shoulder girdle, courses through the arm, enters the cubital fossa, and is continued through the forearm, in the early stages, as the volar interosseous artery, which terminates in the deep part of the palm, in the deep volar arch. At a later period, ontogenetically, a median artery appears as a branch of the parent stem, and it terminates in a superficial volar arch; still later the radial and ulnar branches are formed. The latter grow rapidly, soon exceeding in size the parent stem, and they terminate in the superficial and deep volar arches. The interosseous and median arteries decrease, and generally lose their direct connexions with the volar arches. The dorsal interosseous artery is also a secondary branch from the parent stem, and the digital arteries are offsets from the volar arterial arches.

The chief arteries of the lower extremities spring directly from the secondary roots of the umbilical arteries, and may be looked upon as being essentially intersegmental; whether they represent the whole or only parts of typical somatic intersegmental arteries, however, is not clear.

The arteries of the lower limbs certainly show no very obvious indications of division into dorsal and ventral branches, though such indications are not entirely wanting. In their comparative absence it is supposed that the dorsal branches have been either suppressed or incorporated with the common stems; that similarly the ventral branches and their lateral offsets are indistinguishably fused, and that probably both are represented in a limb artery.

The original stem vessel of the lower limb is the inferior gluteal artery, which is continued distally, caudal to the pelvic girdle, into the popliteal and peroneal arteries, and so to the sole of the foot, where it ends in a vascular plexus. Subsequently the external iliac artery is given off from the secondary root of the umbilical artery, dorsal to the origin of the inferior gluteal, and, passing into the limb cranialward of the pelvic girdle, it becomes the greater part of the femoral artery. This vessel ultimately unites with the proximal part of the popliteal artery, and after this communication is established the distal part of the inferior gluteal atrophies and loses its connexion with the popliteal, which henceforth appears to be the direct continuation of the femoral trunk; therefore, whilst the main artery of the upper limb is formed by the prolongation of the lateral branch of one segmental artery, the corresponding vessel of the lower extremity is developed from representatives of, probably, two somatic segmental arteries, the external iliac and femoral trunks being the representatives of one, whilst the popliteal and its continuation, the peroneal, are parts of another.

The first main artery of the leg, ontogenetically, is the peroneal, which is continued into the plantar arch; after a time, however, the posterior and anterior tibial branches are evolved. As a rule, they soon preponderate in size, and they terminate in the plantar arch, whilst the original trunk diminishes and loses its direct connexion with the arch.

The peroneal artery corresponds in position and development with the common interosseous trunk and the volar interosseous artery in the forearm. The posterior tibial apparently corresponds with the median artery; it develops in a similar way, and has similar relations to homologous nerves, the tibial nerve representing the combined median and ulnar nerves of the upper extremity.

The anterior tibial artery represents the dorsal interosseous, whilst the radial and ulnar arteries of the upper extremity are not represented in the lower limb.

MORPHOLOGY OF THE VEINS.

Two dorsal longitudinal vessels, one on each side, connect the successive intersegmental veins together. They do not, however, in any part of their course, fuse together to form a single vessel comparable to the descending aorta.

Of these dorsal longitudinal vessels, that on the right side greatly enlarges, and from it the main stem vessels which return blood from the body walls, the head and neck, and the limbs, are almost entirely formed. The left dorsal longitudinal vessel remains relatively small—in parts, indeed, it altogether disappears — and the blood conveyed to it by the corresponding intersegmental veins is transmitted, across the median plane, to the chief functional stem by later developed and superadded transverse communicating channels, which are formed between the more primitive longitudinal anastomoses.

The primitive dorsal longitudinal anastomosing channels include on each side—(1) the precardinal vein, (2) the postcardinal vein, and (3) the duct of Cuvier; the last-named vessel, which opens into the sinus venosus of the primitive heart, is, originally, part of the anterior cardinal vein; it becomes enlarged and receives a special name after the union of the posterior with the anterior cardinal vein.

The cardinal veins return blood not only from the limbs and body wall, but they are also, in the early stages, the only vessels by which blood is returned from the derivatives of the intermediate cell tract, *i.e.* the kidneys, the genital glands, and the suprarenal glands. At a later period other longitudinal anastomoses, called the subcardinal veins, appear, and into these a large part of the blood from the derivatives of the intermediate cell tract is poured. Still later supracardinal veins are formed. It is from these vessels, and communications which are established between them, that the chief veins of the head and neck and the body are formed. Moreover, it must not be forgotten that the veins of the extremities are, like the extremities themselves, secondary structures, and that they are developed at a later period than the veins of the trunk, with which, however, they ultimately communicate.

In the light of these facts the morphology of the chief veins of the head and neck, the trunk and limbs, may now be considered.

The cavernous sinuses are remnants of the primary head vein. The other blood sinuses of the cranium are either secondarily formed vessels, or anastomoses between the tributaries of the anterior cardinal veins, or anastomoses between those tributaries and other newly formed veins.

The internal jugular veins are also portions of the precardinal veins.

The right innominate vein is a part of the right precardinal vein. A small part of the left innominate vein is formed from the left precardinal vein, the greater part is derived from a transverse anastomosis between the two precardinal veins.

Other remnants of the precardinal veins are the upper parts of the superior vena cava and left superior intercostal vein.

The basilic vein and its prolongations, the axillary vein and the subclavian vein, are derived from the ulnar or post-axial primitive veins of the superior extremities. The external jugular vein is a secondary formation, and the cephalic vein is the radial or pre-axial vein of the upper extremity which opens first into the external jugular vein and at a later period into the axillary vein.

The superior vena cava represents the lower part of the anterior cardinal vein and the right duct of Cuvier, and the oblique vein of the left atrium represents the left duct of Cuvier.

The azygos vein is derived partly from the right precardinal and partly from the right supracardinal vein. The vertical parts of the hemiazygos and accessory hemiazygos veins are remnants of the left supracardinal vein, whilst the transverse portions of the hemiazygos and accessory hemiazygos veins represent transverse anastomoses between the supracardinal veins.

The inferior vena cava is a compound structure representing parts of different structures. Its upper end is the transformed cephalic end of the right vitelline vein. The portion posterior to the liver is a secondary outgrowth from the right vitelline vein. The part between the liver and the right renal vein represents a part of the right subcardinal vein. Next comes a part formed from an anastomosis between the right postcardinal combined with a supra-subcardinal anastomosis. This is followed by a section consisting of fused supracardinal veins, and the right postcardinal vein enters into the formation of its caudal end.

The right common iliac vein is a part of the right posterior cardinal vein, but the left is a compound structure. Its lower part probably represents a portion of the left posterior cardinal vein, but the greater part is a persistent transverse anastomosis between the posterior cardinal veins.

The hypogastric veins are remnants of the posterior cardinal veins.

The popliteal and the inferior gluteal veins are remnants of the primitive fibular vein of the lower limb, and the external iliac vein is the trunk formed by the union of the tibial and the deep veins of the lower limb which are secondary formations.

Visceral Veins.—The portal vein represents portions of both vitelline veins and of the middle anastomosis between them.

The right gastric vein is a splanchnic ventral longitudinal anastomosing vein. The left gastric vein is partly a ventral and partly a dorsal splanchnic longitudinal anastomosis, and the superior and inferior mesenteric veins are dorsal splanchnic longitudinal venous anastomoses, the splenic vein being merely a tributary from a lymphoid organ developed in the dorsal meso-gastrium.

The anterior facial vein is a combination of somatic and splanchnic veins of several segments, and the internal maxillary vein is probably of similar nature. The thyreoid and bronchial veins return blood from organs developed from diverticula from the walls of the alimentary canal; they are, therefore, more or less modified splanchnic veins; so also apparently are the vesical and the middle and inferior hæmorrhoidal veins.

The cardiac veins are simply "vasa vasorum," and they belong therefore to the splanchnic group of vessels, but it is impossible to say whether they are segmental or intersegmental. The coronary sinus into which they open is a portion of the sinus venosus of the heart, and therefore of an originally segmental vessel.

The hepatic veins are parts of the primitive vitelline veins; and the pulmonary veins are splanchnic veins returning blood from diverticula of the gut.

It is noteworthy that some parts of the splanchnic venous system, *i.e.* the portal vein and the coronary sinus, are portions of the most primitive vascular system, and that others—the thyreoid, bronchial, mesenteric, vesical, and hæmorrhoidal veins—appear to belong to a somewhat secondary group of splanchnic veins of combined segmental and intersegmental character; moreover, some of the secondary group of veins open into the primary splanchnic veins, *e.g.* the superior and inferior mesenteric into the portal vein; some open into the dorsal longitudinal anastomosing veins, *e.g.* the vesical and hæmorrhoidal veins open into the postcardinal veins, which are intersegmental anastomoses; others again open into the internal jugular, which is part of the precardinal vein.

Veins of the Limbs.—The veins of the limbs, like the arteries, were probably at one time intersegmental in character, but we have no indisputable proof that this was the case. Looked at from an embryological standpoint, the most primitive limb veins are a superficial distal arch and a post-axial trunk vein in each extremity; at a later period digital veins are connected with the distal arch, and a pre-axial trunk is formed. In the upper extremity the distal arch and its tributaries remain as the dorsal venous arch and the digital veins, and the post-axial vein becomes the basilic, axillary, and subclavian veins. The pre-axial vein of the upper extremity is represented in the adult by the cephalic vein; the latter vessel originally terminated in the external jugular vein, above the clavicle, the union with the axillary portion of the post-axial vessel being a secondary condition; the primary condition is, however, frequently retained in man, and is constant in many monkeys. The anastomosis between the pre-axial and post-axial veins in the region of the elbow, and the connexion of the anastomosing channels, is brought about by newly-formed vessels of secondary character.

The distal arch in the lower extremity and the tributaries connected with it remain in the adult as the dorsal venous arch of the foot and the digital veins. The post-axial vein becomes the small saphenous vein, which was originally continued proximally as the popliteal and inferior gluteal veins to the hypogastric portion of the posterior cardinal vein.

The pre-axial vein of the lower limb becomes the great saphenous vein, which is continued proximally to the cardinal portion of the left common iliac vein as the proximal part of the femoral and the external iliac veins.

The venæ comites of the arteries in both the upper and lower extremities are secondarily developed vessels which become connected with the upper portions of the pre-axial venous trunks.

ABNORMALITIES AND VARIATIONS OF THE VASCULAR SYSTEM.

Abnormalities are of special interest to the anatomist because of their morphological significance, and the vascular system is, perhaps more than any other, rich in such abnormalities, many of which are of great practical importance.

With the exception of those irregularities which are directly due to the effect of morbid conditions and external influences, all abnormalities are the result of modifications of normal developmental processes. The exceptions referred to are, however, very numerous; thus disease and external influences may lead to the obliteration of vessels, a condition which is invariably associated with the enlargement of collateral vessels, and it will be obvious that abnormalities so produced may occur in almost any situation.

Abnormalities which are determined by, or are dependent upon, modifications of the usual developmental processes are of greater interest. In the human subject they are generally due either to the retention of conditions which, normally, are only transitory in ontogenetic development, or to the acquirement of conditions which, though not as a rule present at any time in man, occur normally in some animals.

There are, in addition, other variations from the normal, such as the division of the axillary artery into radial and ulnar branches; the higher or lower division of the brachial artery; the formation of "vasa aberrantia," *e.g.* of long slender vessels connecting the axillary or brachial to the radial, ulnar, or interosseous arteries; the altered position of certain vessels, *e.g.* the transference of the subclavian artery to the front of the scalenus anterior, or of the ulnar artery to the front of the superficial flexor muscles; all of which, though undoubtedly due to alterations of ordinary developmental processes, still do not represent any known conditions met with, either temporarily or permanently, in man or in other animals. Their occurrence cannot at present be adequately explained, and their retention in the adult is entirely dependent upon their utility.

To the first and the last of these different groups of abnormalities it is not necessary to refer further, whilst with regard to the rest they have been already sufficiently indicated after the account of the heart and vessels. They can only, however, be fully understood and explained on the basis of a comprehensive knowledge of the development and morphology of the vascular system, to the chapters on which the reader is referred. Those who require more detailed information should consult special monographs.[1]

ABNORMALITIES OF VEINS.

Abnormalities or variations of veins are more frequently met with than those of arteries, and they are due to similar causes.

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[1] Quain, R., *The Anatomy of the Arteries of the Human Body*. Dubrueil, I. M., *Des Anomalies artérielles*. The *Index Medicus* notes the more recently reported cases.

THE RESPIRATORY SYSTEM.

THE ORGANS OF RESPIRATION AND VOICE.

By the late D. J. Cunningham, F.R.S.,
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Revised by Richard J. A. Berry, F.R.C.S.,
Professor of Anatomy, University of Melbourne.

The organs of respiration are the larynx and trachea, which, together, constitute a median air-passage; the two bronchi or branches into which the thoracic end of the trachea divides; and the two lungs to which the bronchi conduct the air. In connexion with the lungs there are also the pleural membranes—two serous sacs which line the portions of the thoracic cavity which contain the lungs, and at the same time give a thin coating to those organs.

The larynx opens above into the inferior or caudal part of the pharynx, and the air which passes in and out from the air-passages likewise traverses the pharynx, the nasal cavity, and also the oral cavity if the mouth be open. This connexion between the digestive and respiratory systems is explained by the fact that the respiratory apparatus is secondarily developed, as an outgrowth, from the ventral aspect of the primitive fore-gut of the embryo. In most mammals the superior or cranial aperture of the larynx opens into the part of the pharynx which lies immediately dorsal, or posterior, to the nasal cavities. In man, however, the superior opening of the larynx is placed below, that is inferior or caudal to, the communication between the mouth and pharynx, and both nasal and oral breathing may be carried on with very nearly equal ease.

LARYNX.

The **larynx** or **organ of voice** is the upper part of the air-passage, specially modified for the production of voice. Above it opens into the pharynx, whilst below its cavity becomes continuous with the lumen of the trachea or windpipe.

Position and Relations of the Larynx.—In the natural position of the neck, and whilst the organ is at rest, the larynx is placed on the ventral side of the bodies of the fourth, fifth, and sixth cervical vertebræ. Its highest point, represented by the tip of the epiglottis, extends to the inferior border of the body of the third cervical vertebra, whilst its lowest limit (the inferior border of the cricoid cartilage) usually corresponds to the inferior border of the body of the sixth cervical vertebra. From the vertebral column the larynx is separated, not only by the prevertebral muscles and the prevertebral fascia, but also by the dorsal wall of the pharynx—indeed the dorsal surface of the larynx forms the inferior part of the ventral or anterior wall of the pharynx, and is covered by the lining mucous membrane of that section of the alimentary canal.

The larynx lies below the hyoid bone and the tongue, and in the interval between the great vessels of the neck. It forms a more or less marked projection on the ventral side of the neck, and, in the median plane, it approaches very closely to the surface, being merely covered by skin and the two layers of fascia. Laterally it is more deeply placed. There, it is overlapped by the sterno-cleido-mastoid muscle, and is covered by the two strata of thin ribbon-like muscles which are attached to the thyreoid cartilage and the hyoid bone; and it is hidden, to some extent, by the upper prolongations of the lateral lobes of the thyreoid gland.

The position of the larynx is influenced by movements of the head and neck. Thus it is elevated or raised when the head moves dorsally, and depressed when the chin is carried downwards towards the chest. Again, if the finger is placed upon it during deglutition, it will be noted that the larynx moves to a very considerable extent. The pharyngeal muscles attached to it, and more especially the stylo-pharyngeal muscles, are chiefly responsible for bringing about these movements. During singing, changes in the position of the larynx may also be noted, a high note being accompanied by a slight upward movement, and a low note by a similarly slight downward movement of the organ.

The position of the larynx is not the same at all periods of development and growth. In the fœtus, shortly before birth, it lies much nearer the head, and its inferior border corresponds to the inferior border of the fourth cervical vertebra. Its permanent position is not reached until the period of puberty is attained (Symington). In the early stages of growth all the thoracic viscera undergo a gradual subsidence and the larynx follows them. Indeed, it cannot do otherwise, seeing that the bifurcation of the trachea between infancy and puberty moves downwards towards the caudal end of the body more than the depth of one thoracic vertebra.

General Construction of the Larynx.—The wall of the larynx is constructed upon a somewhat complicated plan. There is a framework composed of several cartilages. These are connected together, at certain points, by distinct joints and also by elastic membranes. Two elastic cords, which stretch in a ventro-dorsal direction from the ventral to the dorsal wall of the larynx, form the groundwork of the vocal folds. Numerous muscles also are present. These operate upon the cartilages of the larynx, and thereby not only bring about changes in the relative position of the vocal folds, but also produce different degrees of tension of these folds. The cavity of the larynx is lined with mucous membrane, under which, in certain localities, are collected masses of mucous glands.

CARTILAGINES LARYNGIS.

Three single cartilages and three pairs of cartilages enter into the construction of the laryngeal wall. They are named as follows:—

- Single cartilages
  - Thyreoid.
  - Cricoid.
  - Epiglottis.
- Paired cartilages
  - Arytænoids.
  - Corniculate cartilages (Santorini).
  - Cuneiform cartilages.

Cartilago Thyreoidea.—The **thyreoid cartilage**, the largest of the laryngeal cartilages, is formed of two quadrilateral plates termed the **laminæ**, which meet ventrally at an angle, and become fused along the median plane. Dorsally the laminæ diverge from each other, and enclose a wide angular space which is open dorsally. The *ventral borders* of the laminæ are fused only in their inferior parts. Above they are separated by a deep, narrow V-shaped median notch, called the **incisura thyreoidea** or **thyreoid notch**. In the adult male the angle formed by the meeting of the ventral borders of the two laminæ, especially in its upper part, is very projecting, and with the margins of the thyreoid notch, which lies above, constitutes a marked subcutaneous prominence in the neck, which receives the name of the **prominentia laryngea** (O.T. **Adam's Apple**).

The angle which is formed by the meeting of the two laminæ of the thyreoid cartilage varies, to some extent, in different individuals of the same sex, and shows marked differences in the two sexes and at different periods of life. In the adult male the average angle is said to be 90°; in the adult female it is 120°; whilst in the infant the laminæ meet in the form of a gentle curve, convex ventrally.

The *dorsal border* of each lamina of the thyreoid cartilage is thick and rounded, and is prolonged beyond the superior and inferior borders in the form of two slender cylindrical processes, termed cornua. The **superior cornu** is longer than the inferior cornu. It is directed upwards, towards the head, with a slight dorso-medial inclination, and ends in a rounded extremity, which is joined to the tip of the great cornu of the hyoid bone by the lateral hyo-thyreoid ligament. The **inferior cornu** is shorter and stouter than the superior cornu. As it proceeds downwards it curves slightly towards the median plane, and upon the medial face of its extremity there is a circular, flat facet, by means of which it articulates with a similar facet on the lateral aspect of the cricoid cartilage.

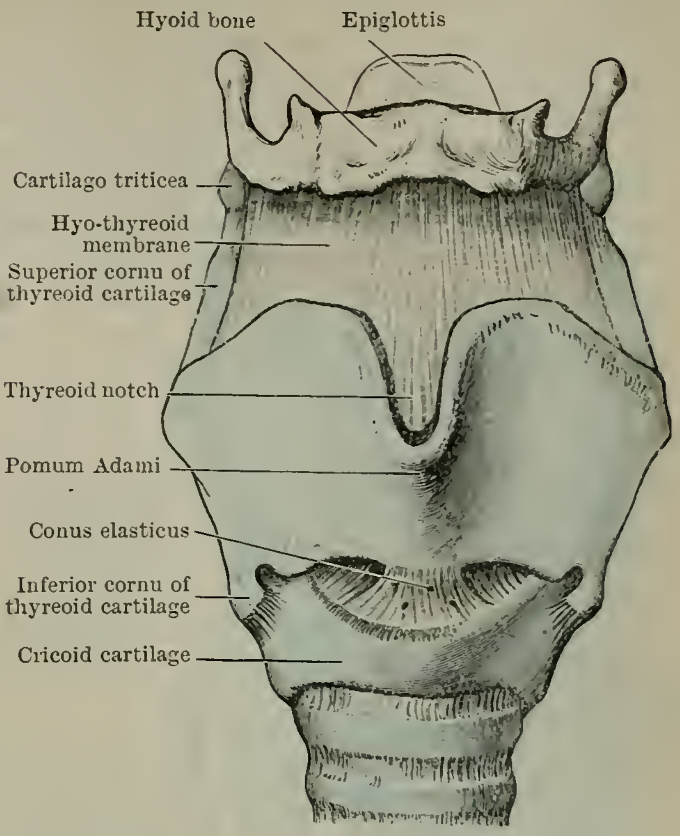


FIG. 821.—VENTRAL ASPECT OF THE CARTILAGES AND LIGAMENTS OF THE LARYNX.

The *superior border* of each lamina is, for the most part, slightly convex, and, ventrally, it dips suddenly to become continuous with the margin of the thyreoid notch. Dorsally, where it joins the superior cornu, it exhibits a shallow notch or concavity. The *inferior border* is almost straight, but it is marked off by a projection, termed the **inferior thyreoid tubercle**, into a short dorsal part, which shows a shallow concavity close to the inferior cornu and a longer part which lies ventral to the tubercle, and is also concave, but to a less degree.

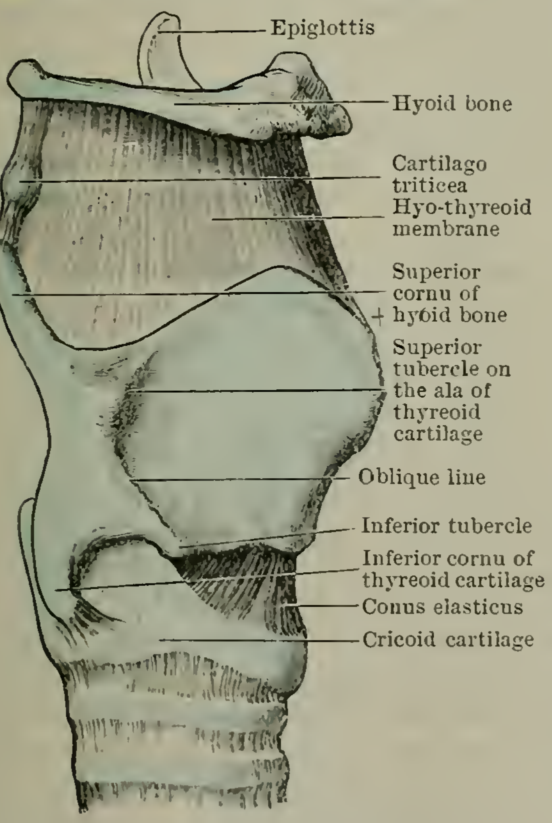
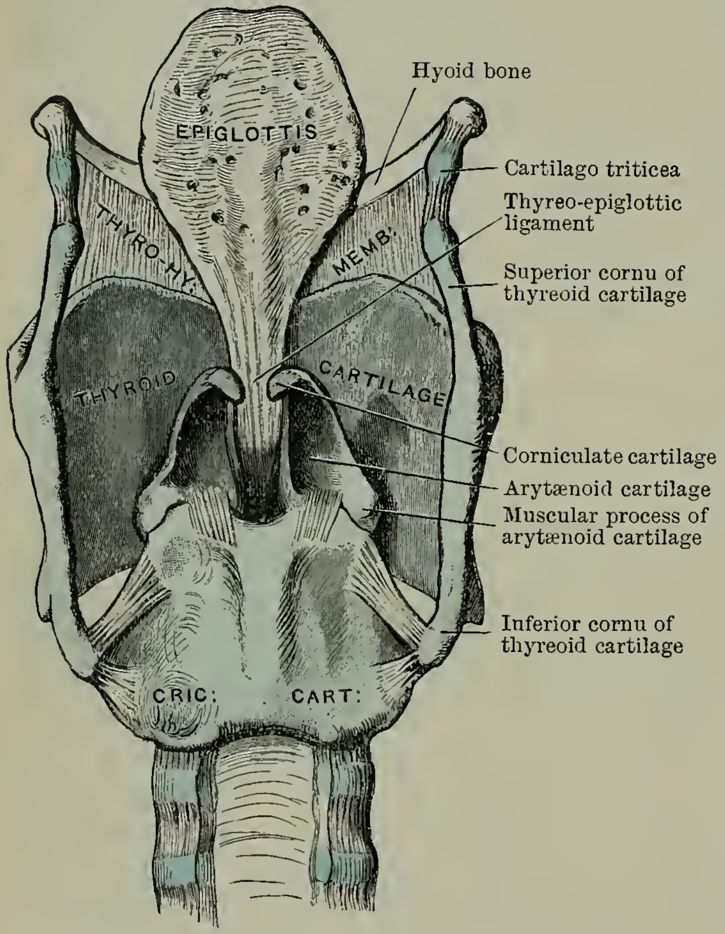


FIG. 822.—PROFILE VIEW OF THE CARTILAGES AND LIGAMENTS OF THE LARYNX.

The *lateral surface* of each lamina is divided into two unequal areas by the **oblique line.** This line begins above at the **superior thyreoid tubercle**, a prominence situated immediately below the superior border, and a short distance ventral to the root of the superior cornu. From the tubercle the oblique line proceeds forwards and downwards to end in the inferior tubercle on the inferior border of the lamina. The area which lies dorsal to the oblique line is much smaller than that which lies on its ventral side. It is covered by the inferior constrictor muscle of the pharynx. The larger ventral area is for the most part covered by the thyreo-hyoid muscle. To the oblique line are attached the sterno-thyreoid, thyreo-hyoid, and inferior constrictor muscles. The *medial surface* of the lamina of the thyreoid cartilage is smooth and slightly concave.

Cartilago Cricoidea.—The **cricoid cartilage** is shaped like a signet-ring. Dorsally there is a broad, thick plate, somewhat quadrilateral in form, termed the **lamina**; whilst ventrally and laterally the circumference of the ring is completed by a curved band, called the **arch.** The lumen of the ring enclosed by these parts is circular below, but the upper part of the ring is compressed laterally, so that the lumen becomes elliptical. The upper border of the **lamina** presents a faintly marked median notch. On either side of this there is an oval facet which looks more laterally than upwards; it articulates with the base of the arytænoid cartilage. The dorsal surface of the lamina is divided by an elevated median ridge into two depressed areas which give attachment to the posterior crico-arytænoid muscles. The ventral part of the arch of the cricoid is in the form of a narrow band, but as it proceeds dorsally towards the lamina its upper border rises rapidly, and in consequence the arch becomes much broader. The *inferior border* of the cricoid is nearly straight, although it frequently presents a median ventral projection and two lateral projections. It is joined to the first ring of the trachea by an elastic membrane—the crico-tracheal ligament. On the *lateral surface* of the cricoid cartilage, at the place where the arch joins the lamina, a vertical ridge runs downwards from the arytænoid articular facet. On this, a short distance from the inferior border of the cartilage, a prominent circular articular facet is visible, for articulation with the inferior cornu of the thyreoid cartilage (Fig. 824, p. 1067). The *medial surface* of the cricoid cartilage is smooth, and is covered with mucous membrane.



Hyoid bone
EPIGLOTTIS
THYRO-HY.
MEMB.
Cartilago triticea
Thyreo-epiglottic ligament
Superior cornu of thyreoid cartilage
THYROID
CARTILAGE
Corniculate cartilage
Arytænoid cartilage
Muscular process of arytænoid cartilage
Inferior cornu of thyreoid cartilage
CRIC.
CART.

Fig. 823.—Dorsal Aspect of the Cartilages and Ligaments of the Larynx.

The narrow band-like part of the arch of the cricoid cartilage lies below the inferior border of the thyreoid cartilage, whilst the lamina is received into the interval between the dorsal portions of the laminæ of the thyreoid cartilage.

Cartilagines Arytænoideæ.—The **arytænoid cartilages** are placed one on each side of the median plane, and rest upon the upper border of the lamina of the cricoid cartilage, in the interval between the dorsal portions of the laminæ of the thyreoid cartilage. Each presents a somewhat pyramidal form, the pointed **apex** of which is directed upwards, and at the same time curves dorsally and medially. It supports the corniculate cartilage (Santorini). Of the three surfaces, the medial one faces the corresponding surface of the opposite cartilage, from which it is separated by a narrow interval; another looks dorsally; whilst the third is directed laterally and ventrally. The *medial surface*, which is the smallest of the three, is triangular in outline. It is narrow, vertical, and even, and is clothed with the lining mucous membrane of the larynx. The *dorsal surface* is smooth and concave in the cranio-caudal direction; it lodges and gives attachment to the transverse arytænoid muscle. The *ventro-lateral surface* is the most extensive of the three (Fig. 824, p. 1067). Its middle part is marked by a deep depression in which is lodged a mass of mucous glands. Upon this surface of the arytænoid cartilage the vocalis and thyreo-arytænoid muscles are inserted, whilst a small tubercle a short distance above the base gives attachment to the ventricular ligament—the feeble supporting ligament of the ventricular fold (O.T. false vocal cord). The three surfaces of the arytænoid cartilages are separated from each other by a ventral, a dorsal, and a lateral border. The *lateral border* is the longest, and it pursues, as it is traced from the apex to the base, a sinuous course. Reaching the base of the cartilage, it is prolonged laterally and dorsally in the form of a stout prominent angle or process, termed the **muscular process**. Into the ventral side of this process is inserted the lateral crico-arytænoid muscle; whilst into its dorsal aspect the posterior crico-arytænoid muscle is inserted. A small nodule of yellow elastic cartilage, called the **sesamoid cartilage**, is frequently found on the lateral border of the arytænoid cartilage, where it is held in position by the investing perichondrium. The *ventral border* of the arytænoid is vertical, and at the base of the cartilage is prolonged ventrally into a small sharp-pointed process called the **vocal process**, which receives this name because it gives attachment to the vocal ligament or supporting band of the vocal fold (O.T. true vocal cord). The **base** of the arytænoid cartilage presents on its inferior surface, particularly in the region of the muscular process, an elongated concave facet for articulation with the facet on the superior border of the lamina of the cricoid cartilage.

Cartilagines Corniculatæ (Santorini).—The **corniculate cartilages of Santorini** are two minute conical nodules of yellow elastic cartilage which surmount the apices of the arytænoids, and prolong the upper curved ends of these cartilages in a dorso-medial direction. Each corniculate cartilage is enclosed within the dorsal part of the corresponding ary-epiglottic fold of mucous membrane.

Cartilagines Cuneiformes (Wrisbergi).—The **cuneiform cartilages of Wrisberg** are not always present. They are two minute rod-shaped pieces of yellow elastic cartilage, each of which occupies a place in the corresponding ary-epiglottic fold, immediately ventral to the arytænoid cartilage and the corniculate cartilage of Santorini. On the superficial surface of each a collection of mucous glands is present, and this tends to make the cartilage stand out in relief under the mucous membrane.

Cartilago Epiglottica.—The **epiglottis** is supported by a thin, leaf-like lamina of yellow fibro-cartilage, the **epiglottic cartilage**, which is placed dorsal to the root of the tongue and the body of the hyoid bone, and ventral to the aperture of the larynx. When divested of the mucous membrane, which covers it dorsally and also to some extent ventrally, the epiglottic cartilage is seen to present the outline of a bicycle-saddle, and to be indented by pits and pierced by numerous perforations. In the pits glands are lodged, whilst through the foramina, blood-vessels and, in some cases, nerves pass. The *broad end* of the epiglottic cartilage is directed upwards, and is free. Its *margins* are, to a large extent, enclosed within the ary-epiglottic fold. The *ventral surface* is free only in its upper part. This part is covered with mucous membrane, and looks towards the pharyngeal part of the tongue. The *dorsal surface* is covered throughout its whole extent with the lining mucous membrane of the laryngeal cavity. The *inferior pointed extremity* is prolonged downwards in the form of a strong fibrous band, termed the thyreo-epiglottic ligament.

Ossification of the Cartilages of the Larynx.—The thyreoid and cricoid cartilages and the greater part of the arytænoid cartilages are composed of the hyaline variety of cartilage. The apical parts, and also the vocal processes of the arytænoid cartilages, the corniculate cartilages of Santorini, the cuneiform cartilages, and the epiglottis, are formed of yellow fibro-cartilage, and at no period of life do they exhibit any tendency towards ossific change. The thyreoid, cricoid, and basal portions of the arytænoids, as life advances, become more or less completely transformed into bone. In males over twenty years of age, and in females over twenty-two years of age, the process will usually be found to have begun (Chievitz). It is impossible, however, by an examination of the laryngeal cartilages, to form an estimate of the age of the individual, although in old age it is usual to find the thyreoid, cricoid, and the hyaline parts of the arytænoids completely ossified. It would appear that the process is somewhat slower in the female than in the male. The thyreoid is the first to show the change; then, but almost at the same time, the cricoid; and lastly, a few years later, the arytænoids.

ARTICULATIONS, LIGAMENTS, AND MEMBRANES OF THE LARYNX.

Crico-thyreoid Joints. — These are diarthrodial joints, and are formed by the apposition of the circular facets on the tips of the inferior cornua of the thyreoid cartilage with the elevated circular facets on the sides of the cricoid cartilage. An articular capsule surrounds each articulation, and this is lined with a synovial layer. On the dorsal aspect of the joint a strengthening band is present in the capsule. The movements which take place at the crico-thyreoid joints are of a twofold character, viz., gliding and rotatory. In the first case the thyreoid facets glide upon the cricoid surfaces in different directions. The rotatory movement is one in which the thyreoid cartilage rotates to a slight extent around a transverse axis which passes through the centres of the two joints.

Crico-arytænoid Joints.—These also are diarthrodial articulations. In each case there is a joint cavity surrounded by an articular capsule, which is lined with a synovial layer. The cricoid articular surface is convex, whilst that of the arytænoid is concave; both are elongated or elliptical in form, and they are applied to each other so that the long axis of the one intersects or crosses that of the other at an acute angle. In no position of the joint do the two surfaces accurately coincide—a portion of the cricoid facet is always left uncovered. The capsule of the joint is strengthened dorsally by a band which is inserted into the dorso-medial part of the base of the arytænoid cartilage, and plays a somewhat important part in the mechanism of the joint; it effectually arrests excessive ventral movement of the arytænoid cartilage.

The movements which take place at the crico-arytænoid joints are of a twofold kind, viz., gliding and rotatory. The ordinary position of the arytænoid during easy, quiet breathing is one in which it rests upon the lateral part of the cricoid facet. By a gliding movement it can move upon the cricoid facet, and advance towards the median plane and its fellow of the opposite side. The gliding movements, therefore, are of such a character that the two arytænoid cartilages approach or retreat from each other and from the median plane. In the rotatory movement the arytænoid cartilage revolves around a vertical axis. By this movement the vocal process is swung laterally or medially, so as to open or close the rima glottidis.

The **joint between the arytænoid and the corniculate cartilage (Santorini)** may either partake of the nature of an amphiarthrosis or of a diarthrosis. The tips of the two corniculate cartilages can generally be made out to be connected to the upper border of the lamina of the cricoid cartilage by a delicate Y-shaped band of connective tissue termed the **corniculo-pharyngeal ligament.**

Hyo-thyreoid Membrane.—This is a broad, membranous, and somewhat elastic sheet which occupies the interval between the hyoid bone and the thyreoid cartilage. It is not equally strong throughout. It presents a central thick portion and cord-like right and left dorsal margins, whilst in the intervals between these it is thin and weak (Figs. 821 and 822, p. 1063). The **central thickened part**, or the **middle hyo-thyreoid ligament**, is largely composed of elastic fibres. Below it is attached to the margins of the thyreoid notch, whilst above it is fixed to the dorsal part of the upper border of the body of the hyoid bone. The upper part of its ventral surface, therefore, is placed dorsal to the dorsal hollowed-out surface of the body of the hyoid bone; a synovial bursa of variable extent is placed between them, and in certain movements of the head and larynx the upper border of the thyreoid cartilage moves towards the head on the dorsal side of the hyoid bone. On each side of the strong central part the hyo-thyreoid membrane is thin and loose, and is there attached, below, to the upper border of the thyreoid cartilage, and above, to the medial aspect of the great cornu of the hyoid bone. It is pierced by the internal ramus of the superior laryngeal nerve and by the superior laryngeal vessels. The dorsal border of the hyo-thyreoid membrane on each side is thickened, round, and cord-like, and is chiefly composed of elastic fibres; it is termed the **lateral hyo-thyreoid ligament**, and extends from the tip of the great cornu of the hyoid bone to the extremity of the upper cornu of the thyreoid cartilage. In this ligament there is usually developed a small oval cartilaginous or bony nodule, which receives the name of the **cartilago triticea**. The deep surface of the lateral part of the hyo-thyreoid membrane is covered with the pharyngeal mucous membrane, and its central part lies ventral to the epiglottis, but separated from it by a mass of adipose tissue (Fig. 827, p. 1070).

Conus Elasticus.—The **elastic cone**, or the crico-thyreoid membrane, is a very important structure, which it is convenient to consider in three parts, viz., one median and two lateral, all of which are directly continuous with one another, and differ only in the nature of their upper connexions. The **median part** (crico-thyreoid ligament) is strong, tense, and elastic. It is triangular in shape, and is attached by its broad base to the upper border of the arch of the cricoid cartilage, whilst its apex is fixed to the medial part of the lower border of the thyreoid cartilage (Fig. 824, p. 1067). It is pierced by minute apertures, and is crossed superficially by the crico-thyreoid branch of the superior thyreoid artery. The median part of the elastic cone, therefore, closes, ventrally, the interval between the cricoid and thyreoid cartilages. The **lateral part**, on each side, presents very different connexions. It is not attached to the inferior border of the thyreoid cartilage, but slopes upwards and medially on the inner side of the thyreoid lamina, and thus diminishes materially the transverse or frontal width of the cavity of the larynx. Its attachments are very definite. *Inferiorly* it is fixed to the superior border of the cricoid cartilage immediately subjacent to the lining mucous membrane of the larynx; *above* it is directly continuous with the vocal ligament or supporting band of the vocal fold. That ligament, indeed, may be looked upon as constituting the superior thickened free border of the lateral part of the elastic cone. *Ventrally* the lateral part of the elastic cone is attached to the inferior half of the medial surface of the lamina of the thyreoid cartilage, close to the angle, and, *dorsally*, to the inferior border of the vocal process of the arytænoid cartilage. In contact with the *outer surface* of the lateral part of the elastic cone, and separating it from the thyreoid lamina, are the lateral crico-arytænoid muscles; the *inner surface* is clothed with the lining mucous membrane of the larynx.

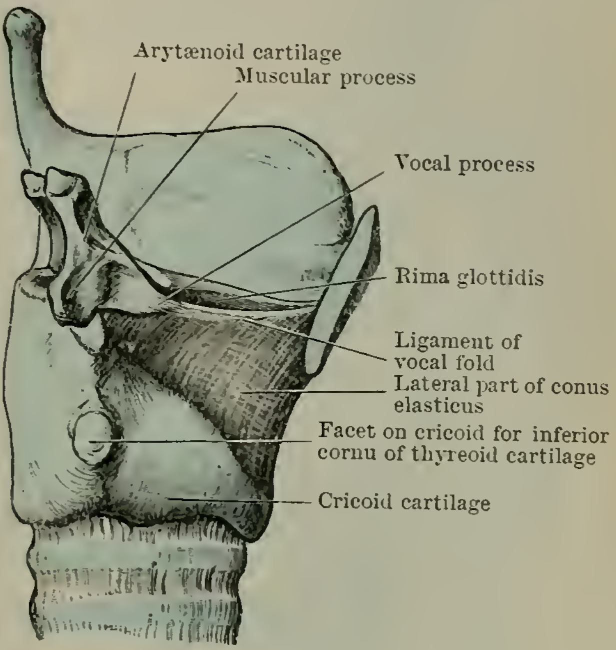


Fig. 824.—Dissection to show the Conus Elasticus. The right lamina of the thyreoid cartilage has been removed.

The **vocal ligament** (O.T. **inferior thyreo-arytænoid lig.**) is formed in connexion with the superior border of the elastic cone, and constitutes the supporting ligament of the vocal fold. It is attached *ventrally*, close to its fellow of the opposite side, to the middle of the angular depression between the two laminæ of the thyreoid cartilage. From there it stretches *dorsally*, and becomes incorporated with the tip and superior border of the vocal process, which projects ventrally from the base of the arytænoid cartilage. The vocal ligament is composed of yellow elastic fibres, and embedded in its ventral extremity there is, frequently, a minute nodule of elastic cartilage. Its medial border is sharp and free, and is clothed with mucous membrane, which in that position is very thin and tightly bound down to the ligament.

The **ventricular ligament** supports the ventricular fold. It is weak and indefinite, but somewhat longer than the vocal ligament. *Ventrally* it is attached to the angular depression between the two laminæ of the thyreoid cartilage, above the vocal ligament and close to the attachment of the thyreo-epiglottic ligament; it extends, *dorsally*, to be fixed to a tubercle on the ventro-lateral surface of the arytænoid cartilage, a short distance above the vocal process. It is composed of connective tissue and elastic fibres which are continuous with the fibrous tissue in the ary-epiglottic fold.

The **epiglottis** is bound by ligaments to the base of the tongue, to the wall of the pharynx, to the hyoid bone, and to the thyreoid cartilage. The **glosso-epiglottic fold** is a prominent median fold of mucous membrane which proceeds from the middle of the ventral free surface of the epiglottis to the root of the tongue. The **pharyngo-epiglottic folds** are similar elevations of mucous membrane which proceed from the lateral margins of the epiglottis to the lateral walls of the pharynx at the side of the tongue. Between the two layers of mucous membrane which form each of these folds is a certain amount of elastic tissue. By the three folds the depression between the root of the tongue and the epiglottis is marked off into two fossæ, termed the **epiglottic valleculæ.** From the lateral margins of the epiglottis there also pass off the **ary-epiglottic folds** to the arytænoids.

The **hyo-epiglottic ligament** is a short, broad elastic band, somewhat broken up by adipose tissue, which connects the ventral surface of the epiglottic cartilage to the upper border of the hyoid bone (Fig. 827, p. 1070). The **thyreo-epiglottic ligament** is strong and thick (Fig. 832, p. 1075). Composed mainly of elastic tissue, it proceeds downwards, from the inferior pointed extremity of the epiglottic cartilage, and is attached to the angular depression between the two laminæ of the thyreoid cartilage, below the median notch.

A triangular interval is left between the ventral surface of the epiglottis and the hyo-thyreoid membrane. This is imperfectly closed above by the hyo-epiglottic ligament, and contains a pad of soft fat (Fig. 827, p. 1070).

CAVUM LARYNGIS.

The **cavity of the larynx** is smaller than might be expected from an inspection of its exterior. On looking into its interior, through the laryngeal aperture, it is seen to be subdivided into three portions by two pairs of elevated folds of mucous membrane, which extend ventro-dorsally, and project medially from each lateral wall of the cavity. The upper pair of folds are the **ventricular folds** (O.T. **false vocal cords**); the lower, more definite pair, are the **vocal folds** (O.T. **true vocal cords**) (Fig. 826). The latter are the chief agents in the production of the voice, and the larynx is so constructed that changes in their relative position and in their degree of tension are brought about by the action of the muscles and the recoil of the elastic ligaments.

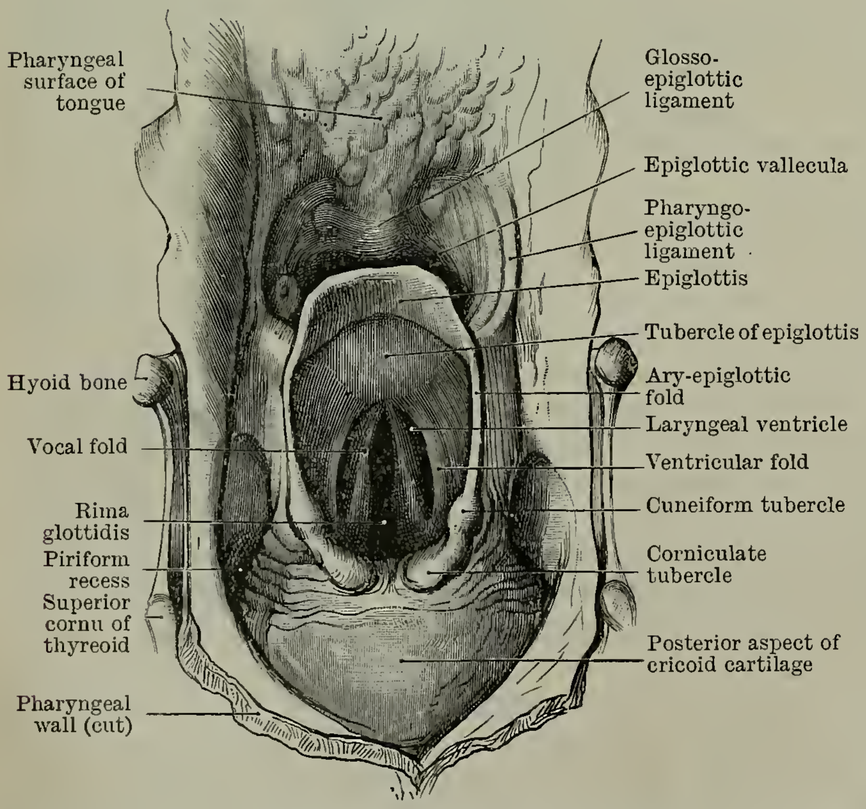


Fig. 825.—Aditus Laryngis, exposed by the Removal of the Dorsal Wall of the Pharynx.

Aditus Laryngis.—The **laryngeal aperture** is a large obliquely placed opening, which slopes rapidly in a dorsal and downwards direction and looks upwards and dorsally into the laryngeal part of the pharynx. Somewhat triangular in outline, the basal part of the aperture, placed superiorly and ventrally, is formed by the free border of the epiglottis. The opening rapidly narrows as it runs downwards, and it ends in the interval between the two arytænoid cartilages. The sides of the aperture are formed by two sharp and prominent folds of mucous membrane, the **ary-epiglottic folds**, which stretch between the lateral margins of the epiglottis, ventrally, and the arytænoid cartilages dorsally. The two layers of mucous membrane which compose the ary-epiglottic folds, enclose, between them, some connective tissue, muscular fibres belonging to the ary-epiglottic muscles, and in their dorsal parts the cuneiform and corniculate cartilages, which latter surmount the arytænoid cartilages. These small nodules of cartilage raise the dorsal part of the ary-epiglottic fold in the form of two rounded eminences, termed respectively the cuneiform and corniculate tubercles.

On each side of the laryngeal opening there is, in the pharynx, a small recess, directed downwards, which presents a wide entrance, but rapidly narrows towards the bottom. It is termed the **piriform recess**, and is of importance to the surgeon, because foreign bodies introduced into the pharynx are liable to be caught in this little pocket. On the medial side the piriform recess is bounded by the arytænoid cartilage and the ary-epiglottic fold, whilst on the lateral side it is limited by the inner surface of the laminæ of the thyreoid cartilage, clothed with the pharyngeal mucous membrane.

Vestibulum Laryngis.—The **vestibule of the larynx** is the **uppermost compartment** of the cavity of the larynx. It extends from the laryngeal aperture to the ventricular folds. In its inferior part it exhibits a marked lateral compression. Its width, therefore, diminishes in the vertical direction, whilst, owing to the obliquity of the laryngeal aperture, its depth rapidly diminishes ventro-dorsally. *Ventrally* it is bounded by the dorsal surface of the epiglottis, clothed with mucous membrane. This wall passes obliquely from its superior end in an inferior ventral direction, and becomes narrower as it approaches the ventral ends of the ventricular folds. The superior part of the dorsal surface of the epiglottis is convex, owing to the manner in which the upper margin is curved ventrally towards the tongue; below the convexity there is a slight concavity, and still lower a marked bulging or convexity, over the superior part of the thyreo-epiglottic ligament. This swelling, the **epiglottic tubercle**, forms a conspicuous object in laryngoscopic examination of the larynx. Each *lateral wall* of the vestibule of the larynx is formed by the medial surface of the corresponding ary-epiglottic fold. For the most part it is smooth and slightly concave, and it diminishes considerably in vertical depth as it passes dorsally. In its dorsal part the mucous membrane stands out in two elongated vertical elevations, placed one dorsal to the other (Fig. 833, p. 1076). The more ventral elevation is formed by the subjacent cuneiform cartilage with the mass of glands associated with it; the more dorsal elevation is produced by the upper part of the arytænoid cartilage and the corniculate cartilage (Santorini). The *dorsal wall* of the laryngeal vestibule is narrow, and corresponds to the interval between the upper parts of the two arytænoid cartilages. Its width, to a large extent, depends on the position of those cartilages, and when they are placed near each other the mucous membrane which covers the dorsal wall is thrown into longitudinal folds.

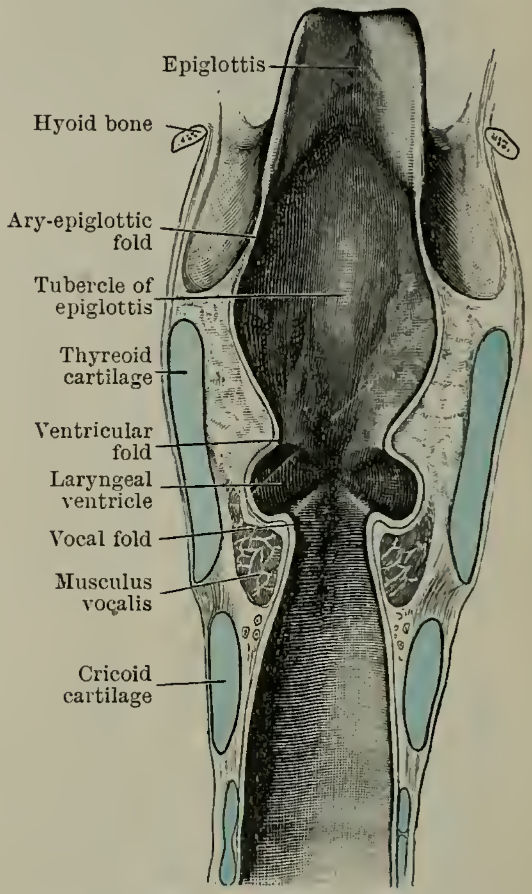


FIG. 826.—FRONTAL SECTION THROUGH THE LARYNX TO SHOW ITS COMPARTMENTS.

The **middle compartment of the larynx** is much the smallest of the three. It is bounded above by the ventricular fold and below by the vocal folds, whilst it communicates between those folds with the vestibule on the one hand and the inferior compartment on the other.

The **ventricular folds** (O.T. **false vocal cords**) are two prominent folds of mucous membrane which extend ventro-dorsally on the lateral walls of the laryngeal cavity. Ventrally they reach the angle between the two laminæ of the thyreoid cartilage, but dorsally they do not extend so far as the dorsal wall of the larynx. They come to an end at the inferior extremity of the elongated swelling produced by the cuneiform cartilage. The ventricular fold is soft and somewhat flaccid, and presents a free border which is slightly arched—the concavity looking downwards. Within the fold of mucous membrane which forms this fold are contained: (1) the feeble ventricular ligament; (2) numerous glands which are chiefly aggregated in its middle part; and (3) a few muscle fibres.

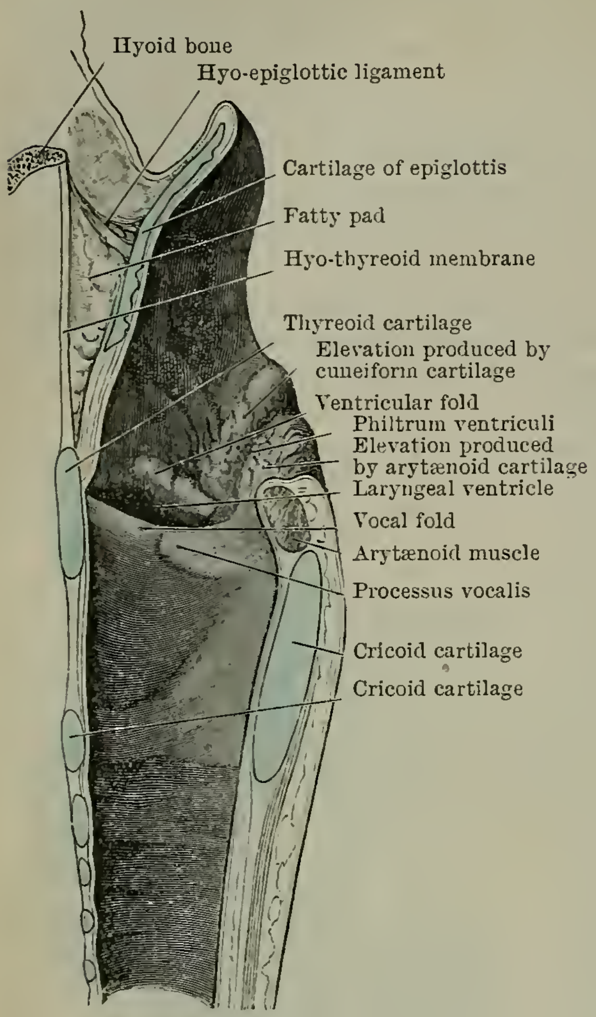


FIG. 827.—SECTION THROUGH LARYNX IN THE MEDIAN PLANE TO SHOW THE SIDE WALL OF THE RIGHT HALF.

The interval between the ventricular folds is termed the **rima vestibuli** and is considerably wider than the **rima glottidis**, or the interval between the two vocal folds. It follows, therefore, that when the cavity of the larynx is examined from above with the laryngoscope all four folds are distinctly visible.

The **vocal folds**, or **true vocal cords**, placed below the ventricular folds, extend from the angle between the laminæ of the thyreoid cartilage ventrally, to the vocal processes of the arytænoid cartilages dorsally. The vocal fold is sharp and prominent, and the mucous membrane which is stretched over it is very thin and firmly bound down to the subjacent ligament. In colour it is pale, almost pearly white, whilst, dorsally, the point of the vocal process of the arytænoid, which stands out clearly in relief, presents a yellowish tinge. In cross-section the vocal fold is prismatic in form, and its free border looks upwards as well as medially.

The vocal folds are the agents by means of which the voice is produced. The ventricular folds are of little importance in this respect; indeed, they can in great part be destroyed and no appreciable difference in the voice result.

Rima Glottidis.—This name is applied to the elongated fissure by means of which the middle compartment of the larynx communicates with the lower compartment. It is placed somewhat below the middle of the laryngeal cavity, of which it constitutes the narrowest part. Ventrally it corresponds to the interval between the vocal folds; dorsally it corresponds to the interval between the bases and vocal processes of the arytænoid cartilages. It is composed, therefore, of two distinct parts: (1) a narrow ventral portion, between the vocal folds, involving more than half of its length, and called the **intermembranous part** of the rima glottidis; (2) a broader, shorter portion, between the arytænoid cartilages, and termed the **intercartilaginous part.** By changes in the position of the arytænoid cartilages the form of the rima glottidis undergoes constant alterations. In ordinary easy breathing it is somewhat lanceolate in outline. The intermembranous part presents, under these conditions, the form of an elongated triangle the base of which is directed dorsally and corresponds to an imaginary

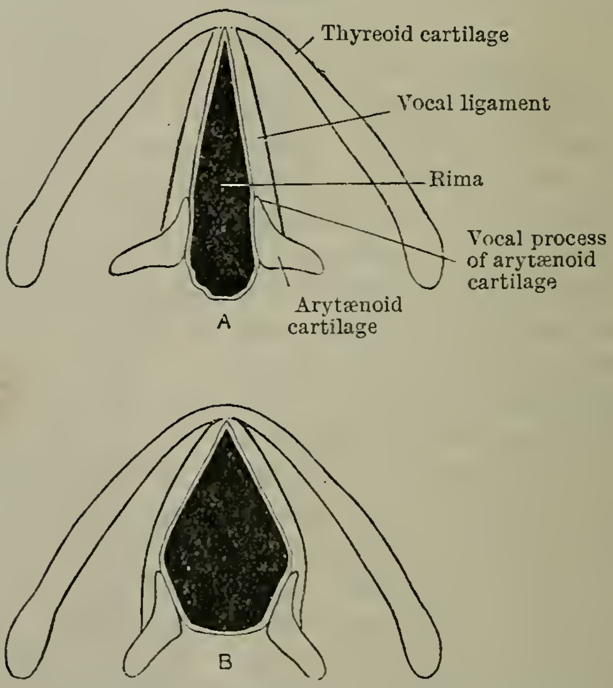


FIG. 828.—DIAGRAM OF RIMA GLOTTIDIS.
A. During ordinary easy breathing. B. Widely opened.

line drawn between the points of the vocal processes of the arytænoid cartilages, whilst the intercartilaginous part is somewhat quadrangular. When the glottis is opened widely the broadest part of the fissure is at the extremities of the vocal processes of the arytænoids, and there each side of the rima glottidis presents a marked angle. The two vocal folds, on the other hand, may be approximated to each other so closely, as in singing a high note, that the intermembranous part is reduced to a linear chink.

The length of the rima glottidis differs very considerably in the two sexes, and upon this depends the different character of the voice in the male and female. According to Moura, the following are the average measurements in the quiescent condition of the rima :—

Male—Length of entire rima glottidis, 23 mm.	intermembranous, 15·5 mm. intercartilaginous, 7·5 mm.
Female—Length of entire rima glottidis, 17 mm.	intermembranous, 11·5 mm. intercartilaginous, 5·5 mm.

By stretching the vocal folds, however, the length of the rima glottidis in the male may be increased to 27·5 mm., and in the female to 20 mm.

The position of the rima glottidis may be indicated on the surface by marking a point on the middle line of the neck 8·5 mm. below the thyreoid notch in the male and 6·5 mm. in the female. This is the average position (Taguchi).

The lateral wall of the larynx, in the interval between the ventricular and the vocal folds, exhibits a marked pocket-like depression or recess called the **ventricle of the larynx**. The ventricle passes upwards, so as to undermine somewhat the ventricular fold, and its mouth is somewhat narrower than its cavity. Ventrally it reaches to the angle between the laminæ of the thyreoid cartilage, whilst dorsally it ends at the ventral border of the arytænoid cartilage.

Under cover of the ventral part of the ventricular fold a small slit-like aperture may be detected ; this leads upwards from the laryngeal ventricle into a small diverticulum of mucous membrane, termed the **appendix**, which passes upwards, between the ventricular fold and the lamina of the thyreoid cartilage. The laryngeal appendix is of variable extent, but as a rule it ends blindly at the level of the upper border of the thyreoid cartilage.

The **lowest compartment** of the cavity of the larynx leads caudally into the trachea. Above it is narrow and compressed laterally, but it gradually widens out until it becomes circular, in correspondence with the trachea, with which it is continuous. It is bounded by the sloping medial surfaces of the elastic cone and by the medial aspect of the cricoid cartilage—both covered with smooth mucous membrane. In the operation of laryngotomy the opening is made through the crico-thyreoid ligament in the ventral wall of this compartment.

Tunica Mucosa Laryngis.—The **mucous membrane** which lines the larynx is continuous above with the lining of the pharynx, and below with the mucous membrane of the trachea. Over the dorsal surface of the epiglottis it is closely adherent, but elsewhere, above the level of the vocal folds, it is loosely attached by submucous tissue which extends into the ary-epiglottic folds. As it passes over the vocal folds the mucous membrane is very thin, and is tightly bound down.

It is important to bear these facts in mind, because, in certain inflammatory conditions, the lax submucous tissue in the upper part of the larynx is liable to become infiltrated with fluid, producing what is known as œdema glottidis. This may proceed so far as to cause occlusion of the upper part of the cavity. The close adhesion of the mucous membrane to the vocal folds, however, prevents the œdema extending beyond the level of the rima glottidis, and the surgeon is thus able to relieve the patient by making an opening through the ventral part of the elastic cone into the cavity of the larynx.

Above the level of the rima glottidis the laryngeal mucous membrane is extremely sensitive, and when touched by a foreign body there is an immediate response in the shape of an explosive cough. In the lower compartment of the larynx the mucous membrane is lined with columnar ciliated epithelium. Over the vocal folds this is replaced by squamous epithelium. In the ventricle of the larynx and in the inferior part of the vestibule of the larynx the columnar ciliated epithelium again reappears. The upper part of the epiglottis and the upper parts of the lateral walls of the vestibule are covered with squamous epithelium similar to that present in the mouth and pharynx.

The mucous membrane of the larynx has a plentiful supply of acinous glands, and in only one place, viz., over the surface of the vocal folds, are these completely absent. For the most part the glands are aggregated in groups.

THE MUSCLES OF THE LARYNX.

Of the many muscles connected with the larynx, two groups may be recognised, extrinsic and intrinsic.

The **extrinsic muscles** reach the larynx, to which they are attached and upon which they act, from other parts, and, strictly speaking, include all those attached to the hyoid bone, which is physiologically a part of the larynx.

Of the **intrinsic muscles** all are composed of striated muscular fibres, and are innervated by the accessory nerve through the laryngeal branches of the vagus. They all lie, with the exception of the crico-thyreoid muscle, under cover of the thyreoid cartilage. In this group there are ten, and occasionally eleven, series of muscles, which may be classified physiologically as follows :—

a. Acting upon the vocal folds—
Tension.—The crico-thyreoids.
Relaxation.—The (external) thyreo-arytænoids.
The vocal muscles.

b. Acting upon the rima glottidis—
Dilatation.—The posterior crico-arytænoids.
Closure.—The transverse arytænoids.
The oblique arytænoids.
The lateral crico-arytænoids.

c. Acting upon the aditus and vestibule of the larynx—
Closure.—The ary-epiglottics, assisted by some of the foregoing.
Dilatation.—The thyreo-epiglottics.

d. Acting upon the ventricular folds—
The ventricular muscle.

The inconstant cerato-cricoids complete the list of intrinsic muscles.

The muscles of the larynx have, however, another function to perform besides vocalisation and regulating the amount of air passing to and fro through the glottis. During deglutition it is requisite that the communication between the pharynx and larynx should be closed, to prevent the fluid or solid parts of the food entering the respiratory passages. In the process of closing the laryngeal entrance the epiglottis stands erect, whilst the dorsal wall formed by the arytænoids is carried ventrally, the arytænoid cartilages are closely approximated, glide ventrally, and are then inclined towards the epiglottis. The result of this is that the laryngeal opening is converted into a T-shaped fissure. The median limb of the T is formed by the interval between the closely applied arytænoid cartilages, whilst the cross limb, which lies ventrally, is bounded ventrally (anteriorly) by the epiglottis and dorsally by the ary-epiglottic folds. The apices of the arytænoid cartilages, with the corniculate cartilages (Santorini), are pressed against the tubercle of the epiglottis, whilst the lateral margins of the epiglottis are pulled dorsally so as to make the transverse limb of the fissure distinctly concave in a dorsal direction. The muscles chiefly concerned in producing these movements are the thyreo-arytænoid and the transverse arytænoid muscles. These form a true sphincter vestibuli. The thyreo-epiglottic and ary-epiglottic muscles also come into play. They pull upon the epiglottis so as to produce tight application of its tubercle to the arytænoid cartilages and the corniculate cartilages (Santorini), and they also curve its margins dorsally so as to increase its dorsal concavity.

Innervation of the Larynx.—The nerve supply of the larynx is derived from the superior and inferior (laryngeal) branches of the vagus nerve.

The superior laryngeal nerve is the "sensory" or receptor nerve from the mucous membrane of the larynx, and also gives off a branch which furnishes "motor" or effector fibres to the crico-thyreoid muscle. All the other muscles of the larynx receive their "motor" or effector nerve fibres from the recurrent (laryngeal) nerve. As this last nerve recurs, on the left side around the arch of the aorta, it is frequently involved in aneurism of the aortic arch, so that this question of the innervation of the larynx and its muscles is of more than ordinary clinical importance, and should be carefully noted. If the recurrent (laryngeal) nerve be divided or compressed on one side, the voice is lost, because the corresponding vocal fold cannot be adducted. Breathing is also somewhat laboured, because the vocal fold cannot be abducted. Under these conditions, and as seen on the living subject with the laryngoscope, the paralysed vocal fold does not move on phonation to the middle line as it should do, nor does it move away from it on inspiration. When the recurrent (laryngeal) nerve is more gradually affected it is the abductor muscle — the posterior crico-arytænoid—which fails first.

Paralysis of the superior laryngeal nerve, much less common than that of the recurrent (laryngeal) nerve, leads to loss of laryngeal sensation, and also causes hoarseness, because the paralysis of the crico-thyreoid muscle leads to deficient tension of the vocal folds.

Attachments of the Laryngeal Muscles.—The following are the unimportant details of the attachments of the laryngeal muscles :—

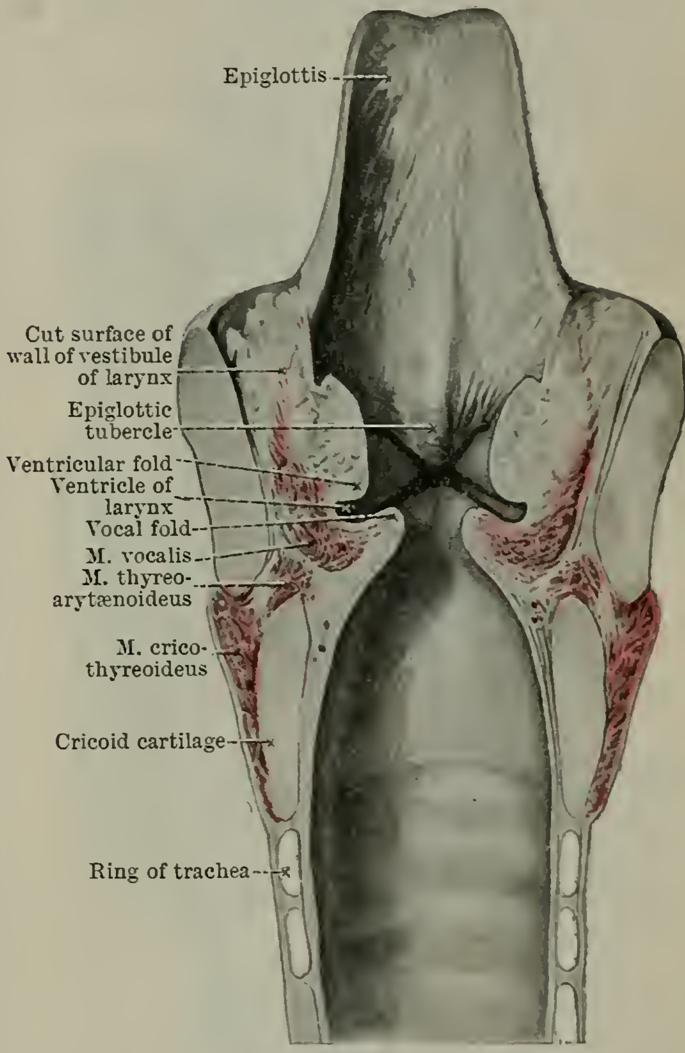


Fig. 829.—Frontal Section of the Larynx, showing Muscles.

The **crico-thyreoid muscles** are a pair of quadrangular muscles which lie on the cricoid cartilage and bridge over the crico-thyreoid interval, and are, therefore, the only intrinsic laryngeal muscles which are visible in an ordinary dissection of the neck. Each is covered laterally and in part by the thyreoid gland and the sterno-thyreoid and the sterno-hyoid muscles. Between the two muscles of opposite sides there is an intermediate triangular area left in which the crico-thyreoid ligament is visible.

Each crico-thyreoid muscle arises from the lower border and lateral surface of the arch, of the cricoid cartilage, and from this origin its fibres radiate dorsally and upwards to be *inserted* into the inferior border and medial surface of the lamina of the thyreoid cartilage, as far as its inferior cornu, and also into the inferior cornu itself. As a general rule each muscle is divided into two parts, viz., (1) a **pars recta** composed of those fibres which are inserted into the lamina of the thyreoid cartilage; and (2) a **pars obliqua** formed of those fibres which are inserted into the inferior cornu. The muscle is closely associated with the inferior constrictor muscle of the pharynx, and sometimes shows a certain amount of continuity with it.

The **(external) thyreo-arytænoid muscle** is a thin, quadrangular muscle, which is only separable from the corresponding vocal muscle, with which it forms a common mass, by artificial means.

It lies in the lateral wall of the larynx, between the lamina of the thyreoid cartilage on its lateral side, and the ventricle of the larynx, the vocal muscle, and the elastic cone on its medial side; its inferior border is in contact with the lateral crico-arytænoid muscle, whilst its superior border extends farther upwards than the vocal fold, and is in contact with the inferior border of the thyreo-epiglottic muscle.

It **arises** from the inferior half of the medial surface of the lamina of the thyreoid cartilage, close to its ventral angle, and also from the lateral part of the elastic cone. The muscular fibres pass dorsally and upwards to be **inserted** into the lateral border and muscular process of the arytænoid cartilage; some of the fibres, however, turn round this cartilage and become continuous with the transverse arytænoid muscle.

By its **action** the muscle rotates the arytænoid cartilage and draws it ventrally in such a way that its vocal process is carried ventrally and medially and the vocal fold is rendered somewhat flaccid. The muscle thus antagonises the crico-thyreoid. The main action of the muscle must, however, be that of a constrictor of the supraglottic region of the larynx.

The **vocal muscle** of each side is a triangular, somewhat prismatic muscle, which forms with the thyreo-arytænoid a common muscular mass separable only with difficulty into its two constituent portions. The vocal muscle lies within the vocal fold, closely applied to the lateral aspect of the vocal ligament, and receives its prismatic form from this adaptation. Of its three surfaces, the *medial* lies adjacent to the vocal ligament and the elastic cone; the *upper* surface is bounded by the labium vocale and the entrance to the ventricle of the larynx; whilst the *lateral* surface is bounded by, and is in contact with, the thyreo-arytænoid muscle.

The vocal muscle arises from the inferior part of the angular depression between the two laminæ of the thyreoid cartilage, and also from the corresponding vocal fold, whence the fibres run dorsally to be **inserted** into the lateral aspect of the vocal process and the depression on the ventro-lateral surface of the arytænoid cartilage.

It follows that the **action** of the muscle is to draw the vocal process of the arytænoid cartilage ventrally, thereby relaxing the vocal fold and ligament.

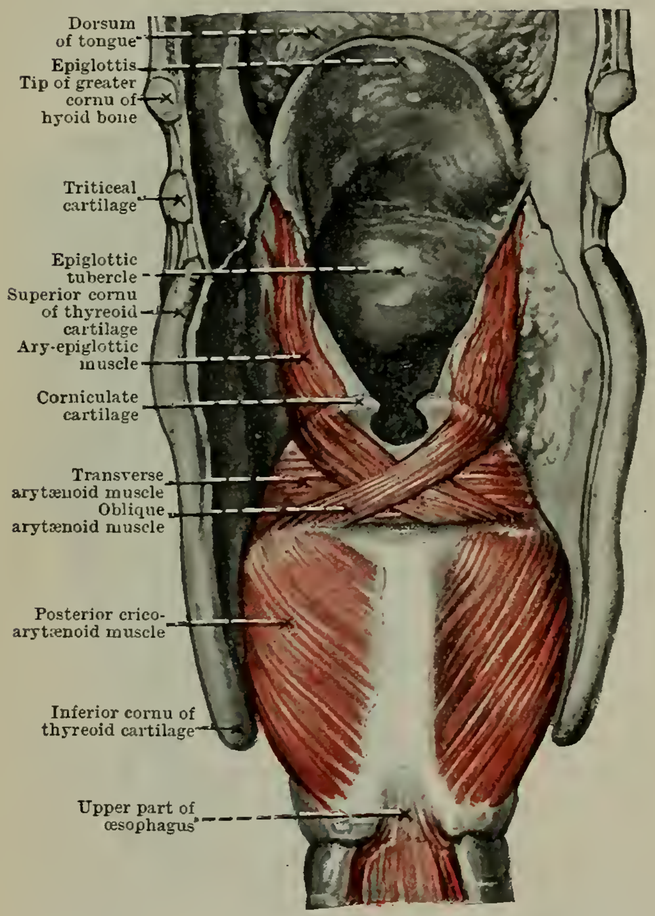

Dorsum of tongue
Epiglottis
Tip of greater cornu of hyoid bone
Triticeal cartilage
Epiglottic tubercle
Superior cornu of thyreoid cartilage
Ary-epiglottic muscle
Corniculate cartilage
Transverse arytænoid muscle
Oblique arytænoid muscle
Posterior crico-arytænoid muscle
Inferior cornu of thyreoid cartilage
Upper part of œsophagus

FIG. 830.—DISSECTION OF THE MUSCLES ON THE DORSAL ASPECT OF THE LARYNX.

The **posterior crico-arytænoid muscles** are a pair of triangular muscles, each of which lies on the dorsal surface of the lamina of the cricoid cartilage, under cover of the tela submucosa of the pharynx. Each **arises**, by a broad origin, from the medial and inferior part of the depression on the dorsal surface of the lamina of the cricoid cartilage at the side of the median ridge; from that origin its fibres converge upwards and laterally to be **inserted** into the dorsal surface and apex of the muscular process of the corresponding arytænoid cartilage. In their course from origin to insertion the muscular fibres display very different degrees of obliquity. The most superior fibres are short and nearly horizontal; the intermediate fibres are the longest and are very oblique; whilst the most inferior fibres are almost vertical in their direction.

By its action the posterior crico-arytænoid draws the muscular process of the arytænoid cartilages medially and dorsally, swings the vocal process and the vocal fold laterally, and thereby opens the rima glottidis.

The **transverse arytænoid muscle** is a thick, oblong, unpaired muscle which lies in the dorsal wall of the larynx and bridges across the interval between the two arytænoid cartilages. The ventral surface of the muscle is in contact with the dorsal concave surfaces of the arytænoid cartilages, and between them with the mucous membrane of the larynx. Its dorsal surface is partly concealed by the oblique arytænoid and by the submucous tissue of the pharynx. The inferior border extends to the lamina of the cricoid cartilage, and its upper border does not quite reach the apices of the arytænoid cartilages.

The **attachments** of the muscle are, on both sides, to the dorsal surface of the muscular process and the lateral edge of the arytænoid cartilages. All the fibres run in a frontal (coronal) direction, and some turn round the arytænoid cartilage to become continuous with the thyreo-arytænoid. The transverse arytænoid and the thyreo-arytænoid muscles form, together, a sphincter of the glottis.

By its action the transverse arytænoid muscle approximates the arytænoid cartilages, thereby tending to close the rima glottidis. Its assistance in the sphincter action of the thyreo-arytænoid muscle has already been pointed out.

The **oblique arytænoid muscles** are a pair of muscles which lie in the dorsal wall of the larynx, immediately dorsal to the transverse arytænoid and ventral to the submucous tissue of the pharynx.

Each muscle consists of a bundle of muscular fibres which **arise** from the dorsal aspect of the muscular process of the corresponding arytænoid cartilage. From their origins the two fleshy slips proceed upwards and medially, and cross each other in the median plane like the two limbs of the letter X. Reaching the apex of the arytænoid cartilage of the opposite side, many, but not all, of the fibres are **inserted** there, but others receiving a fresh attachment *arise* from the apex of the arytænoid cartilage as the **ary-epiglottic muscle** and extend ventrally and upwards in a series of arches within the ary-epiglottic fold to terminate in the thyreo-epiglottic ligament and the lateral margin of the epiglottic cartilage; and as the muscle approaches the latter structure its fibres are joined by the fibres of the thyreo-epiglottic muscle. With its superior border are also commingled some fibres from the stylo-pharyngeal muscle.

Action.—The oblique arytænoid and ary-epiglottic muscles combined act as a rudimentary sphincter muscle for the aditus and the vestibule of the larynx, that is for the superior aperture of the larynx, inasmuch as they extend from the base of one arytænoid cartilage to the apex of the arytænoid cartilage of the opposite side, and then on to the epiglottis within the ary-epiglottic fold.

The **lateral crico-arytænoid muscles** are a pair of triangular muscles, each of which lies in the lateral wall of the larynx upon the elastic cone and concealed by the lamina of the thyreoid cartilage, the thyreoid gland, and the infra-hyoid muscles.

Each muscle **arises** from the upper border and the lateral surface of the arch of the cricoid cartilage as far dorsally as the facet which supports the base of the arytænoid cartilage, and also from the lateral part of the elastic cone.

From this origin the muscular fibres run dorsally and upwards, and converge to be **inserted** into the ventral surface of the muscular process of the arytænoid cartilage. The muscle is not infrequently inseparable from the (external) thyreo - arytænoid muscle.

By its **action** the lateral crico-arytænoid muscle draws the muscular process of the arytænoid cartilage ventrally and downwards, thus turning the vocal process of the same cartilage medially, and tending thereby to stretch the vocal fold and to approximate it to its fellow of the opposite side, thus assisting in closure of the rima glottidis.

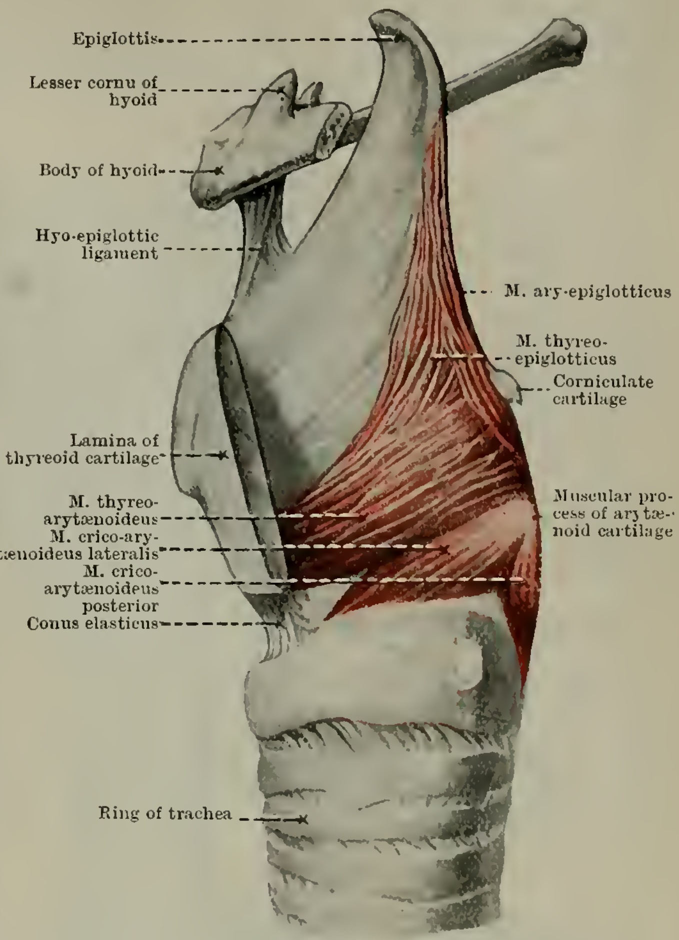


FIG. 831.—DISSECTION OF THE MUSCLES OF THE SIDE WALL OF THE LARYNX.

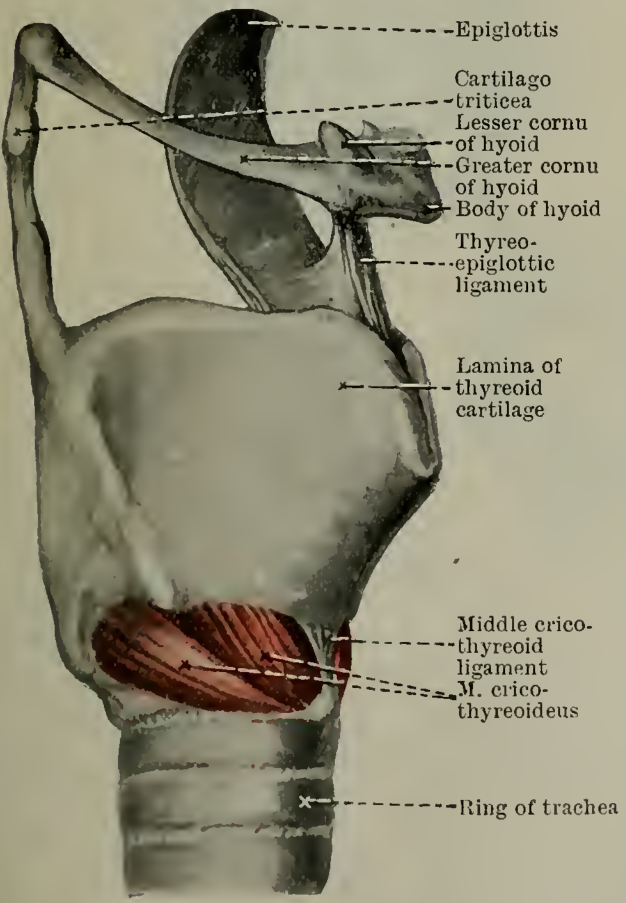


FIG. 832.—THE CRICO-THYREOID MUSCLE OF THE RIGHT SIDE.

The **thyreo-epiglottic muscles** are a pair of thin, oblong, very variable muscles, which lie in the side walls of the larynx. Each is bounded below by the thyreo-arytænoid, medially by the thyreo-epiglottic ligament and the ventricle of the larynx, and laterally by the lamina of the thyreoid cartilage.

Each thyreo-epiglottic muscle **arises** from the medial surface of the lamina of the thyreoid cartilage, immediately above the origin of the thyreo-arytænoid. From this origin the fibres run in arches, upwards and dorsally, to be **inserted** partly into the margin of the ary-epiglottic fold, and partly into the lateral margin of the epiglottis, being intermingled with the fibres of the ary-epiglottic muscle.

By its **action** the thyreo-epiglottic muscle of the larynx widens the aditus and the vestibule.

The **ventricular muscle** is composed of several bundles of fibres, visible under the microscope, which pass, in a vertical direction, from the lateral edge of the arytænoid cartilage to the lateral margin of the cartilage of the epiglottis. There are also intermingled with it fibres from the thyreo-arytænoid and ary-epiglottic muscles.

Growth - Alteration and Sexual Differences in the Larynx.—A considerable amount of variation may be noticed in the size of the larynx in different individuals. This is quite independent of stature, and explains to a great extent the difference in the pitch of the voice in different persons. But quite apart from these individual variations, there is a sexual difference in the size of the larynx. The male larynx is not only absolutely, but also relatively, larger than the female larynx in all its diameters, but more particularly in the ventro-dorsal diameter; and to a large extent the increase in that direction is produced by the strong development of the laryngeal prominence in the male. The greater ventro-dorsal diameter of the male larynx necessarily implies a greater length of the vocal folds and a lower or deeper tone of the voice in the male than in the female.

In a newly born child the larynx, in comparison with the rest of the body, is somewhat large (C. L. Merker), and it continues to grow slowly and uniformly up to the sixth year of childhood. At that period there is a cessation of growth until puberty is reached, and then a stage of active growth supervenes. Up to that time the larynx in both sexes is similar in its dimensions, and although the growth which now occurs affects both the male and the female larynx, it is much more rapid and much more accentuated in the male than in the female. As a result the voice of the male "breaks" and assumes its deep tone.

Growth activity of the larynx, at puberty, is intimately connected with the development of the sexual organs. In a male subject who has been castrated when young, the larynx attains a size which exceeds that of the female only to a small degree, and the high pitch of the voice is retained.

Appearance of the Interior of the Larynx when examined by the Laryngoscope.

When the cavity of the larynx is illuminated and examined by laryngoscopic mirrors, the parts which surround the superior aperture of the larynx, as well as the interior of the organ, come into view. Not only this, but when the vocal folds are widely separated it is possible to inspect the interior of the trachea as far as its bifurcation.

In such an examination the arched upper border of the epiglottis is a conspicuous object, whilst, dorsal to that, the bulging on the ventral wall of the vestibule, formed by the tubercle of the epiglottis, may also be a feature of the picture. The median glosso-epiglottic fold with the glosso-epiglottic vallecula on either side of it, can also be inspected in the interval between the epiglottis and the base of the tongue. The sharp ary-epiglottic folds are clearly visible, and in the dorsal portion of each can be seen the two prominent tubercles which are formed by the enclosed cuneiform and corniculate cartilages. Dorsal to those tubercles is the dorsal wall of the pharynx, whilst to their lateral side the deep piriform recess may be seen. In the interior of the larynx the ventricular and the vocal folds are easily recognised, and the interval between the two, or, in other words, the entrance into the laryngeal ventricle, appears as a dark line on the lateral wall of the larynx. The ventricular folds are red and fleshy-looking; the vocal folds during phonation are tightly stretched and pearly white—the white colour being usually more apparent in the female than in the male. The outline and yellowish tinge of the vocal process at its attachment to the vocal fold, and the outline of the ventral part of the base of the arytænoid cartilage to a slight extent as well, can be made out in a successful laryngoscopic examination. The vocal folds during ordinary inspiration are seldom at rest, and with the laryngoscope their movements may be studied. It should be borne in mind that the picture afforded by the laryngoscope does not give a true idea of the level at which the different parts lie. The cavity appears greatly shortened, and its depth diminished.

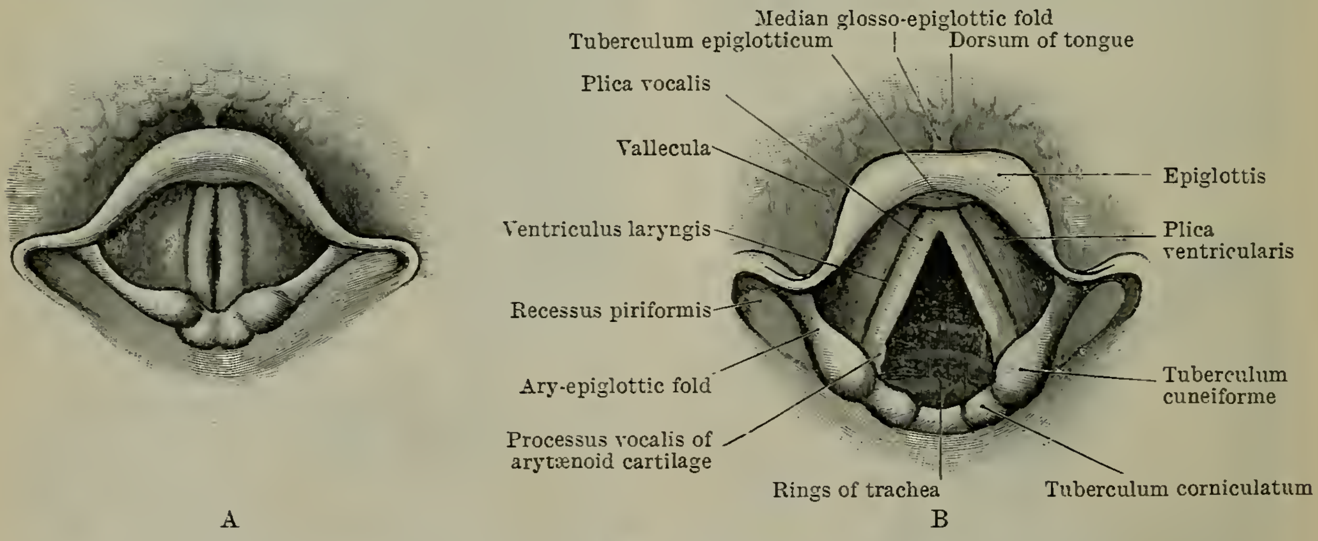


FIG. 833.—CAVITY OF THE LARYNX, as seen by means of the laryngoscope.
A. Rima glottidis closed. B. Rima glottidis widely opened.

TRACHEA.

The **trachea** or **windpipe** is a wide tube which is kept permanently patent by a series of bent cartilaginous bars embedded in its wall. These bars are deficient dorsally, and consequently the tube is not completely cylindrical: its dorsal wall is flattened. The trachea begins at the inferior border of the cricoid cartilage, opposite the inferior margin of the sixth cervical vertebra. From that level it extends, through the neck, into the superior mediastinum of the thorax, and it ends, at the level of the superior border of the fifth thoracic vertebra, by dividing into the right and left bronchi. The length of the trachea in the male is from four to four and a half inches, and in the female from three and a half to four inches, but even in the same individual it varies considerably in length with the movements of the head and neck.

The inferior end of the trachea is fixed in position. This is a necessary provision to prevent dragging on the roots of the lung during movements of the head and neck. The remainder of the tube is surrounded by a quantity of loose areolar tissue, and possesses a considerable amount of mobility. Further, its wall is highly elastic, and thus when the head is thrown back the tube elongates through stretching, and when the chin is depressed its length is diminished by the recoil of its wall.

The trachea does not present an absolutely uniform calibre throughout its whole length. About its middle it exhibits a slight expansion or dilatation, and from that the calibre diminishes towards both extremities. Close to the bifurcation it is again slightly expanded (Braune and Stahel).

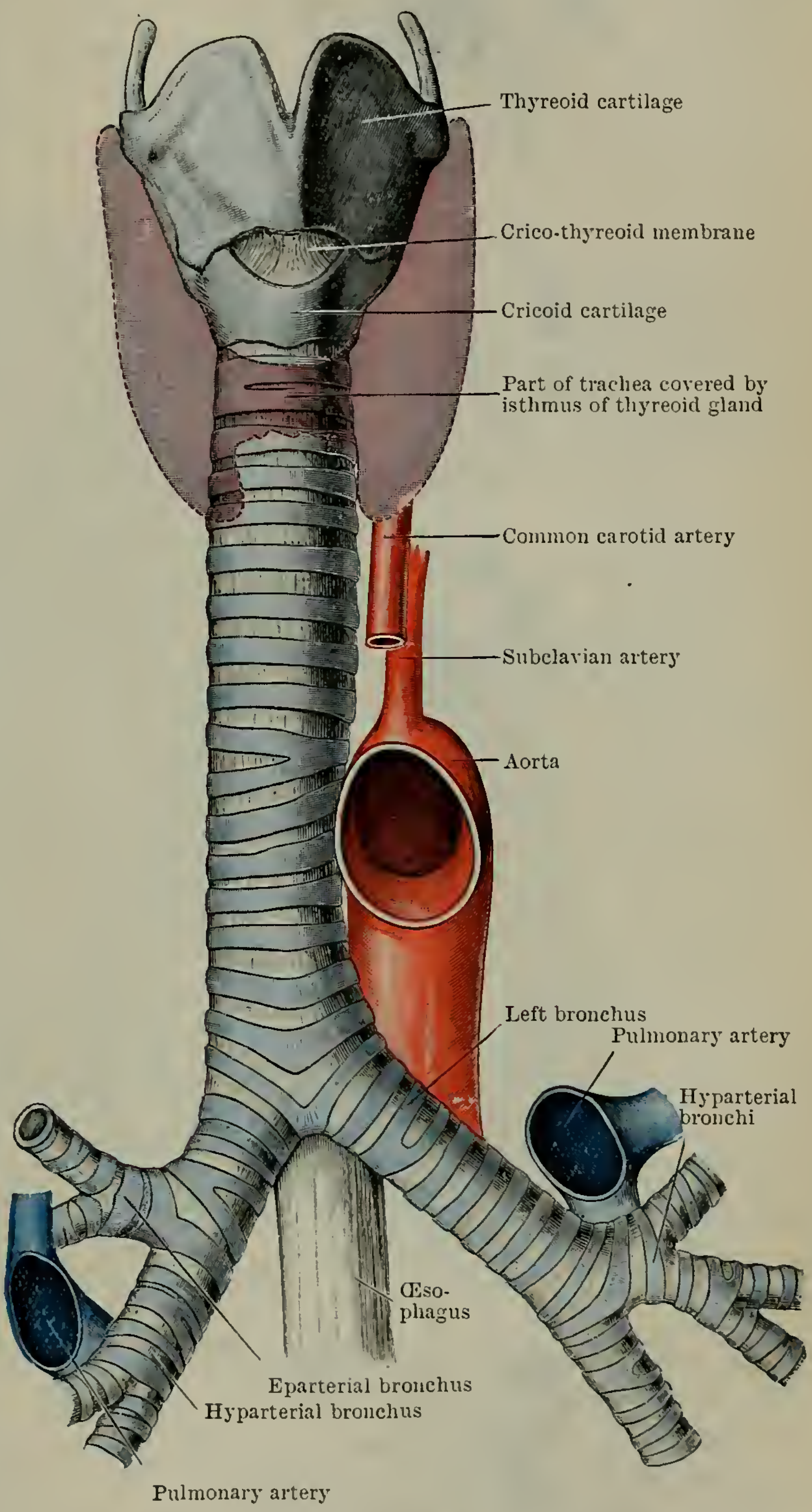


FIG. 834.—THE TRACHEA AND BRONCHI.

The thyreoid gland is indicated by a dotted line and a purple tint.

These differences in the calibre of the tube are determined by the surroundings of the trachea. The cervical part is narrowed owing to its being clasped by the thyreoid gland. Further, a short distance above its bifurcation, an impression, sometimes strongly marked, is usually seen on the left side of the trachea. It is due to the close contact of the aortic arch as it passes dorsally against that part of the tube.

It is evident therefore that the second slight diminution in calibre which is described by Braune and Stahel is produced by the proximity of the aorta. Lejars gives the average ventro-dorsal diameter of the trachea in the living person as 11 mm., and the transverse diameter as 12·5 mm. In the dead subject the lumen of the tube is considerably greater.

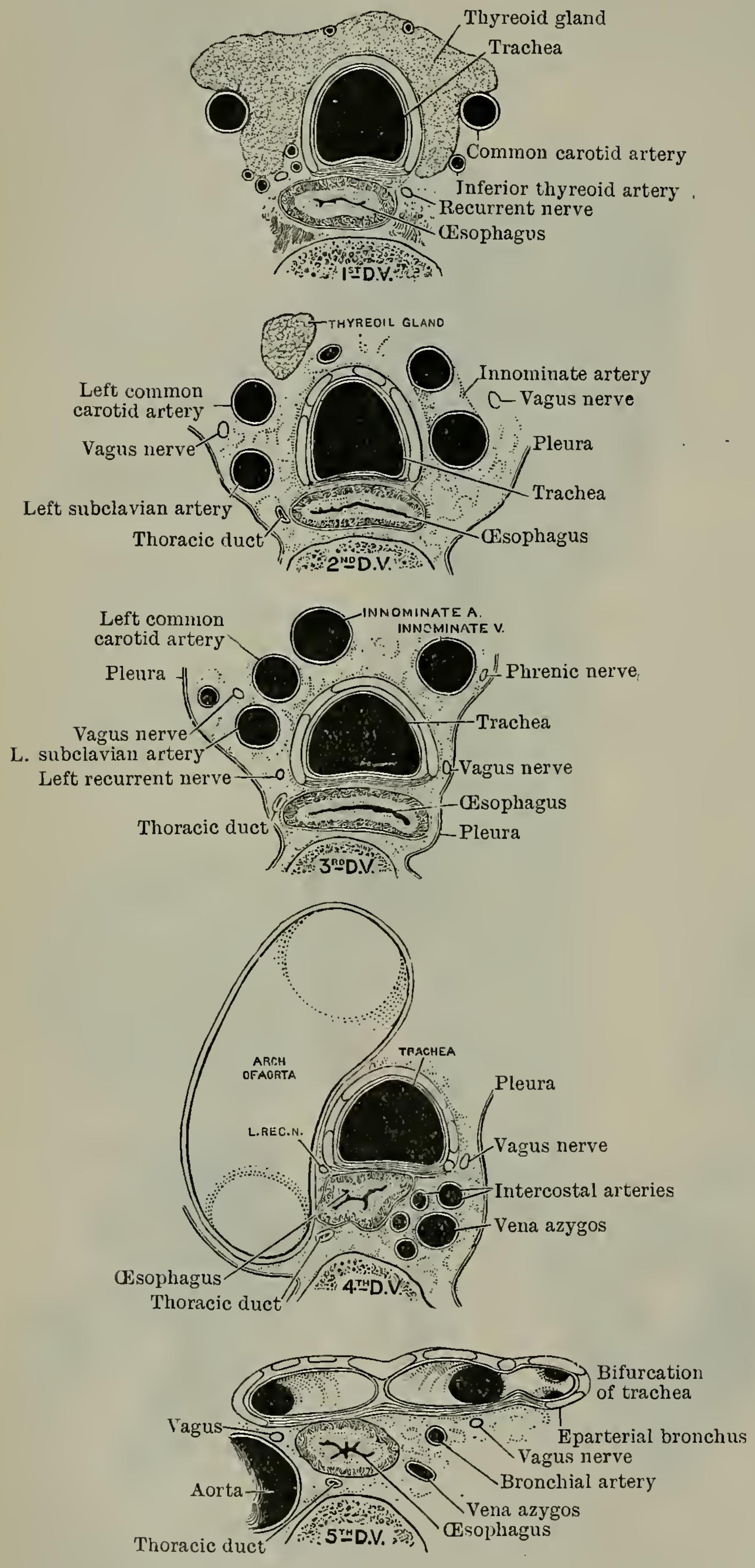


FIG. 835.—TRANSVERSE SECTIONS through the trachea and its immediate surroundings at the level of each of the upper five thoracic vertebræ.

The trachea adheres rigorously to the median plane except towards its termination, where it deviates very slightly to the right. As it passes downwards it recedes rapidly from the surface. This is due to its following the curvature of the vertebral column, from which it is separated by the œsophagus alone.

Relations of the Trachea.—In the study of the relations of the trachea it is convenient to consider it in the two stages of cervical and thoracic.

When the chin is held so that the face looks directly forwards the **cervical part** of the trachea measures from 2 to 2½ inches in length; but when the head is thrown dorsally or backwards the length is considerably increased. It is clasped by the thyreoid gland, the isthmus of which is applied to its ventral surface, and covers the second, third, and fourth rings; while on each side the corresponding lobe of the thyreoid gland is applied to the side of the trachea and extends downwards to the fifth or sixth ring. On either side of the cervical part of the trachea is the common carotid artery, whilst the recurrent nerve passes upwards in the groove between the trachea and the œsophagus. Dorsally the trachea is in relation to the œsophagus, which intervenes between it and the bodies of the vertebræ and deviates somewhat to the left as it passes downwards.

In addition to the isthmus of the thyreoid gland two thin muscular strata, composed of the sterno-hyoid and the sterno-thyreoid muscles, as well as the deep cervical fascia and integument, separate the cervical part of the trachea from the surface. In the median plane of the neck there is a narrow diamond-shaped space between the medial margins of these muscles, within which the trachea is covered merely by the integuments and fasciæ. It is important to note that in the inferior part of the neck the cervical fascia is in two layers—viz., a strong stratum applied to the ventral surface of the sterno-hyoid and sterno-thyreoid muscles, and a weaker superficial layer stretching across between the two sterno-cleido-mastoid muscles. Dorsal to these muscular and fascial layers the inferior thyreoid veins pass downwards on the ventral surface of the trachea, and sometimes the occasional thyreoidea ima artery passes upwards on the ventral aspect of the tube. At the superior border of the manubrium sterni the innominate artery may be seen crossing the trachea obliquely.

The **thoracic part** of the trachea is situated in the dorsal part of the superior mediastinum, being separated from the bodies of the vertebræ by the œsophagus alone. Immediately above its bifurcation the deep cardiac plexus of nerves is placed on the ventral and lateral aspects of the trachea. At the level of the fourth thoracic vertebra the aortic arch is very intimately related to it, lying first on the ventral side of the tube, and thereafter on its left side. The three great vessels which spring from the aortic arch are also placed in close proximity to the trachea. The innominate and the left common carotid arteries lie at first ventral to the trachea, and then gradually diverging as they proceed upwards, come to lie on either side of it—the innominate to the right, and the left common carotid to the left. Ventral to these vessels are the left innominate vein and the remains of the thymus. On the right side the thoracic part of the trachea is in relation to the right vagus nerve, and is clothed by the right mediastinal pleura; on the left side are the left subclavian artery and the left recurrent nerve.

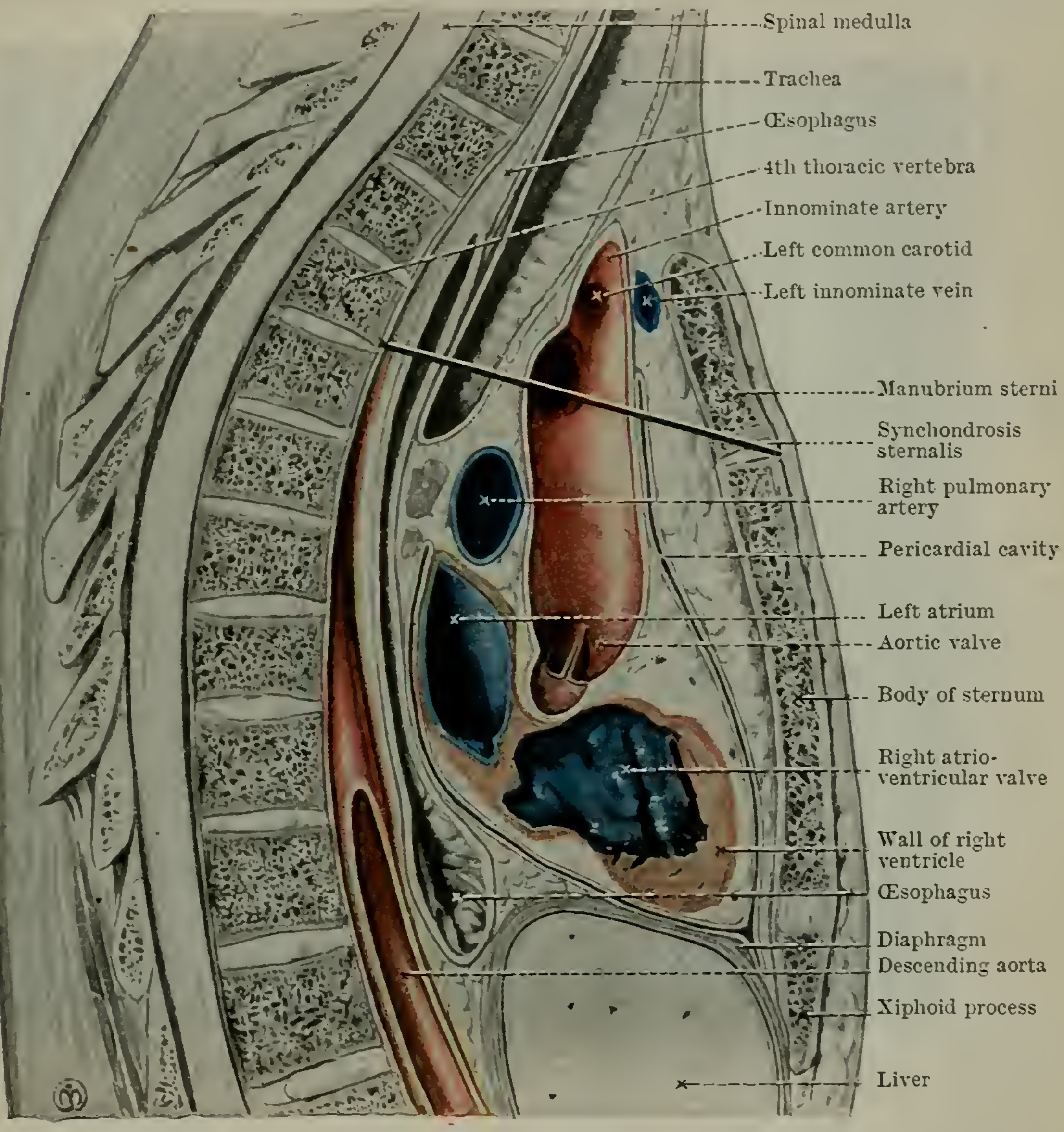


FIG. 836.—SAGITTAL SECTION THROUGH THE THORAX OF AN OLD MAN. The superior border of the manubrium sterni and the bifurcation of the trachea are lower than in the average adult.

Structure of the Wall of the Trachea.—The walls of the trachea and bronchi are composed of (1) a fibro-elastic membrane in which the tracheal cartilages are embedded; (2) within this, and on the dorsal aspect of the tube, a layer of muscular tissue, termed the musculus trachealis; (3) a submucous coat; and (4) the lining mucous membrane.

The **fibro-elastic membrane** is strong and dense. It passes round the whole circumference of the tube, and becomes continuous, above, with the perichondrium which invests the cricoid cartilage. Embedded in its substance are the **tracheal cartilages**. These vary in number from 15 to 20, and are composed of hyaline cartilage. They are horseshoe-shaped, the dorsal fourth of the circumference being deficient, so that dorsally each cartilage ends in two rounded extremities. The outer surface of each tracheal cartilage is flat and even, and does not project much beyond the level of the membrane in which it is embedded; the inner surface, however, is convex in the vertical direction, and consequently it bulges slightly into the lumen of the tube. The intervals between the tracheal cartilages are somewhat narrower than the cartilages themselves, and neighbouring ones frequently show a more or less complete fusion, whilst others present other irregularities, such as a tendency to bifurcate. The lowermost tracheal cartilage is specially adapted to the tracheal bifurcation. In the median plane, ventrally, it inclines downwards, and from this median peak a cartilaginous strip is carried backwards in the fork between the two bronchi.

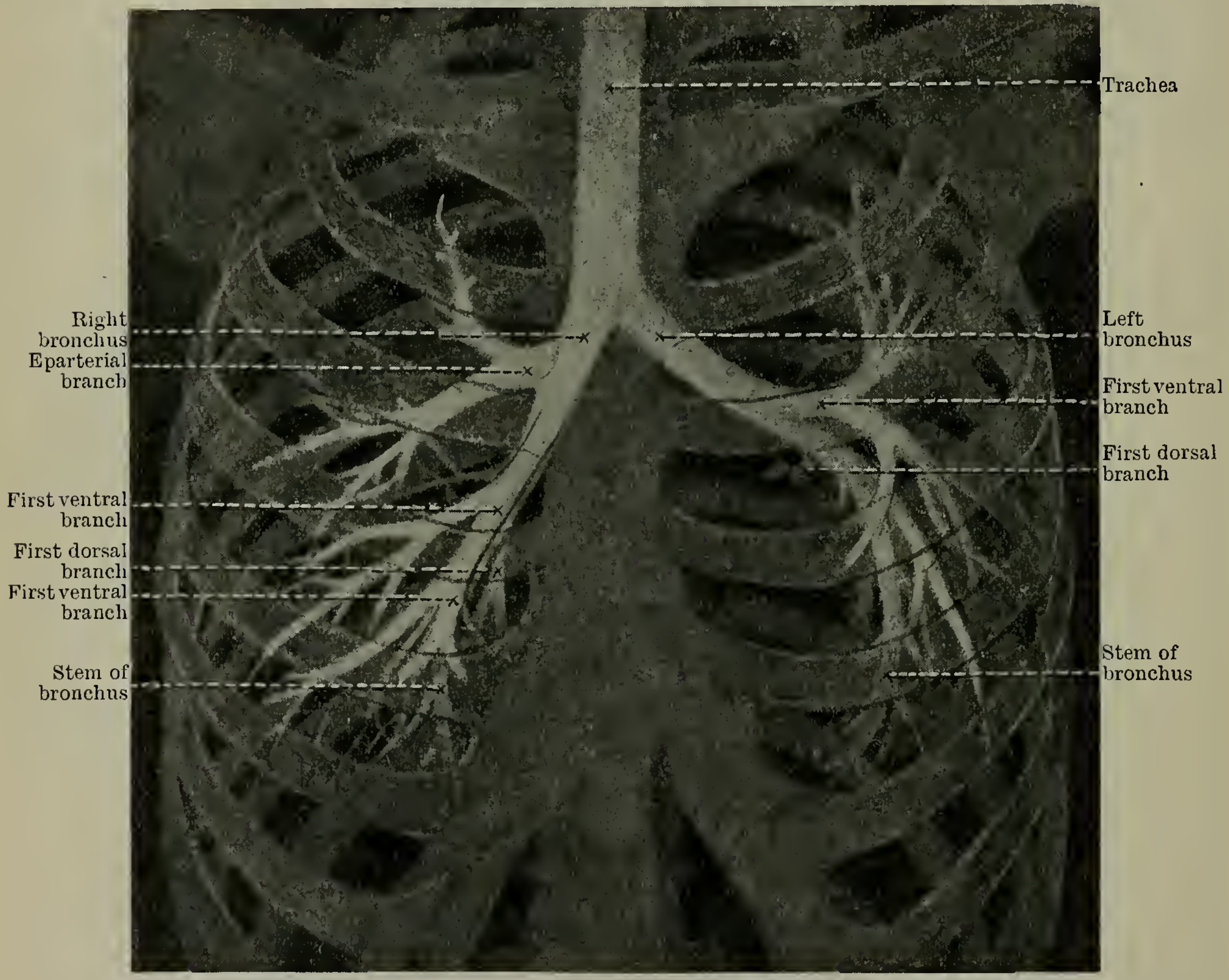


FIG. 837.—DRAWING OF A STEREOSCOPIC SKIAGRAPH OF THE TRACHEA AND BRONCHI INJECTED WITH STARCH AND RED LEAD.

The **m. trachealis** is a continuous layer of involuntary muscular tissue, placed in the dorsal part of the wall of the trachea internal to the fibro-elastic membrane. The muscular bundles are arranged transversely, and are attached to the extremities of the tracheal cartilages, and also to their inner surfaces for a short distance beyond their extremities. In the intervals between the cartilages the transverse muscular bundles are attached to the fibro-elastic membrane. It is evident that, by its contraction, this muscle will reduce the lumen of the tube.

The **mucous membrane** is laid smoothly over the interior of the tube upon a layer of submucous areolar tissue. Lymph tissue enters largely into the composition of the tracheal mucous membrane, and its inner surface is lined with pseudo-stratified columnar ciliated epithelial cells. The action of the cilia exercises an important influence in producing an upward movement of the mucus which is present on the surface of the mucous membrane.

Numerous longitudinal bundles of elastic tissue are present in the dorsal wall of the trachea, more particularly in its inferior part, between the mucous membrane and the trachealis muscle.

In connexion with the submucous coat there is a plentiful supply of mixed glands, containing both mucous and serous cells. These are placed in the submucous tissue, and also, on the dorsal aspect of the tube, on the exterior of the m. trachealis as well as amidst its muscular bundles. They send their ducts to the surface of the mucous membrane, where they open by trumpet-shaped mouths.

BRONCHI.

The two chief **bronchi** proceed obliquely downwards and laterally from the termination of the trachea, each towards the hilum of the corresponding lung. Like the trachea, they are kept permanently patent by the presence of cartilages in their walls. These cartilages are deficient dorsally, so that each bronchus exhibits a flattened dorsal surface, in every respect similar to the trachea. The two bronchi differ from each other, not only in the relations which they present to surrounding structures, but also in length, in width, and in the direction which they pursue (Fig. 837, p. 1080).

The first collateral branch of the right bronchus or the eparterial bronchus arises much nearer the trachea than the first branch of the left bronchus. This difference determines the length of the primary divisions of the trachea, and, although there is much variation in the matter, it may be said that, as a rule, the left bronchus is at least twice as long as the right bronchus. According to Henle there are from six to eight cartilages in the right, and from nine to twelve in the left, bronchus. A difference is also noticeable in the calibre of the two tubes. The right is wider than the left in the proportion of 100 to 78·4 (Braune and Stahel), and this asymmetry is clearly due to the fact that the right lung is more bulky than the left. The right bronchus, as it passes towards the hilum of the right lung, takes a more vertical course than the left bronchus. It therefore lies more in the line of the trachea, and to this, as well as to its greater width, is due the greater tendency which foreign bodies exhibit, when introduced into the trachea, to drop into the right bronchus, in preference to the left. The average angle which the right bronchus forms with the median plane is 24·8°, whilst the angle formed by the left bronchus with the median plane is 45·6°. The more horizontal course of the left bronchus is probably determined by the projection of the heart to the left side of the median plane (Merkel).

Relations of the Bronchi.—Arching above the right bronchus, from behind forwards, is the vena azygos, whilst arching above the left bronchus, from before backwards, there is the arch of the aorta. Occupying the interval between the bronchi there is a cluster of bronchial lymph glands, and an irregular chain of similar glands is carried along each tube towards the hilum of the lung. On the dorsal aspect of each bronchus the vagus nerve breaks up into the posterior pulmonary plexus, whilst the left bronchus, as it proceeds downwards and laterally, crosses the ventral surfaces of the œsophagus and descending thoracic aorta. The most interesting relation is, however, that presented on each side by the corresponding pulmonary artery. On the left side the pulmonary artery crosses ventral or anterior to the left bronchus on the superior side of its first collateral branch, and then turns round its lateral side to gain its dorsal aspect. All the left bronchial branches, therefore, are placed inferior to the left pulmonary artery, and are in consequence termed **hyparterial**. The right pulmonary artery, on the other hand, crosses ventral to the continuation of the right bronchus, inferior to its first collateral branch. This branch is therefore termed the **eparterial bronchus**, whilst all the others are classified as hyparterial.

Structure of the Walls of the Bronchi.—The walls of the bronchi present a structure similar to that seen in the trachea.

CAVUM THORACIS.

The **cavity of the thorax** is divided into two large lateral chambers, which contain the lungs, by a median partition termed the **mediastinal septum**, which extends from the vertebral column to the ventral thoracic wall. From the fact that each of these chambers is lined by an extensive and separate serous membrane called the **pleura**, they receive the name of the **pleural cavities**.

Septum Mediastinale.—The **mediastinal septum** is built up of several structures which lie in, or in close proximity to, the median plane. The more important of these are the heart, enveloped in its pericardium, the thoracic aorta, with the great vessels which spring from its arch, the pulmonary artery, and the great veins in the neighbourhood of the heart, the thymus or its remains, the trachea, œsophagus, and thoracic duct, and the vagi and phrenic nerves.

Cavum Pleuræ.—The pleural cavities, in which the two lungs lie, comprise much the larger part of the thoracic cavity. Each **pleural cavity** is bounded *inferiorly* by the corresponding cupola of the diaphragm; and as the right cupola rises to a higher level than the left, the right pleural cavity presents a smaller vertical depth than the left. *Ventrally*, the wall of each pleural chamber is formed by the costal cartilages and the sternum; *laterally*, by the bodies of the ribs and the intercostal muscles as far as the costal angles; *dorsally*, by the portions of the ribs, with the intervening intercostal muscles, which lie medial to the costal angles; and *medially*, by the bodies of the vertebræ and the mediastinal septum, which completely shuts off the one chamber from the other.

The mediastinal septum is not uniformly median in position. Owing to the projection of the heart to the left side, and to the position of the thoracic aorta on the left side of the median plane, the left pleural chamber, although it is deeper than the right, is reduced in width. The two pleural cavities, therefore, are very far from being symmetrical in form, and consequently the mediastinal septum tends to extend to the left of the median plane of the body.

Each pleural cavity is completely lined by a separate serous membrane termed the **pleura**. The portion of this membrane which clothes the mediastinum or intervening partition forms the lateral boundary of an area termed the **mediastinal** or **interpleural space**, within which the parts which build up the mediastinal septum are placed.

PLEURÆ.

The pleura of each side not only lines the corresponding pleural cavity, but at the pulmonary root, it is prolonged on to the lung so as to give it a complete investment. It is customary, therefore, to recognise a **pulmonary** or **investing part** (pleura pulmonalis) and a **parietal** or **lining part** (pleura parietalis). The inner surface of the pleura (*i.e.* that surface which is turned towards the interior of the cavity) is coated with squamous endothelium, and presents a smooth, glistening, and polished appearance; further, it is moistened by a small amount of serous fluid. In consequence of this the surface of the lung covered by pulmonary pleura can glide on the wall of the cavity, lined as it is by parietal pleura, with the least possible degree of friction. In the pathological condition known as pleurisy the inner surface of the pleura becomes

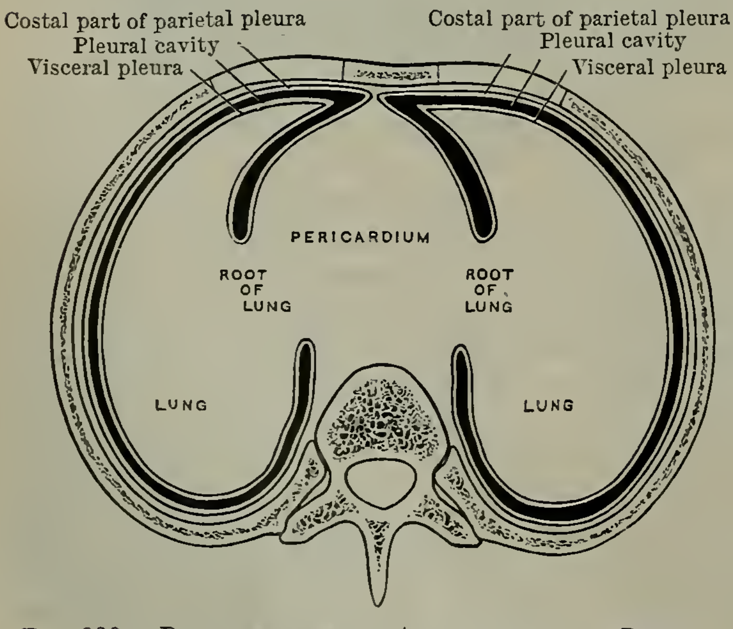


Fig. 838.—Diagram showing Arrangement of Pleural Sacs as seen in Transverse Section.

roughened by inflammatory exudation, and the so-called "friction sounds" are heard when the ear is applied to the chest.

Pleura Pulmonalis.—The **pulmonary pleura** is very thin, and is so firmly bound down to the surface of the lung that it cannot be detached without laceration of the pulmonary substance, and then only in small pieces. It dips into the fissures of the lungs, lines them down to the very bottom, and thus completely separates the different lobes of the lungs from each other. The pulmonary pleura becomes continuous with the mediastinal pleura at the root of the lung, and also through the ligamentum pulmonale.

Pleura Parietalis. — Different names are applied to the **parietal pleura** as it lines the different parts of the wall of the cavity in which the lung lies. Thus there are the *costal pleura*, the *diaphragmatic pleura*, the *mediastinal pleura*, and the *cupula pleuræ*; but it must be borne in mind that these terms are merely used for convenience in description, and that the portions of the pleura so designated are all directly continuous with one another.

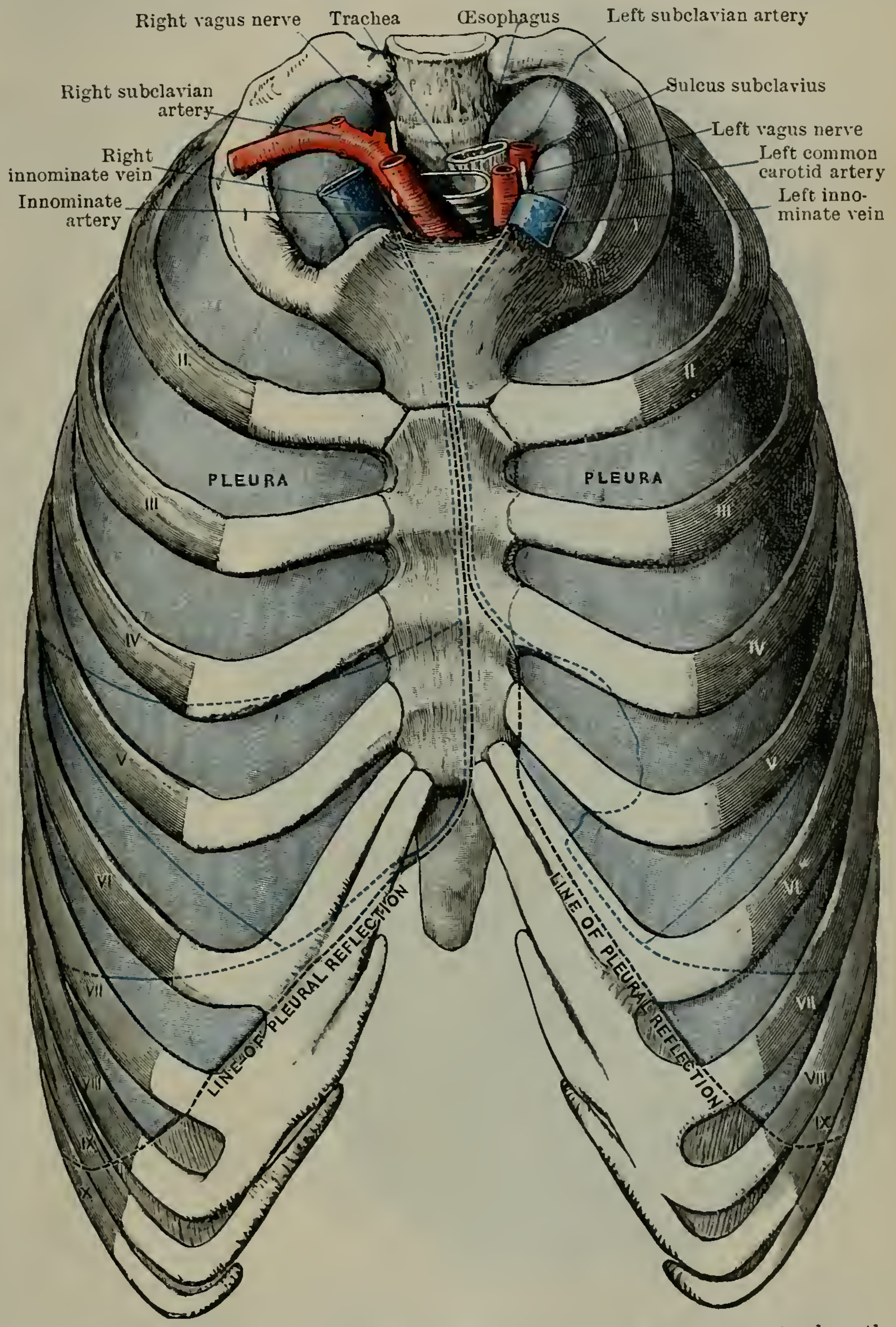


FIG. 839.—DISSECTION OF A SUBJECT HARDENED BY FORMALIN INJECTION, to show the relations of the two pleural sacs, as viewed from the front. The anterior and diaphragmatic lines of pleural reflection are exhibited by black dotted lines, whilst the outlines of the lungs and their fissures are indicated by the blue lines.

The **cupula pleuræ** or the cervical pleura rises into the root of the neck, through the superior aperture of the thorax, and forms a dome-shaped roof for the pleural cavity. Its highest point or summit reaches the level of the inferior border of the neck of the first rib; but owing to the great obliquity of the first costal arch, this point is placed from one to two inches above the ventral or anterior extremity of the first rib, and from a half to one and a half inches above the medial half of the clavicle. The cupula pleuræ is supported on the lateral side by the scalenus anterior and scalenus medius muscles, whilst the subclavian artery, arching laterally, lies in a groove on its medial and ventral aspects a short distance below its summit. At a lower level the innominate and subclavian veins also lie upon its medial and ventral aspects.

The cupula pleuræ is strengthened and held in place by an aponeurotic expansion, first described by Sibson, which is spread over it, and is attached to the internal concave margin of the first rib. This fascia is derived from a small muscular slip which takes origin from the transverse process of the seventh cervical vertebra.

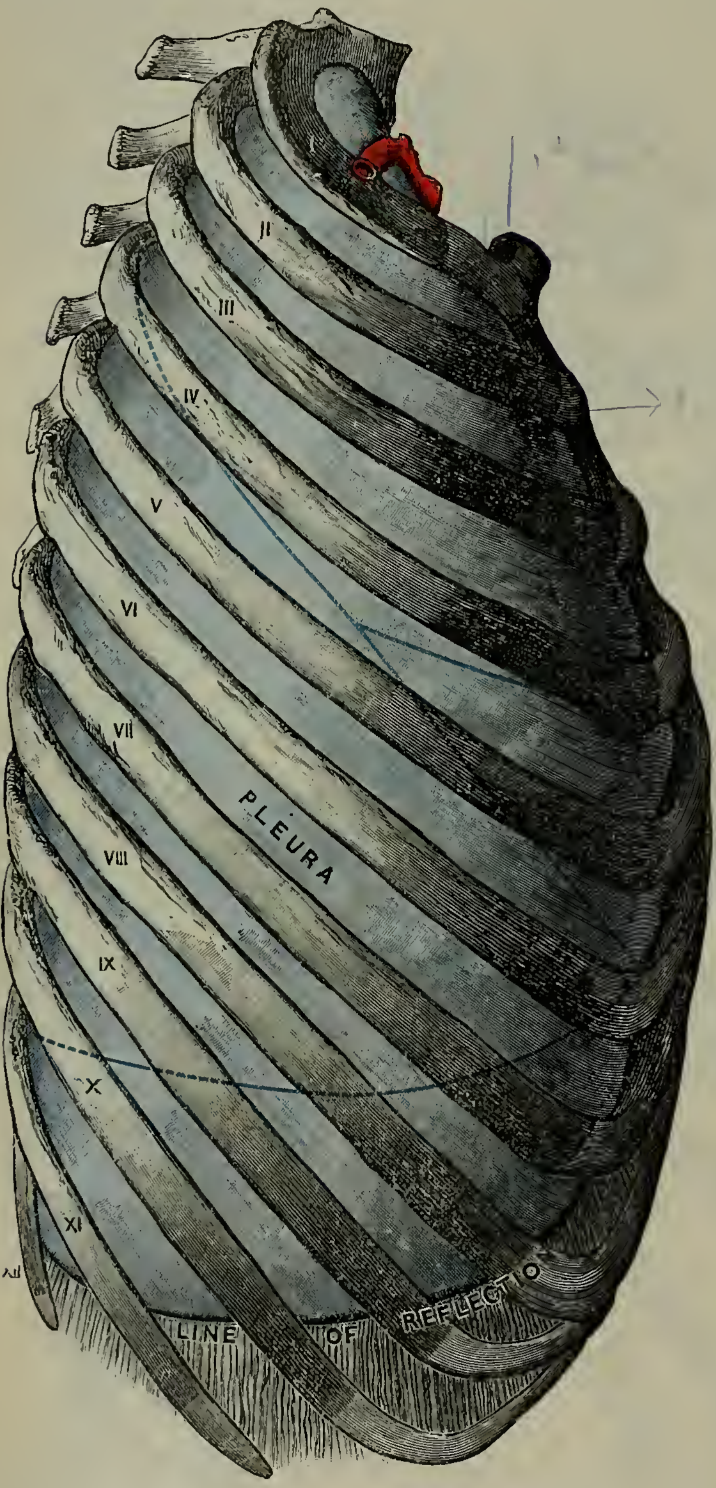


FIG. 840.—LATERAL VIEW OF THE RIGHT PLEURAL SAC IN A SUBJECT HARDENED BY FORMALIN INJECTION. The blue lines indicate the outline of the right lung, and also the position of its fissures.

Pleura Costalis.—The **costal pleura** is the strongest and thickest part of the parietal pleura. It lines the internal surfaces of the costal arches and of the intervening intercostal muscles. Ventrally it reaches the sternum, whilst dorsally it passes from the ribs over the sides of the bodies of the vertebræ. It is easily detached from the parts which it covers, except as it passes from the heads of the ribs on to the vertebral column. There it is somewhat tightly bound down.

Pleura Diaphragmatica.—The **diaphragmatic pleura** covers that portion of the thoracic surface of the diaphragm which lies to the lateral side of the base of the pericardium, but it does not dip down to the bottom of the narrow interval between the thoracic wall and the diaphragm. In other words, a strip of the thoracic surface of the diaphragm adjoining its costal attachment is left uncovered.

Pleura Mediastinalis.—The **mediastinal pleura** extends from the dorsal surface of the ventral thoracic wall to the vertebral column, and clothes the side of the mediastinal septum, which intervenes between the two pleural cavities. It is continuous with the costal pleura of its own side, both ventrally and dorsally, along two lines which are respectively termed the **sternal** and **vertebral lines of pleural reflection**; whilst inferiorly it becomes continuous with the diaphragmatic pleura of its own side at the base of the pericardium.

Above the root of the lung the mediastinal pleura passes directly from the sternum to the vertebral column. In that region the *left mediastinal pleura* is applied to the arch of the aorta and the phrenic and vagus nerves; to the left innominate vein, the left superior intercostal vein and the left common carotid and left subclavian arteries; to the œsophagus and the thoracic duct. The *right mediastinal pleura*, on the other hand, is applied, above the root of the lung, to the superior part of the superior vena cava and the right innominate vein; to the innominate artery; to the vena azygos, as it hooks forwards above the bronchus; to the vagus and phrenic nerves; and to the right side of the trachea.

Opposite the root of the lung, as well as in the region below it, the mediastinal pleura clothes the corresponding aspect of the pericardium (pleura pericardiaca), and is somewhat firmly attached to it. As the phrenic nerve passes downwards upon the pericardium it likewise is covered over by the pleura. In the region corresponding to the superior part of the lateral aspect of the pericardium the mediastinal pleura is prolonged laterally, so as to form an investment for the root of the lung, and becomes continuous around the hilum of the lung with the pulmonary pleura. Below the root of the lung the two layers of pleura which invest it come into apposition with each other, and are prolonged downwards as a distinct fold, termed the **ligamentum pulmonale.** This fold stretches between the pericardium and the inferior part of the mediastinal surface of the lung, and ends inferiorly in a free border.

Dorsal to the root of the lung and the ligamentum pulmonale the mediastinal pleura on the *right side* passes over the œsophagus to the vertebral column, whilst on the *left side* it passes dorsally over the thoracic aorta, and to a small extent over the lower end of the œsophagus, in the region immediately adjoining the diaphragm and ventral to the thoracic aorta.

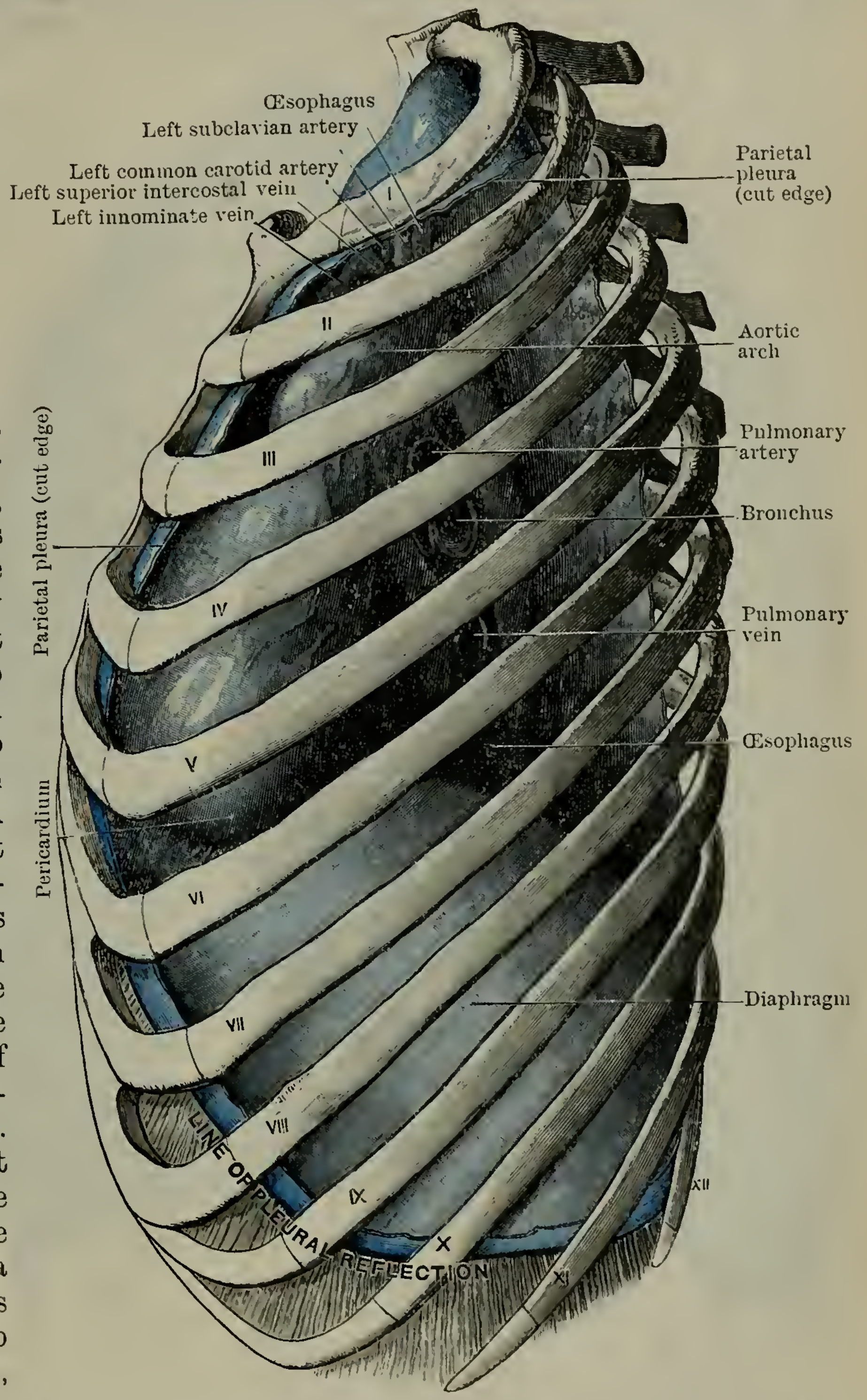


FIG. 841.—LEFT PLEURAL SAC IN A SUBJECT HARDENED BY FORMALIN INJECTION, opened into by the removal of the costal part of the parietal pleura. The lung has also been removed so as to display the mediastinal pleura.

Lines of Pleural Reflection.—These are three in number—viz., the sternal, the vertebral, and the diaphragmatic. The pleural cavities are not symmetrical. The left is longer and narrower than the right, and it thus happens that the lines of pleural reflection do not accurately correspond on the two sides of the body. Further, although the vertebral line of reflection is fairly constant, the other two reflection-lines are subject to variations in different subjects. Consequently the following description must be regarded as merely giving the average condition.

The **vertebral line of pleural reflection** is that along which the costal pleura is continued ventrally from the vertebral column to become the mediastinal pleura. On the *right side,* above the root of the lung, the pleura passes from the bodies of the vertebræ on to the right side of the trachea; whilst lower down, and dorsal to the pericardium, it passes from the vertebral bodies on to the œsophagus. On the *left side,* and above the arch of the aorta, the pleura along this line of reflection is carried from the vertebral column on to the œsophagus and thoracic duct; below that level it passes on to the thoracic aorta. In the superior part of the chest the right and left lines of reflection are placed well apart from each other, and about equidistant from the median plane. As they are traced downwards they approach more closely to each other and deviate to the left, so that whilst the reflection on the *right side* takes place from the ventral aspect of the vertebral bodies, on the *left side* it takes place from the left aspect of the vertebral column. This is due to the position of the thoracic aorta.

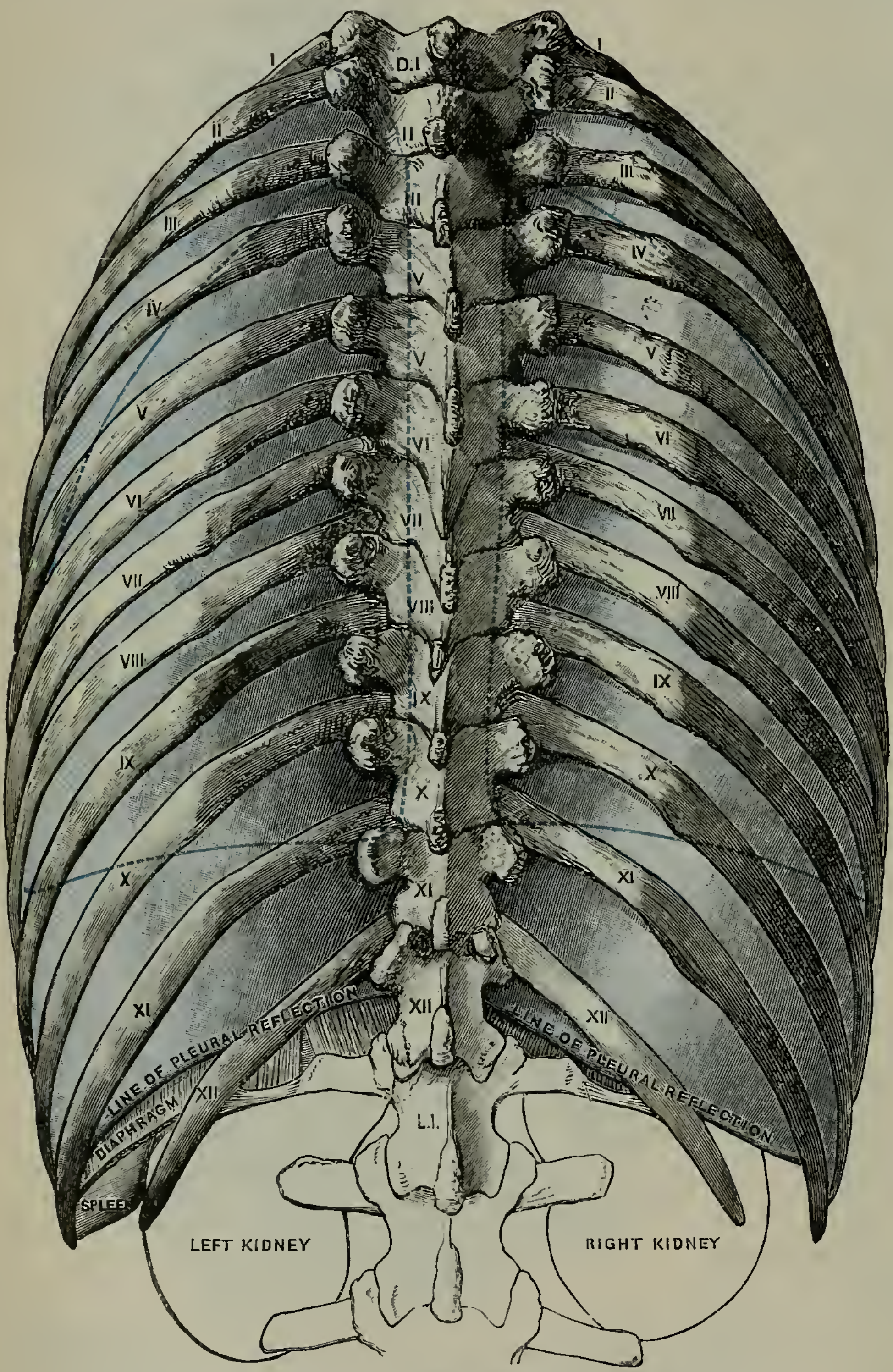


FIG. 842.—DISSECTION OF THE PLEURAL SACS FROM BEHIND.
The blue lines indicate the outlines and the fissures of the lungs.

The **sternal line of pleural reflection** is that along which the costal pleura leaves the ventral thoracic wall to become the mediastinal pleura. The lines differ somewhat on the two sides, and in both cases show a tendency to deviate to the left (Fig. 839, p. 1083). In the vicinity of the manubrium sterni the two pleural sacs are separated from each other by an angular interval. The lines of reflection at the superior thoracic aperture or inlet correspond to the sterno-clavicular joints. From those points the lines, as they are traced downwards, converge behind the manubrium, until at last they meet at its inferior border. There the two sacs come into contact with each other, and the lines of reflection coincide. Thence they proceed downwards, on the back of the body of the sternum, with a slight deviation to the left of the median plane, until a point immediately above the level of the sternal attachments of the fourth costal cartilages is reached, and there the two sacs part company. The line of reflection of the *right pleura* is continued downwards in a straight line to the xiphoid process, where the sternal reflection-line passes into the right diaphragmatic reflection-line. Opposite the sternal attachment of the fourth costal cartilage the reflection-line of the *left pleura* deviates laterally, and is continued downwards at a variable distance from the right pleura. A small triangular area of pericardium is thus left uncovered by pleura, and therefore in direct contact with the ventral chest-wall. Leaving the sternum, the reflection-line of the left pleura passes downwards, parallel and close to the left margin of the sternum, dorsal to the fourth intercostal space, the fifth costal cartilage and the fifth intercostal space, to the sixth costal cartilage. There it turns laterally and downwards, and passes into the diaphragmatic reflection-line of the left side.

From the back of the sternum the *right pleura* is reflected, in the superior part of the chest, on to the remains of the thymus, the right innominate vein and the superior vena cava, and, at a lower level, directly on to the ventral aspect of the pericardium. The *left pleura* is reflected from the back of the manubrium sterni on to the left innominate vein and the aortic arch, and, at a lower level, directly on to the ventral side of the pericardium.

The **diaphragmatic line of reflection** is that along which the pleura leaves the thoracic wall and is reflected on to the thoracic surface of the diaphragm. This reflection takes place along a curved line, which, except as it approaches the vertebral column, is placed a short distance above the inferior border of the thoracic wall. It differs somewhat on the two sides of the body.

On the *left side* the diaphragmatic line of reflection proceeds downwards along the ascending part of the sixth costal cartilage, crosses the ventral end of the sixth intercostal space and the descending part of the cartilage of the seventh rib (Fig. 841). Still continuing to pass downwards, it crosses the eighth costal arch at the junction between its cartilaginous and bony portions. This is a fairly constant relation on both sides of the body, and it should be noted that a vertical line—the mamillary line,—drawn downwards from the nipple of the breast, intersects the line of pleural reflection, close to the point where it presents this relation to the eighth costal arch. Beyond that point the line of diaphragmatic reflection is carried downwards and laterally across the extremities of the bony portions of the ninth and tenth ribs. As it crosses the tenth rib, or, it may be, as it proceeds across the tenth intercostal space, the line of pleural reflection reaches its lowest point, and it is important to observe that this point lies in the mid-lateral line (*i.e.* in a vertical line drawn on the side of the chest, midway between vertebral column and sternum). Thence, as it curves dorsally towards the vertebral column, it passes slightly upwards. Thus it cuts across the eleventh rib and reaches the twelfth rib. The relation which it presents to the twelfth rib varies in accordance with the length of that rib. When the last rib is not abnormally short the pleura clothes its medial half, and the line of reflection falls below that portion of the rib, so as to reach the vertebral column, midway between the capitulum of the last rib and the transverse process of the first lumbar vertebra (Fig. 842). There, therefore, the line of diaphragmatic reflection falls below the inferior border of the thoracic wall; and this is a point of practical importance, because in operations upon the kidney the incision cannot be carried above the level of the transverse process of the first lumbar vertebra and the lateral lumbo-costal arch without the risk of wounding the pleura.

On the *right side* the line of diaphragmatic pleural reflection differs from that on the left chiefly ventrally (Fig. 839, p. 1083). There it passes at a lower level, and proceeds laterally and downwards from the dorsum of the xiphoid process along the dorsal aspect of the seventh costal cartilage, and then behind the eighth costal arch, as a rule at the same point as on the left side, viz., the junction of its cartilaginous and bony parts. From that point to the vertebral column the relations are so similar to those of the left side that a separate description is unnecessary.

It is commonly stated that the left pleural sac reaches a lower level than the right. In certain cases there is no doubt that it does, but this condition is by no means the rule. In those cases where the two pleural sacs do not reach the same level at their lowest points, it is sometimes the right and sometimes the left pleura which oversteps the mark.

As already stated, the lowest point which the pleura attains is usually found, on both sides, in the mid-lateral line where the diaphragmatic reflection-line crosses the tenth rib or the tenth intercostal space. That point can be very readily ascertained on the surface by drawing a horizontal line round the trunk at the level of the lowest part of the extremity of the spinous process of the first lumbar vertebra, and noting where it is intersected by the mid-lateral line. In the majority of cases the point of intersection will correspond with the lowest part of the pleural sac. Another horizontal line opposite the spine of the twelfth thoracic vertebra will give the level of the diaphragmatic pleural reflection in the mamillary line.[1]

Along the line of the diaphragmatic reflection a strong fascia passes from the uncovered part of the diaphragm, and from the costal cartilages to the surface of the costal pleura, so as to hold it firmly in its place. It may be termed the **phrenico-pleural fascia.**

MEDIASTINUM.

The term mediastinum is applied to the interval between the mediastinal portions of the two pleural sacs. *Ventrally* it is bounded by the sternum, and *dorsally* by the vertebral column. It is customary to subdivide this space in a purely arbitrary manner into four portions, termed respectively the superior or cranial, the ventral or anterior, the middle, and the dorsal or posterior part, according to the relations which they present to the pericardium.

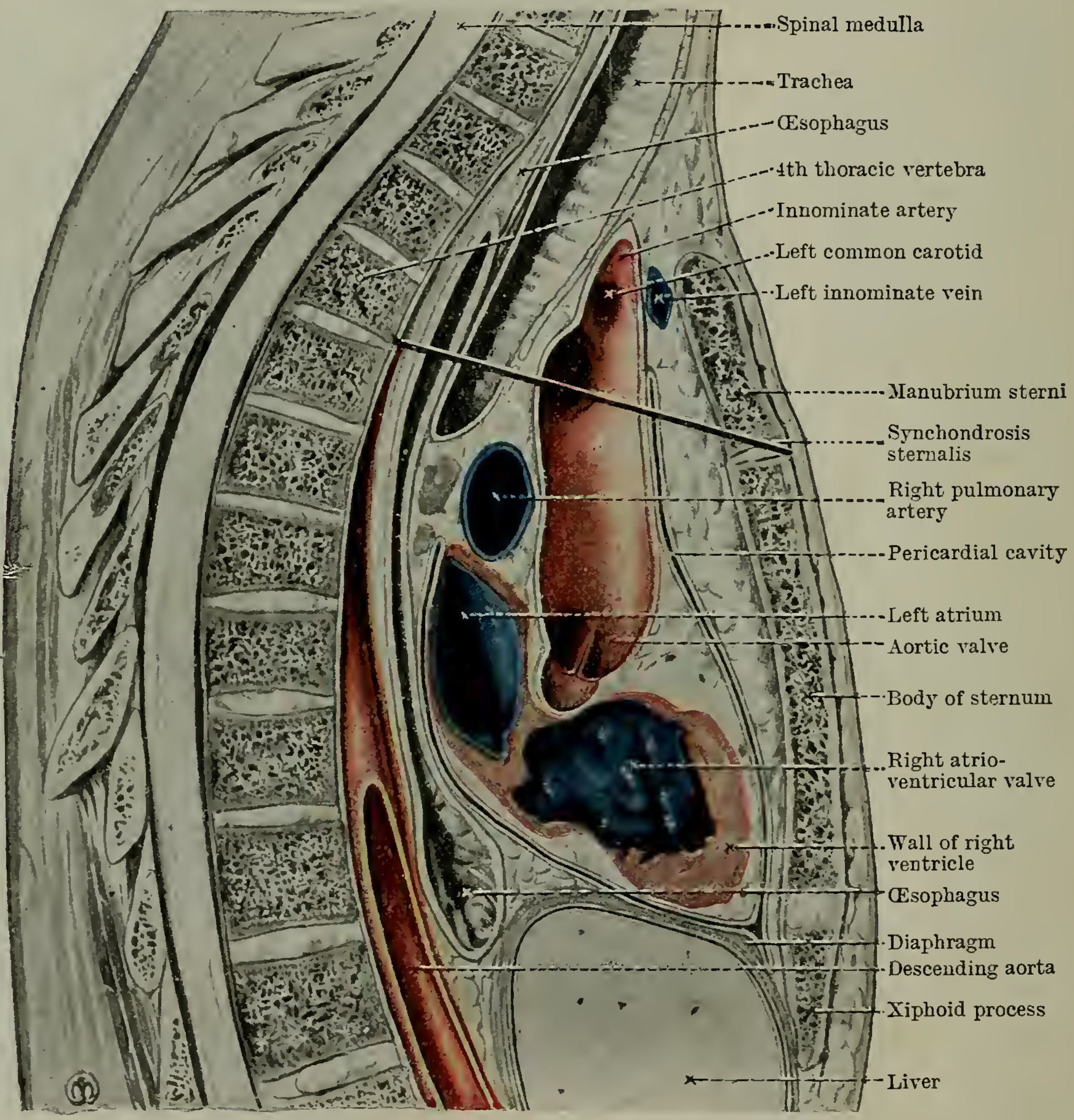


FIG. 843.—SAGITTAL SECTION THROUGH THE THORAX OF AN OLD MAN. The superior border of the manubrium sterni and the bifurcation of the trachea are lower than in the average adult.

The **superior mediastinum** is that part of the general area which lies above the level of the pericardium. Its boundaries are as follows:—*Ventrally*, the manubrium sterni, with the attached sterno-hyoid and sterno-thyreoid muscles; *dorsally*, the bodies of the first four thoracic vertebræ; *below*, an imaginary and oblique plane, which extends from the inferior border of the manubrium sterni to the inferior border of the fourth thoracic vertebra; *laterally,* the mediastinal pleura.

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[1] The above description represents the average results which have been obtained from the study of the pleura in a large number of subjects, eight of which were specially hardened by formalin or other re-agents for the purpose. For many of the dissections I have to thank my former assistant, Dr. H. St. J. Brooks, and for others I am indebted to Professor C. J. Patten of Sheffield.—D. J. C.

Within the superior mediastinum are placed (1) the aortic arch and the three great arteries which spring from it; (2) the innominate veins and part of the superior vena cava; (3) the trachea, œsophagus, and thoracic duct; (4) the phrenic, vagi, and cardiac nerves, and the left recurrent nerve; (5) the thymus.

The **middle mediastinum** is the wide part of the area which contains the pericardium, and lies below the superior mediastinum. In addition to the pericardium and its contents the middle mediastinum contains the phrenic nerves and their accompanying vessels.

The **ventral mediastinum** is that part of the interpleural region which lies between the pericardium dorsally and the body of the sternum ventrally. In its superior part this region can hardly be said to exist, seeing that there the two pleural sacs come into contact with each other on the ventral aspect of the pericardium; but below the level of the sternal ends of the fourth costal cartilages the left pleura falls short of the right pleura, and an interval is apparent. The only contents to be noticed in the ventral mediastinum are a few lymph glands and some areolar tissue, in which ramify some lymph vessels, and some minute twigs from the internal mammary artery.

The **dorsal mediastinum** is that part of the interpleural region which is situated dorsal to the pericardium. It may be regarded as an inferior continuation of the more dorsal part of the superior mediastinum, and many of the structures in the one are prolonged into the other. The arbitrary superior limit of the dorsal mediastinum is the inferior border of the fourth thoracic vertebra. *Ventrally* it is bounded by the pericardium and the vertical part of the diaphragm. *Dorsally* it is limited by the bodies of the last eight thoracic vertebræ and *on each lateral side* by the mediastinal pleura. It contains the descending thoracic aorta, the aortic intercostal arteries, the azygos, hemiazygos and accessory hemiazygos veins, the thoracic duct and the œsophagus, with the two vagi.

Structure of the Pleura.—The pleura on each side is a closed sac, and, like other serous membranes, is attached to the wall of the cavity which it lines and to the surface of the viscus which it covers. It is composed of a thin connective-tissue stratum, in which bundles of fibres cross each other in various directions, and intermixed with which there is a considerable quantity of elastic tissue. On the internal surface of this there is a continuous coating of thin endothelial cells placed edge to edge. The pleura so formed is attached to the parts which it lines and invests by a small amount of areolar tissue termed the **subserous layer.** In the case of the pulmonary pleura the subserous tissue is continuous with the areolar tissue in the substance of the lung, and this accounts for the tight manner in which the membrane is bound down.

The pleura is plentifully supplied with blood. This is conveyed to it by minute twigs from the intercostal arteries, the internal mammary artery, and the bronchial arteries. Lymph vessels are also particularly abundant in the pleura and in the subserous layer, and it is by these that excess of fluid is conveyed from its cavity. Stomata, which have been described, are artificial apertures in the epithelium and are not connected with the lymphatic vessels.

PULMONES.

The Lungs.—When healthy and sound each lung lies free within the corresponding pleural cavity, and is attached only by its root and the ligamentum pulmonale. It is uncommon, however, in the dissecting-room, to meet with a perfectly healthy lung. Adhesions between the pulmonary and parietal layers of pleura, due to pleurisy, are generally present.

Like the cavities in which they are placed, the two lungs are not precisely alike. The right lung is slightly larger than the left, in the proportion of about 11 to 10. The right lung is also shorter and wider than the left lung. This difference is due partly to the great bulk of the right lobe of the liver, which forces the right cupola of the diaphragm to a higher level than the left cupola, and partly to the heart and pericardium projecting more to the left than to the right, thus diminishing the width of the left lung.

The lung is light, soft, and spongy in texture; when pressed between the finger and thumb it crepitates, and when placed in water it floats. The elasticity of the pulmonary tissue is very remarkable. A striking demonstration of this is afforded when the thoracic cavity is opened, and the atmospheric pressure acting upon the interior and exterior of the lung is equalised. Under these conditions the organ immediately collapses to about one-third of its original bulk, and it becomes impossible in such a specimen to study its proper form and dimensions.

The surface of the adult lung presents a mottled appearance. The ground colour is a light slate-blue, but scattered over this there are numerous dark patches of various sizes, and also fine dark intersecting lines. The coloration of the lung differs considerably at different periods of life. In early childhood the lung is rosy-pink, and the darker colour and the mottling of the surface, which appear later, are due to the pulmonary substance, and particularly its interstitial areolar tissue, becoming impregnated, more or less completely, with atmospheric dust and minute particles of soot.

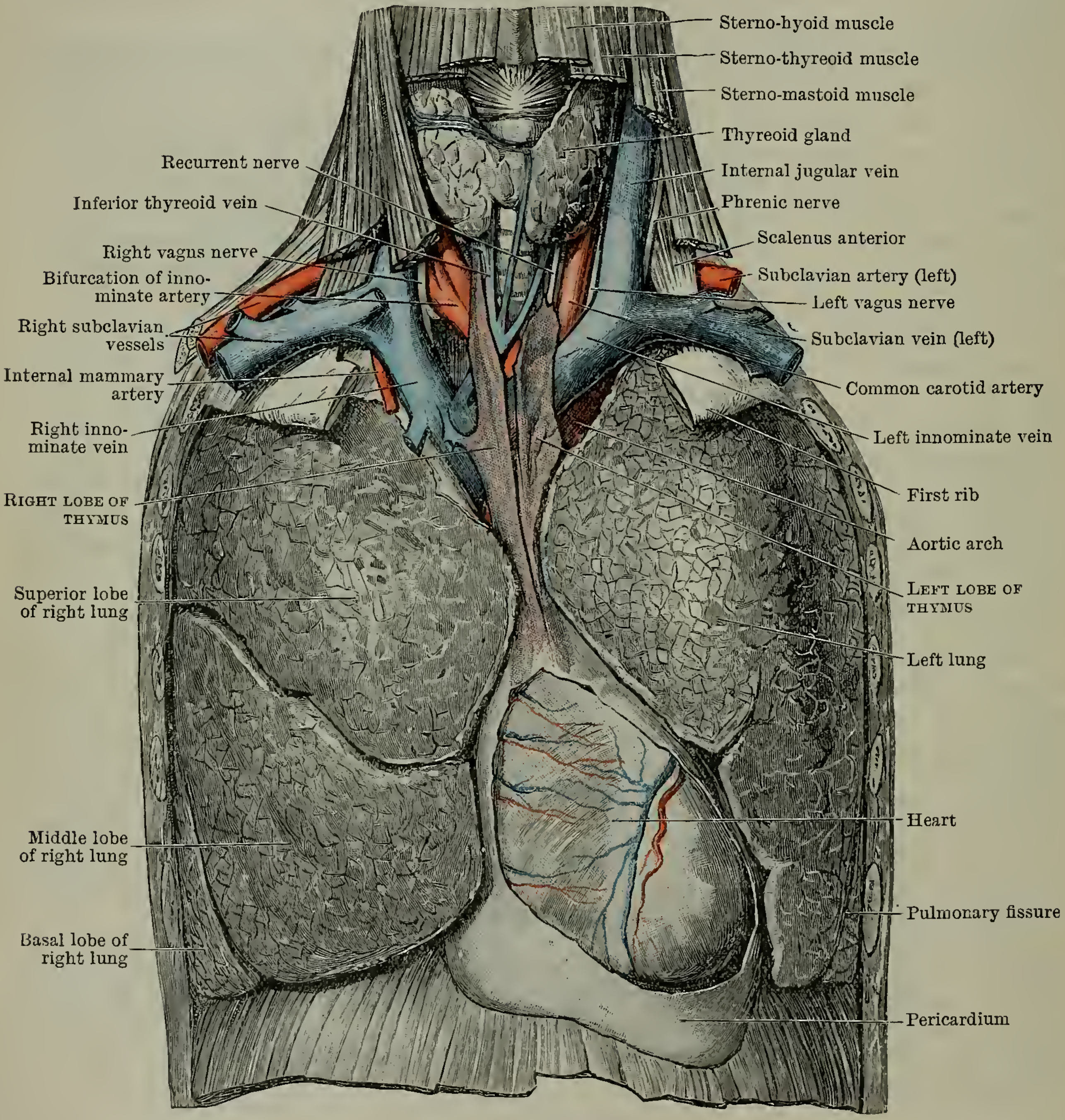

FIG. 844.—DISSECTION OF THORAX AND ROOT OF THE NECK FROM THE FRONT TO SHOW THE RELATIONS OF THE LUNGS, PERICARDIUM, AND THYMUS.

At every breath foreign matter of this kind is inhaled, but only a small proportion of it reaches the lung tissue. The greater part of it becomes entangled in the mucus which coats the mucous membrane of the larger air-passages, and is gradually got rid of along with the mucus through the activity of the cilia attached to the lining epithelium. By the constant upward sweep of these a current towards the pharynx is established. The fine dust and soot particles which reach the finer recesses of the lungs, and ultimately the interstitial tissue, are partly conveyed away by the lymph vessels to the bronchial glands, which in consequence become, in many cases, quite black. The colour of the lung, therefore, depends, to some extent, upon the purity of the atmosphere which is inhaled, and it thus happens that in coal-miners the surface of the lung may be very nearly uniformly black.

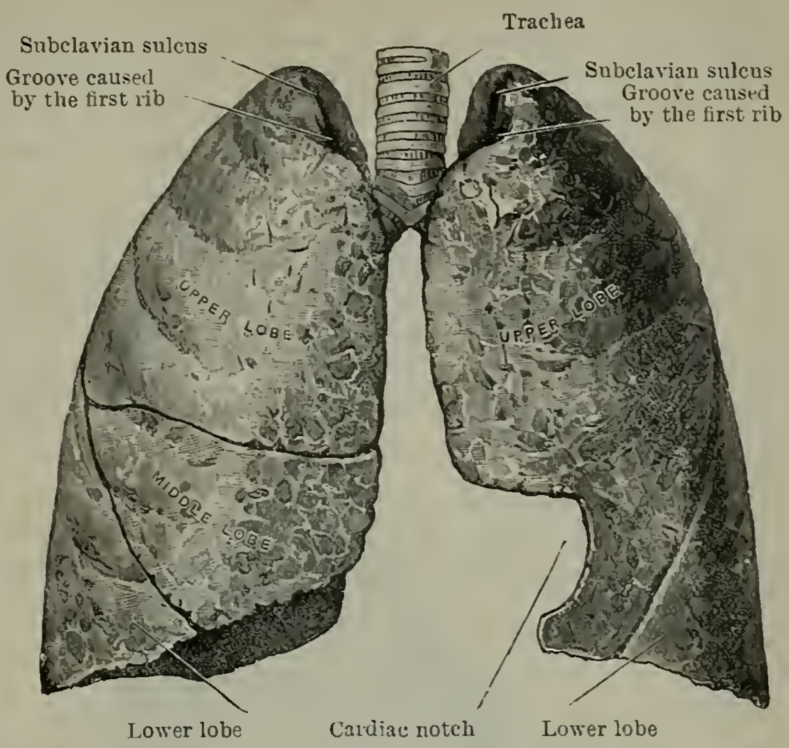

Fig. 845.—The Trachea, Bronchi, and Lungs of a Child, hardened by Formalin Injection.

The fœtal lung differs from the lung of an individual who has breathed. After respiration is fully established, the lung soon comes to occupy almost the whole space allotted to it in the pleural cavity; in the fœtus, on the other hand, the lung is packed away at the dorsal aspect, and occupies a relatively much smaller amount of space in the thoracic cavity. Further, it is firm to the touch, and sinks in water. It is only when air and an increased supply of blood are introduced into the lung that it assumes the soft spongy and buoyant qualities which are characteristic of the adult lung.

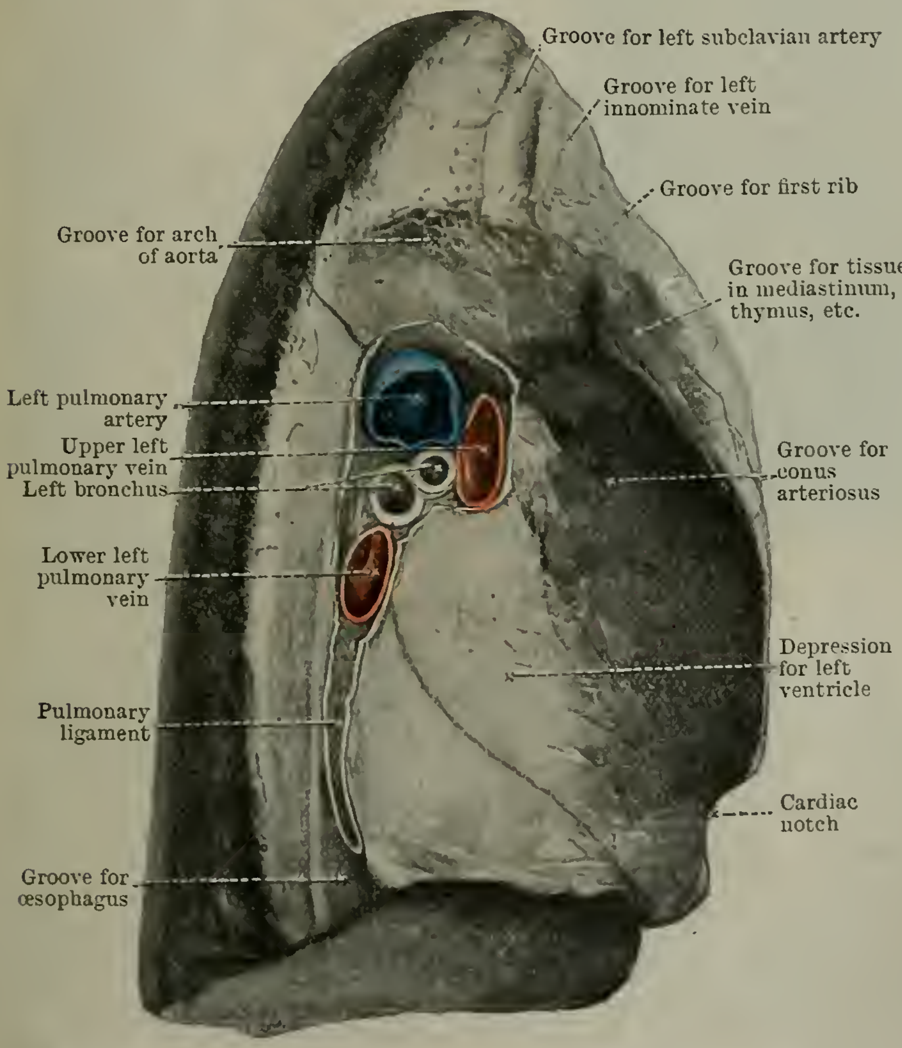
Groove for left subclavian artery
Groove for left innominate vein
Groove for first rib
Groove for arch of aorta
Groove for tissue in mediastinum, thymus, etc.
Left pulmonary artery
Upper left pulmonary vein
Left bronchus
Groove for conus arteriosus
Lower left pulmonary vein
Depression for left ventricle
Pulmonary ligament
Cardiac notch
Groove for œsophagus

Fig. 846.—Medial Surface of a Left Lung hardened *in situ*.

Form of the Lungs.—The lungs are accurately adapted to the walls of the pleural chambers in which they are placed, and in the natural state they bear on the surface impressions and elevations which are an exact counterpart of the irregularities on the walls of the cavity in which they lie.

When care has been taken to harden it *in situ*, each lung presents for examination an apex, diaphragmatic, mediastinal, and costal surfaces, and ventral (anterior) and inferior borders.

The **apex of the lung** is blunt and rounded, and rises above the level of the oblique first costal arch to the full height of the cupula pleuræ. It therefore protrudes, above, through the superior aperture of the thorax, into the root of the neck. The subclavian artery arches laterally on its medial and ventral aspects a short distance below its summit, and a groove, the *subclavian sulcus,* corresponding to the vessel, is apparent upon it. At a lower level on the apex of the lung a shallower and wider groove upon its medial and ventral aspects marks the position of the innominate vein. Although these vessels impress the lung they are separated from it by the cupula pleuræ.

As examined from behind the apex of the lung usually extends as high as a line drawn from the highest portion of the acromion of the scapula to the inferior or caudal border of the spinous process of the seventh cervical vertebra. It may, however, be slightly higher or lower than this level.

The lateral limit of the apex of the lung, and consequently of the pleura, is medial to the superior angle of the scapula. The line is then continued across the supra- and infraspinous fossæ obliquely to reach a point somewhat lateral to the line of the inferior angle of the scapula.

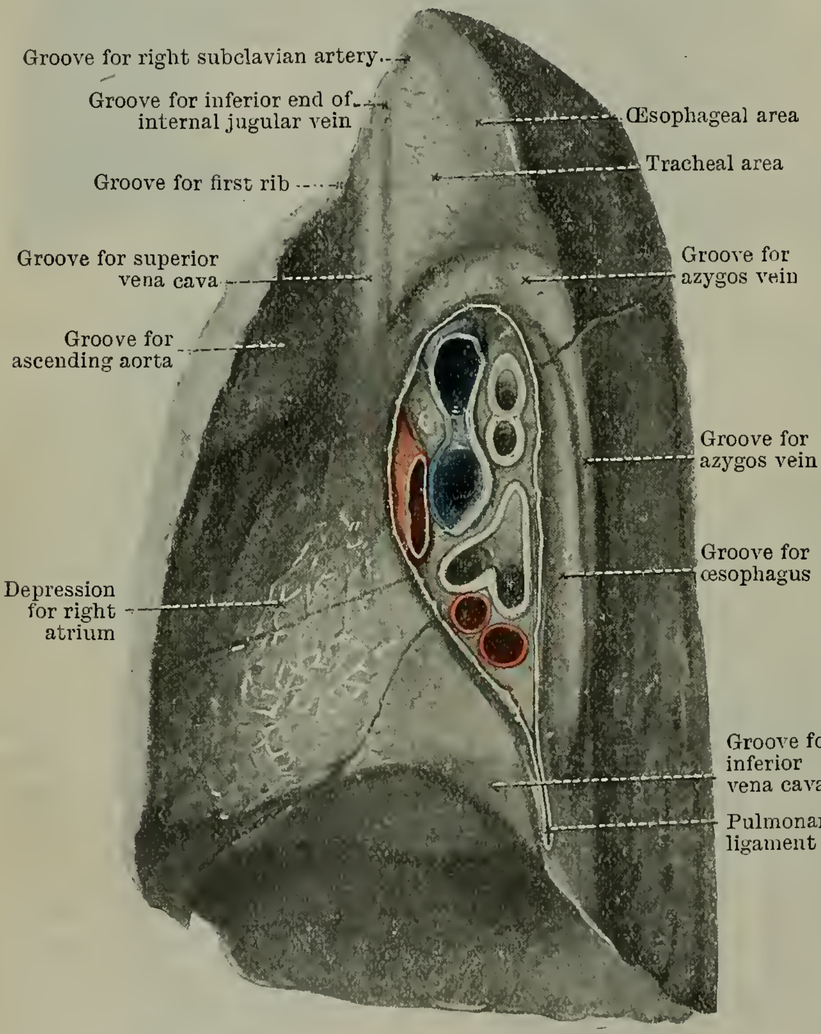
Groove for right subclavian artery
Groove for inferior end of internal jugular vein
Groove for first rib
Groove for superior vena cava
Groove for ascending aorta
Depression for right atrium
Œsophageal area
Tracheal area
Groove for azygos vein
Groove for azygos vein
Groove for œsophagus
Groove for inferior vena cava
Pulmonary ligament

Fig. 847.—The Medial Surface of a Right Lung hardened *in situ*.

Clinically, percussion of the lung would appear to give resonance areas over a more extensive area, especially laterally, than is here set forth, but this is probably due to the differences between the smaller internal concentric circle formed by the first rib, which bounds this part of the lung, and the larger external one formed by the surface of the body itself.

The **diaphragmatic surface,** or base of the lung, presents a semilunar outline, being curved around the base of the pericardium. It is adapted to the thoracic surface of the diaphragm, and is consequently deeply hollowed out. As the right cupola of the diaphragm passes further upwards than the left, the basal concavity of the right lung is deeper than that of the left lung. Laterally and dorsally, the diaphragmatic surface of each lung is limited by a thin salient margin, called the *inferior border* or margin, which extends downwards for some distance in a narrow pleural recess, the *phrenico-costal sinus,* between the diaphragm and the chest-wall. This inferior border of the lung extends further downwards on the lateral side and dorsally than it does ventrally, but it falls considerably short of the bottom of the phrenico-costal sinus. Thus, after expiration, it reaches the inferior border of the sixth rib in the mamillary line; the eighth rib, in the axillary or mid-lateral line; whilst dorsally it proceeds medially along a straight horizontal line so as to reach the vertebral column at the level of the extremity of the spine of the tenth thoracic vertebra. During respiration the thin inferior border moves freely in a vertical direction within the phrenico-costal sinus, but even after the deepest breath it never reaches the extreme lower limit of this recess.

The diaphragmatic surfaces of the lungs establish important relations with certain of the viscera which occupy the costal zone of the abdominal cavity, the diaphragm alone intervening. Thus the diaphragmatic surface of the right lung rests upon the right lobe of the liver; whilst that of the left lung is in relation to the left lobe of the liver, the fundus of the stomach, the spleen, and in some cases to the left colic flexure.

The **costal surface** is extensive and convex. It is accurately adapted to that part of the wall of the pleural cavity which is formed by the costal arches and the intervening intercostal muscles, and it presents markings corresponding to these. Thus the imprint of the ribs appear as shallow oblique grooves, while the intercostal spaces show as elongated intervening bulgings.

The **mediastinal surface** presents a smaller area than the costal surface. It is applied to the mediastinal septum, and presents markings in accordance with the inequalities upon this (Figs. 846 and 847). Thus it is deeply hollowed out in adaptation to the pericardium upon which it fits. This pericardial concavity comprises the greater part of the mediastinal surface, and owing to the greater projection of the heart to the left side, it is much deeper and more extensive in the left lung than in the right lung. Above and dorsal to the pericardial hollow is the **hilum** of the lung. This is a wedge-shaped depressed area, within which the blood-vessels, nerves, and lymph vessels, together with the bronchus, enter and leave the organ. Amidst these structures there are also some bronchial glands. The hilum is surrounded by the reflection of the pleura from the surface of the lung on to the pulmonary root. Dorsal to the hilum and pericardial area there is on each lung a narrow strip of the mediastinal surface of the lung which is in relation to the lateral wall of the dorsal mediastinum. On the *right lung* this part of the surface is depressed, and corresponds to the œsophagus; on the *left lung* it presents a broad longitudinal groove, which is produced by the contact of the lung with the thoracic aorta, and also, close to the base, a small flattened area ventral to this which is applied to the œsophagus immediately above the diaphragm.

The portion of the mediastinal surface of the lung which lies above the hilum and pericardial hollow is applied to the lateral aspect of the superior mediastinum, and the markings are accordingly somewhat different on the two sides. On the left lung a broad deep groove, produced by the aortic arch, curves dorsally above the hilum, and becomes continuous with the aortic groove on the dorsal part of the mediastinal surface. From the groove for the aortic arch a narrower, deeper, and much more sharply marked groove runs upwards, and laterally over the apex pulmonis a short distance from the summit. This is the **subclavian sulcus**, and it contains the left subclavian artery when the lung is in place. Ventral to the subclavian sulcus a shallow wide groove, also leading to the ventral aspect of the apex, corresponds to the left innominate vein. In the *right lung* the hilum is also circumscribed above by a curved groove, which is narrow and more distinctly curved than the aortic groove on the left side. It lodges the vena azygos as it turns ventrally to join the superior vena cava. From the ventral end of the azygos sulcus a wide shallow groove extends upward to the inferior part of the anterior aspect of the apex of the lung. This is produced by the apposition of the lung with the superior vena cava and the right innominate vein. Close to the summit of the apex there is also, on its medial aspect, a sulcus for the superior end of the innominate artery.

In addition to the hilum, it must now be evident that the mediastinal surface of each lung presents three areas which correspond respectively with (1) the middle mediastinum (*i.e.* the pericardial hollow), (2) the dorsal mediastinum, and (3) the superior mediastinum; and that in each of these districts impressions corresponding to structures contained within these portions of the interpleural space may be noticed.

The **dorsal part** of the lung at the junction of the costal and mediastinal surfaces is thick, long, and rounded. It forms the most bulky part of the organ, and occupies the deep hollow in the thoracic cavity which is placed at the side of the vertebral column.

The **ventral** or **anterior border** of the lung is short, and exceedingly thin and sharp. It begins abruptly immediately below the groove on the apex for the innominate vein, and extends to the base, where it becomes continuous with the sharp inferior border. The thin ventral part of the lung is carried ventrally and medially, ventral to the pericardium, into the narrow pleural costo-mediastinal sinus, dorsal to the sternum and costal cartilages. The ventral border of the right lung fills up this recess completely, and in the upper part of the chest is separated from the corresponding border of the left lung only by the two layers of mediastinal pleura which are reflected from the sternum to the pericardium. The ventral border of the left lung, in its lower part, shows a deficiency or notch, the **incisura cardiaca**, corresponding to the apex of the heart, and where this exists the lung margin leaves a considerable portion of the pericardium uncovered, and fails to fill up completely the costo-mediastinal sinus of the pleural cavity. During respiration the ventral margin of the left lung at the cardiac notch advances and retreats to a small extent in this pleural sinus, ventral to the pericardium.

Fissures and Lobes of the Lung.—The *left lung* is divided into two lobes by a long deep **interlobar fissure**, which penetrates its substance to within a short distance of the hilum. On the upper and lower sides of the hilum this fissure cuts right through the lung and appears on the mediastinal surface. Viewed from the costal surface, it begins dorsally about two and a half inches below the apex, about the level of the vertebral end of the third rib, and is continued downwards and ventrally in a somewhat spiral direction to the diaphragmatic surface of the lung, which it reaches a short distance from its ventral end. The **superior lobe** lies above and ventral to this cleft. It is conical in form, with an oblique base, and the apex and the whole of the ventral border of the lung belong to it. The **inferior lobe** lies below and dorsal to the fissure. It is the more bulky of the two, and includes almost the entire diaphragmatic surface and the greater part of the thick dorsal part of the lung.

In the *right lung* there are two interlobar fissures, which subdivide it into three lobes. One of these is very similar in its position and relations to the fissure in the left lung. It is directed, however, rather more vertically, and ends somewhat farther from the median plane. It separates the inferior lobe from the middle and superior lobes. The second interlobar fissure begins in the main fissure at the dorsal part of the lung, and proceeds ventrally, to end at the ventral border of the lung at the level of the fourth costal cartilage. The middle lobe of the right lung is triangular or wedge-shaped in outline.

Variations.—Variations in the pulmonary fissures are fairly common. Thus, it sometimes happens that the middle lobe of the right lung is imperfectly cut off from the superior lobe. Supernumerary fissures also are not infrequent, and in this way the left lung may be cut into three lobes, and the right lung into four or even more lobes. The occurrence of the **lobus azygos** in the right lung is a variation of some interest, seeing that such a lobe is constant in certain mammals. It is a small accessory lobe, pyramidal in form, which makes its appearance on the lower part of the mediastinal surface of the right lung. In certain cases the vena azygos is enclosed within a fold of pleura, and is sunk so deeply in the pulmonary substance of the right lung that it marks off a small accessory lobe.

RADIX PULMONIS.

The term **root of the lung** is applied to a number of structures which enter and leave the lung at the hilum on its mediastinal surface. They are held together by an investment of pleura, and constitute a pedicle which attaches the lung to the mediastinal wall of the pleural cavity. The phrenic nerve passes downwards a short distance ventral to the pulmonary root, whilst the vagus nerve breaks up into the dorsal or posterior pulmonary plexus on its dorsal aspect under cover of the investing pleura. The delicate ventral or anterior pulmonary plexus is placed ventral to the root of the lung under cover of the pleura, whilst from the inferior border of the root of the lung the ligamentum pulmonale extends towards the diaphragm. These relations are common to the pulmonary root on both sides of the body, but there are others which are peculiar to each side. On the *right side* the superior vena cava lies ventral to the pulmonary root, whilst the vena azygos arches over its upper border. On the *left side* the aorta arches above the root of the lung, whilst the descending thoracic aorta passes dorsal to it.

Constituent Parts of the Pulmonary Root.—The large structures which enter into the formation of the pulmonary root are (1) the two pulmonary veins, (2) the pulmonary artery, (3) the bronchus. But in addition to these there are one or more small bronchial arteries and veins, the pulmonary nerves and the pulmonary lymph vessels, and some bronchial glands.

The **pulmonary nerves** come from the vagus nerve and also from the autonomic nervous system. They enter the lung and follow the air-tubes through the organ. The **bronchial arteries** are small vessels which carry blood for the supply of the lung-tissue. They arise from the aorta or from an intercostal artery, and vary in number from one to three for each lung. In the root of the lung they lie on the dorsal aspect of the bronchus, and they follow the air-tubes through the organ. Part of the blood conveyed to the lung by the bronchial arteries is returned by the pulmonary veins; the remainder is returned by special **bronchial veins** which open on the right side into the vena azygos, and on the left side into the vena hemiazygos.

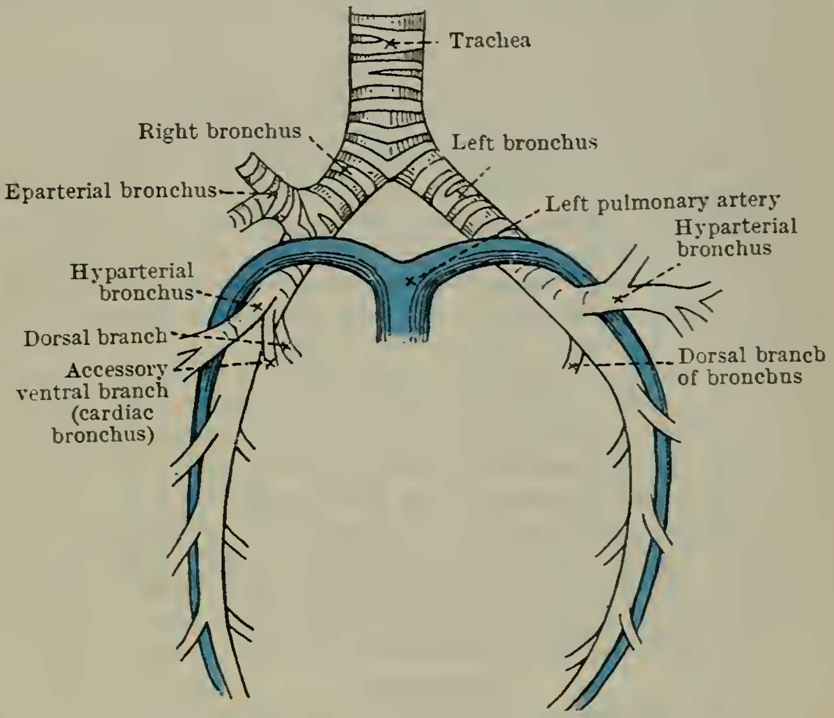

Fig. 848.—Diagram of the Relations of the Pulmonary Artery to the Bronchi.

The **lymph vessels** of the lungs are numerous and well developed, and are divided into two groups, superficial and deep.

The *superficial* lymph vessels form a network on the surface of the lung and eventually terminate by four or five vessels in the broncho-pulmonary glands of the hilum. It is usually stated that the superficial lymph vessels communicate freely with the deep. This, however, is denied by Miller, who maintains that anastomoses between the two systems of vessels are very rare. Free communication between the superficial and deep lymph vessels appears to occur only at the hilum of the lung.

The *deep* lymph vessels are subdivided into bronchial accompanying the bronchi, and vascular accompanying the blood-vessels. Both systems communicate freely together, and at the level of the hilum terminate in the broncho-pulmonary glands.

The pulmonary or broncho-pulmonary lymph-glands, found at the hilum, are usually numerous and variable in size. They are situated either just outside the lung or within the lung-substance itself.

From these broncho-pulmonary glands the lymph-flow is continued onward from the lung, partly directly into the thoracic duct, and partly by a more circuitous route as follows:—

From the broncho-pulmonary lymph-glands vessels pass on to the tracheo-bronchial glands situated at the angles produced by the bifurcation of the trachea into the two bronchi. Of these glands there are, therefore, three groups, an inferior and right and left superior. From these glands the lymph-flow is continued upwards through the tracheal lymph-glands lying on either side of the trachea into the deep cervical lymph-glands, and thence into the thoracic duct.

The **bronchus** in the root of the lung lies dorsal to the great pulmonary vessels. The **pulmonary artery** occupies a different position on the two sides, in relation to the main or undivided part of the bronchus. On the right side it is placed below it, whilst on the left side it crosses the bronchus and occupies a higher level in the pulmonary root. The two **pulmonary veins**, on both sides, lie at a lower level in the root of the lung than the pulmonary artery and bronchus, whilst the superior of the two veins occupies a plane ventral to the pulmonary artery (Figs. 846 and 847).

Distribution of the Bronchial Tubes within the Lungs.—The two lungs are not symmetrical; the right lung is subdivided into three lobes, and the left lung is cleft into two lobes. The bronchi exhibit a corresponding want of symmetry. The *right bronchus*, as it approaches the pulmonary hilum, gives off two branches for the superior and middle lobes of the right lung respectively, and then the main stem of the tube enters the inferior lobe. The *left bronchus* sends off a large branch to the superior lobe of the left lung, and then sinks into the inferior lobe. The first branch of the right bronchus, for the superior lobe, leaves the main stem about one inch from the trachea. The first branch of the left bronchus, on the other hand, takes origin about twice that distance from the trachea.

The relation of the pulmonary artery to the bronchial subdivisions is different on the two sides. On the right side it turns dorsally, to reach the dorsal aspect of the bronchus, inferior to the first, and superior to the second, bronchial branch. On the left side the pulmonary artery turns dorsally above the level of the first bronchial branch. On the right side, therefore, the first bronchial branch is placed above the pulmonary artery, and in consequence it is termed the **eparterial bronchial ramus**; all the others lie below the artery, and are termed **hyparterial bronchial rami.** On the left side there is no eparterial branch; they are all hyparterial.

When the main stem of the bronchus is followed into the inferior lobe of each lung, it is seen to travel downwards and dorsally in the pulmonary substance until it reaches the thin dorsal part of the diaphragmatic surface of the lung which lies between the diaphragm and the thoracic wall, and there it ends. As it proceeds through the inferior lobe it gives off a series of large **ventral** and a series of smaller **dorsal branches.** As a rule these are three in number in each case, and the dorsal and ventral branches do not arise opposite to each other, but alternately, one from the dorsum, and then another, after a slight interval, from the ventral surface of the tube. The first hyparterial division on each side (*i.e.* the branch to the middle lobe of the right lung and the branch to the superior lobe of the left side) is generally regarded as the first member of the ventral group.

It was Aeby who first recognised the existence in each lung of a main or stem bronchus giving off a ventral and dorsal series of branches, and who drew the distinction between the eparterial and hyparterial bronchial rami. A consideration of these relations led this author to conclude that the eparterial bronchus and the superior lobe of the right lung have no morphological equivalents on the left side of the body. In other words, he was led to believe that the middle lobe of the right lung is the homologue of the superior lobe of the left lung. Hasse, who has also investigated the subject, endorsed this view, with certain modifications and additions; and the hypothesis, either in its original state as presented by Aeby, or as subsequently modified by Hasse, has been, until lately, very generally accepted by anatomists. More recent research, however, has seriously affected the stability of this conclusion. Narath contends that the distinction between the eparterial bronchus of the right side and the hyparterial bronchi of both sides is not one of fundamental importance, and that a branch which arises from the first hyparterial bronchus on the left side and turns upwards into the apex of the left lung is the direct equivalent of the eparterial bronchus of the right side. This he terms the **apical bronchus**, and he believes that it represents the first dorsal branch of the left stem-bronchus. Huntington, in a very convincing paper, strongly supports the contention of Narath, and holds that, except "for purposes of topography, we should abandon the distinction between eparterial and hyparterial bronchi." With Narath he regards the eparterial bronchus as a secondary branch which has migrated in an upward direction on the main stem. According to Huntington, therefore, Aeby's proposition should be amended as follows:—

Right side.				Left side.
Superior	and	middle lobes	=	Superior lobe.
Inferior	and	cardiac lobes	=	Inferior lobe.

The cardiac lobe mentioned in this table is the occasional azygos lobe to which reference has already been made, and it is interesting to note that, whilst the lobe in question as a separate entity is rarely seen in the human lung, the bronchus which corresponds to it is always present in the pulmonary substance as an accessory branch, which proceeds from the main stem as it traverses the inferior lobe of the right side. It receives the name of the **cardiac bronchus.**

Structure of the Lung.

The lung is constructed so that the blood which reaches it through the pulmonary artery is brought into the most intimate relation with the air which enters it through the trachea and bronchi. An interchange of materials between the blood and the air is thus rendered possible, and the object of respiration is attained. As a result of this interchange the dark, impure blood, which flows into the lung through the pulmonary artery, is rendered bright red and arterial.

Lobules of the Lung.—A thin layer of subpleural connective tissues lies subjacent to the continuous coating which the lung receives from the pulmonary pleura. From the deep surface of this subpleural layer fine septal processes penetrate into the substance of the lung, and those, with the connective tissue which enters at the hilum upon the vessels and bronchi, constitute a supporting framework for the organ. The lung is lobular, and on the surface the small polygonal areas which represent the lobules are indicated by the pigment present in the connective tissue septa which intervene between them. Although no pigment is present, the lobular character of the lung is particularly well marked in the fœtus, and with a little care the surface lobules in the fœtal lung can be separated from each other by gently tearing through the intervening connective tissue. The lobules thus isolated are piriform or pyramidal in form. The broad bases of these lobules abut against the subpleural layer, whilst each of the deep narrow ends receives a minute division from the bronchial system of tubes. The lobules which lie more deeply in the substance of the organ are not so large, and are irregularly polygonal in form.

The Lung-Unit.—The unit of lung-structure is the lung-lobule. This comprises a terminal bronchus with its air-spaces, blood-vessels, lymph vessels, and nerves.

The terminal bronchus of the lung-unit is attained as follows:—The larger branches of the bronchi, as they traverse the lung, give off numerous divisions, which, by repeated branching, ultimately form a system of tubes which pervade the entire organ. At first the bronchial divisions come off at very acute angles, but as the finer ramifications are reached this character becomes much less apparent. The finer ramifications of the bronchi are termed *bronchioles*, which by subdivision give rise to the *respiratory bronchiole* of the lung-unit.

Within the lung-unit the respiratory bronchiole gives off a series of terminal bronchi or *alveolar ducts*, each of which leads to a group of air-spaces termed *atria*. Each one of the atria communicates, in its turn, with a further and secondary series of air-spaces termed air-sacs or *alveolar saccules*, the walls of which are pouched out to form the very numerous *alveoli* or *air-cells* of the lung-unit.

Structure of the Bronchi.—When the large bronchi enter the lung they become cylindrical, and lose the flattening on the dorsal aspect which is characteristic of the primary bronchi outside the lung. They possess the same coats as are present in the case of the trachea and primary bronchi, but as the tubes become smaller by repeated divisions, these coats become correspondingly thinner and finer. Certain differences also in the manner in which the constituents of these coats are arranged become apparent.

In the **external fibro-cartilaginous coat** the cartilage is no longer present in the form of incomplete rings, but in irregular plates or flakes deposited at various points around the wall. As the tubes diminish, the cartilaginous deposits show a corresponding reduction in size, until at last, in bronchi of 1 mm. diameter, they disappear altogether. The **glands** in relation to the tubes for the most part cease to exist about the same point. The **muscular** or **middle coat**, which in the trachea and primary bronchi is confined to the dorsal wall of the tube, forms a continuous layer of circularly arranged bundles in the bronchi as they ramify within the lung. Spasmodic contraction of the muscular coat gives rise to the serious symptoms which accompany asthmatic affections. The muscular fibres of the middle coat may be traced as far as the atria, on the walls of which they are present in considerable numbers. The **mucous lining** of the tubes becomes greatly thinned as it is followed into the smaller bronchioles. It contains a large number of longitudinally arranged elastic fibres, and is disposed in longitudinal folds, so that when the tube is cut across the lumen presents a stellate appearance. The mucous membrane is lined with ciliated columnar epithelium.

Structure of the Atria and Alveoli.—The walls of the atria and alveoli are exceedingly fine and delicate, but, nevertheless, constituents continuous with those observed in the three coats of a bronchus are found entering into their construction. The epithelium is reduced to a single layer of non-nucleated cells. Further, it is no longer columnar and ciliated, but it has become flat and pavement-like. Two kinds of epithelial cells may be recognised—(1) a few small granular polygonal cells, arranged singly or in groups of two or three, (2) more numerous thin cells of large size and somewhat irregular in outline. Outside the epithelium is a delicate layer of faintly fibrillated connective tissue. This is strengthened by a network of elastic fibres, which is specially well marked around the mouths of the alveoli, and is also to some extent carried over the walls of the air-cells. Muscular fibres also are present on the walls of the atria, but it is questionable if any are prolonged over the air-cells.

Pulmonary Vessels.—The pulmonary artery, as it traverses the lung, divides with the bronchi, and closely accompanies these tubes. The resultant branches do not anastomose, and for the most part they lie above and dorsal to the corresponding bronchi. The fine terminal divisions of the artery join a dense capillary plexus which is spread over the alveoli or air-cells. This vascular network is so close that the meshes are barely wider than the capillaries which form them. In the partition between adjacent alveoli there is only one layer of the capillary network, and thus the blood flowing through these vessels is exposed on both aspects to the action of the air in the air-cells. The radicles of the pulmonary vein arise in, and carry the blood from, the pulmonary capillary plexus. Each afferent arteriole supplies the blood which flows through the capillaries spread over a number of neighbouring alveoli, and in like manner each afferent venous radicle drains an area corresponding to several adjoining air-cells. At first the veins run apart from the arteries, but after they have attained a certain size they join them and the bronchi. As a rule the pulmonary veins are placed on the inferior and ventral aspects of the corresponding bronchi.

X-Ray Appearances of the Chief Thoracic Viscera.—A knowledge of the normal and morbid appearances of the chief thoracic viscera, as seen with X-rays, is of clinical importance. The following account of these appearances is based chiefly on Dr. J. Stuart Dickey's work on the subject.

In health the **lungs** should appear clear, especially during inspiration, and in emphysema will be almost abnormally clear, because the greater the amount of contained air the more permeable does the thorax become to the passage of the X-rays, and the less the shadow cast. On the other hand, organs which contain much blood, such as the liver, heart, and blood-vessels, tend to cast a shadow. It consequently follows that diseases of the lung which are characterised by increased vascular engorgement tend to diminish the permeability of the lung to the passage of the rays, and to throw a shadow. In congestion and œdema of the lungs there is, therefore, a diminished transradiance, as there also is in collapse of the lung. In lobar pneumonia the density of the lung is uniformly increased, whilst in broncho-pneumonia there is a scattered dark mottling of the lung. In such localised affections of the lung as occur in tumours, infarcts, cysts, abscesses, and cirrhosis, there are found localised areas casting a denser shadow.

The **bronchi** can occasionally be seen with the X-rays as faint areas of increased density, especially when expansion of the lung is restricted by consolidation or when the breathing is unusually quiet.

Bronchial lymph-glands are rarely visible unless they are enlarged or tubercular. They usually appear as separate, dark, mottled areas to the right of the cardiac shadow.

As regards the **pleura** it is naturally only visible with the X-rays when diseased. In thickened pleura there may be an increased density which is not affected by position or by tapping. Pleural effusion also gives an increased density of shadow with a blurring of the cardio-hepatic angle and the outline of the diaphragm.

Enlargement of the heart, pericardial effusion, mediastinal tumour, aneurysm of the aorta, etc., all give rise to X-ray areas of increased density, and by leading to compression of the lung may diminish its normal transradiance. Rotch emphasises the importance of the cardio-hepatic angle as a means of diagnosing pericardial effusion from enlargement of the heart. In the latter case the angle is about 90° and is obliterated in pericardial effusion.

Foreign bodies in the bronchi, lungs, or pleural cavities are, of course, often located by means of the X-rays.

DEVELOPMENT OF THE RESPIRATORY APPARATUS.

The larynx, trachea, bronchi, and lungs all arise as an outgrowth from the ventral aspect of the foregut. The first indication of a respiratory tract occurs in the human embryo early in the third week, on or about the fifteenth day of development, and when the embryo is but little more than 3 mm. in length. At that period a median longitudinal groove makes its appearance in the ventral wall of the foregut, extending from the primitive pharynx well towards the primitive stomach, and deepening gradually as it passes caudalwards.

The cranial end of the respiratory tube becomes enlarged and forms the larynx, the intermediate portion forms the trachea, and the caudal end bifurcates in the floor of the groove into two tubes—the future bronchi are already indicated by slight bulgings before the two tubes divide—which grow caudalwards on either side of the heart, into a mesodermic mass, from which the connective tissue of the future lungs is ultimately developed. The respiratory tube is lined with entoderm continuous with the entodermal lining of the foregut.

The groove becomes deeper and constricted, its lateral margins approximate, and finally meet dorsally, and the groove separates off from the foregut as a distinct tube. This differentiation necessarily results in the production of two tubes or canals, a ventral one forming the respiratory tube, and a dorsal one the œsophagus. The separation of the two tubes commences at the caudal end and proceeds cranialwards towards the pharynx, into which both the œsophagus and the respiratory tube open.

The Larynx.—The rudiment of the larynx appears, at the cranial or pharyngeal end of the primitive respiratory tube, about the twenty-fifth day, and before the trachea separates off from the œsophagus in the form of two lateral swellings—the arytænoid swellings, which lie caudal to the fourth visceral pouches, and possibly represent rudimentary fifth branchial arches (Kallius). The arytænoid swellings are connected by a ventral median ridge which intervenes between the ventral ends of the third visceral arches. At this period the site of the future larynx is represented at the pharyngeal end of the respiratory tube by a U-shaped ridge which surrounds the tube cranially and laterally, and is known as the *furcula.*

The cranial or anterior portion of the furcula forms a median elevation from which the epiglottis is developed, whilst the lateral portions of the furcula—the arytænoid swellings—eventually form the ary-epiglottic folds. On the medial side of the latter, about the fourth month, a furrow marks the future site of the ventriculus laryngis [Morgagni], the margins of which later become the vocal folds.

About the eighth week the cartilaginous framework of the larynx is indicated by mesoblastic condensations of the connective tissue around the now slit-like rima glottidis ; and at the same period the rudimentary arytænoids, the cricoid, and the cartilages of the trachea are all continuous laterally.

The *epiglottic cartilage* is developed, as stated, in the anterior portion of the furcula, and chondrifies relatively late. It may possibly represent a rudiment of the cartilage of the sixth branchial arch, and according to Göppert it is at first continuous dorsally with the cuneiform cartilages, which, therefore, are derivatives of the epiglottic cartilage.

The *thyreoid cartilage* is laid down in the form of two separate lateral mesoblastic plates, in each of which chondrification proceeds from two centres, ventral and dorsal, which probably represent the cartilages of the fourth and fifth branchial arches. As development proceeds the sheets of cartilage formed from these centres fuse, and eventually extend ventrally to fuse with their fellows of the opposite side, in the median plane. Chondrification is completed comparatively late, and when incomplete it results in the formation of an abnormality—the thyreoid foramen. The superior cornu of the thyreoid cartilage is at first continuous with the greater cornu of the os hyoideum, and the remains of this cartilaginous connexion is seen in the presence of the cartilago triticea in the lateral hyothyreoid ligament of the adult.

The pro-cartilaginous rudiments of the cricoid and arytænoid cartilages are at first continuous with each other, but later become differentiated by the appearance of separate cartilaginous centres for the arytænoids, and an incomplete ring, for a time deficient dorsally, for the cricoid. The cricoid thus resembles developmentally a tracheal ring, with which it probably corresponds morphologically. Chondrification proceeds in the cricoid by two centres, one on each lateral side. These centres unite ventrally, but dorsally fusion does not take place until much later, and is finally completed by an extension of chondrification from the lateral into the dorsal plate. The cricoid thus differs from the tracheal ring, in having its chondrification completed dorsally, whereas this never takes place in the tracheal ring.

The *arytænoid cartilages* are, as stated, at first continuous with the cricoid cartilage by fibrous tissue, but become eventually completely separated from it by the appearance of one chrondrification centre for each arytænoid.

The *corniculate cartilages* (*Santorini*) are merely portions of the arytænoid cartilages separated off by segmentation; whilst the *cuneiform cartilages* (*Wrisbergi*) are, as previously stated, derivatives of the epiglottic cartilage.

The Trachea.—The trachea is developed from the intermediate portion of the median longitudinal groove. Originally, both this portion of the primitive respiratory tube and the œsophageal portion of the primitive alimentary canal were of equal length; but as development proceeds both tubes lengthen, the latter more rapidly than the former, so that eventually the lung rudiments no longer lie on the ventral and lateral sides of the primitive stomach, but come to lie on the cephalic side of that viscus, and are separated from each other by the œsophagus dorsally and the heart and pericardium ventrally. In this way, that is by unequal growth, it comes about that the trachea in the adult is shorter than the œsophagus, though originally both were of equal length.

The cartilaginous rings of the trachea are developed like the cricoid cartilage, with the difference that in the trachea the process of chondrification does not extend into their dorsal portions, and hence, in the adult, the C-shaped rings of the trachea are deficient dorsally—an arrangement which admirably adapts itself to the functional uses of both trachea and œsophagus.

The Lungs.—The lungs are developed from the two diverticula of the caudal end of the median longitudinal groove and the mesodermal tissue into which these grow. Originally single, this caudal end soon becomes bilobed and pouches out on each side into two lateral diverticula, which represent the primitive bronchi and lungs. From the first the right pulmonary diverticulum or vesicle is slightly the larger of the two. Both diverticula elongate, and almost immediately undergo a subdivision—the right into three vesicles, and the left into two vesicles—thus early indicating the three lobes of the right lung and the two lobes of the left lung. As the primitive respiratory tube lies in the median plane in the dorsal attachment of the septum transversum, the pulmonary diverticula grow laterally and dorsally into the dorsal parietal recesses, that is into the future pleural cavities, carrying before them a covering of mesoblast. From this mesoblast are derived the blood-vessels and other tissues which build up the lung, whilst the entodermal cells which form the lining membrane of the primitive respiratory tube eventually develop into the epithelial lining of the air-passages, and are embedded within the surrounding mesoderm. The main entodermal subdivisions continue to branch and re-branch, pushing their way into the pulmonary mesoblast, until the complete bronchial tree is formed.

The primary pulmonary diverticula increase in size and complexity as additional outgrowths arise by the subdivision of the enlarged terminal part of each diverticulum. Their mode of subdivision is very characteristic, and from the first the various branches are bulbous or flask-shaped at their extremities. These bifurcate, and although at first the two main subdivisions appear, in each case, of equal importance, one grows out as the continuation of the main bronchial stem—the future hyparterial bronchus—whilst the other remains as a branch. This budding of the developing lung is at first monopodial, but later probably becomes dichotomous. When the ramification of the entodermal tubes into the lung-mesoderm is complete, the small terminal flask-shaped extremities of the various branches represent the atria of the lung.

This repeated bifurcation results, as just stated, in the formation of a main bronchus which traverses the entire length of the lung, and into which numerous secondary bronchi open. The latter, from the manner in which they arrange themselves around the main stem of the pulmonary artery, are divided into dorsal and ventral. These alternate with each other, and usually number four in each series; not infrequently the third dorsal bronchus fails to develop. In the left lung the first dorsal bronchus arises, not from the main tube as on the right side, but from the first ventral bronchus—an arrangement which probably results from the fusion on the left side of the superior and middle lobes of the left lung into one, namely, the so-called lobus superior of the adult left lung.

The secondary bronchi elongate, and give rise to the tertiary bronchi, and these in turn to lesser bronchi, and so on down to the terminal bronchi, with their atria, air-sacs, and air-cells of the lung-unit. At first the lung-unit is devoid of air-cells, but between the sixth month and full term the alveolar saccules and air-cells make their appearance on the alveolar ducts; and it is thus clear that the epithelial lining of the entire system of bronchial subdivisions and ramifications is derived originally from the entodermal lining of the primitive foregut. By the close of the fourth month of fœtal life the columnar cells lining the trachea and bronchi have become ciliated.

At first the diverticula of the respiratory tube are surrounded by thick masses of mesoblastic tissue, but as development proceeds the latter fails to keep pace with the former, and hence the mesoblastic tissue becomes greatly reduced in amount and in thickness. Coincidently, this mesoblast becomes vascularised, and thus rich plexuses of blood-vessels come to surround the terminal divisions of the epithelial tubes—an arrangement obviously adapted to the interchange of gases from air to blood and *vice versa*.

The rudiments of the developing lungs grow dorsally on each side of the œsophagus into the fissure-like portion of the cœlom which occupies the thoracic region. They push before them the endothelial lining of the cœlom, and thus come to acquire their covering of pulmonary pleura. By the development of the diaphragm and the pericardium the pleural portions of the cœlom become cut off from the peritoneal cavity and from each other.

THE DIGESTIVE SYSTEM.

Originally written by Professor Ambrose Birmingham, M.D.

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APPARATUS DIGESTORIUS.

The Digestive System.—The physical characters and the chemical composition of the food taken into the body are such that much of it cannot at once be utilised by the organism. Before it can be absorbed and used in nutrition it requires to be acted upon, both chemically and mechanically. The performance of these mechanical and chemical changes is known as *digestion.*

The term **apparatus digestorius** (digestive system) is applied collectively to the organs which are concerned in this process, in the reception of food into the body, and in the excretion of the undigested or unabsorbed residue.

The simple form of digestive system which is found in many of the lower animals consists of a simple tube, passing through the interior of the body, from an anterior or mouth aperture, to a posterior or anal orifice.

In man, a tube of this kind forms the basis of the digestive system. It extends from the mouth, through the neck, thorax, abdomen, and pelvis, to the anal orifice and is termed the alimentary canal. The tube, originally simple, has become modified, in different directions in different parts, for the performance of the various processes. The wall and lining membrane are so constructed as to be capable of acting mechanically and chemically upon the food in its interior, of absorbing and transmitting products of digestion into the adjacent blood and lymph vessels, and of ejecting the unabsorbed remains.

Alimentary Canal.—The alimentary canal, taken as a whole, measures, when fully extended, about 30 feet (9 metres) in length, and consists of the following parts in order:—mouth, pharynx, œsophagus, stomach, small and large intestines. The term **tubus digestorius** is applied to the whole of the canal below the lower end of the pharynx. The general arrangement, position, and size of these various parts are shown in the figure (Fig. 849).

CAVUM ORIS.

The **mouth** forms the first division of the alimentary canal. It lies between the maxillæ and mandible, bounded externally by the lips and the cheeks, and roofed in by the palate. It contains the teeth and greater part of the tongue; and the ducts of the salivary glands open into it. It communicates with the exterior by the aperture of the mouth, and opens posteriorly into the pharynx.

Rima Oris.—The **aperture of the mouth** is bounded above and below by the corresponding lips, which meet at the sides and form the **commissures** of the lips, and bound the angles of the mouth (anguli oris). In a state of rest, with the lips in apposition, the rima forms a slightly curved line, corresponding in length to the interval between the first premolar teeth, and in level to a transverse line just below the middle of the upper incisor crowns. The shape of the rima varies with every movement of the lips, from the resting linear form, curved like

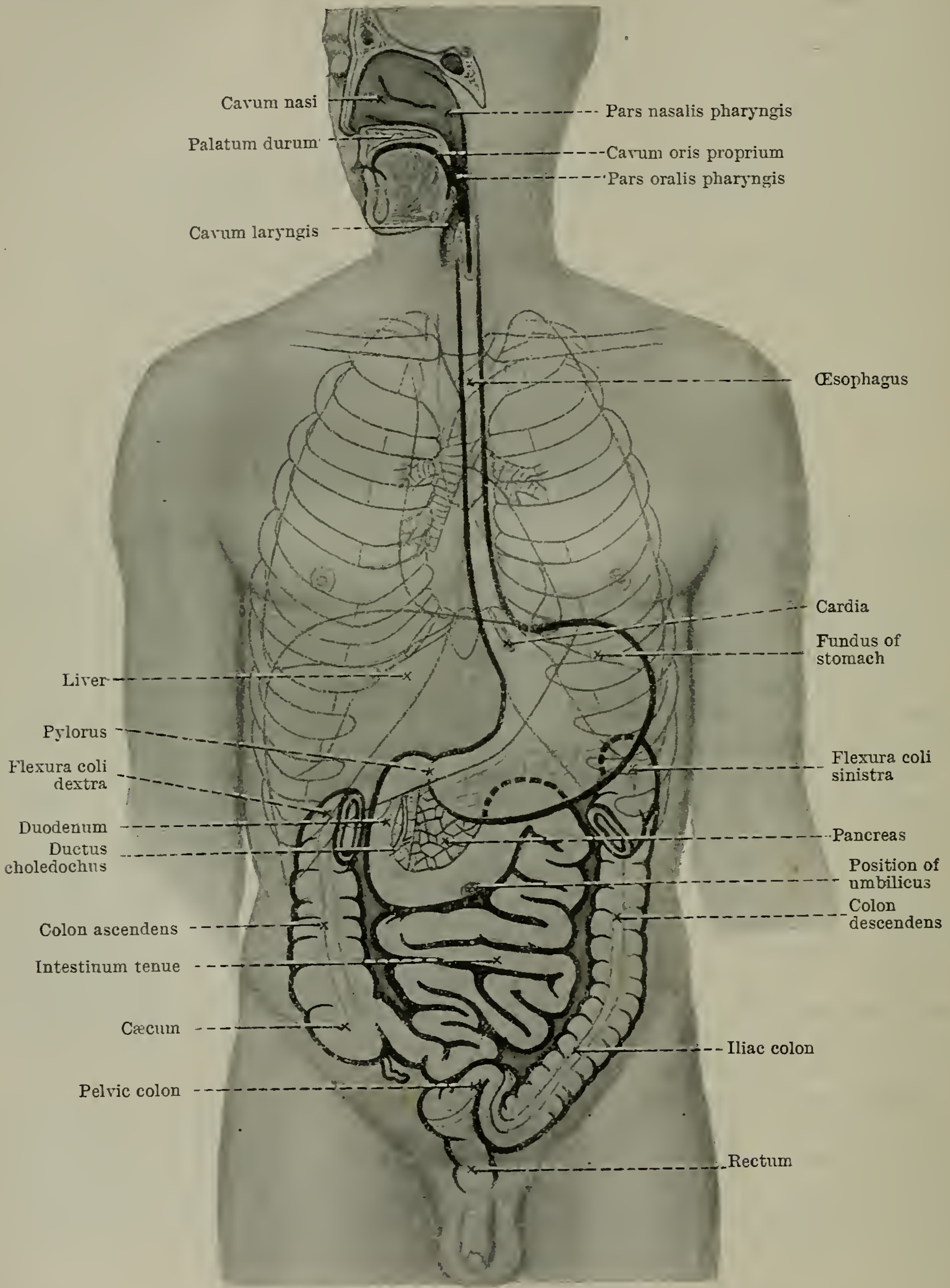


Fig. 849.—Diagram of the General Arrangement of the Digestive System.

The transverse colon is not represented, in order that the duodenum and pancreas, which lie behind it, may be seen.

the conventional bow, to a circular or oval shape when the mouth is widely open, or the "pursed-up" condition produced by the contraction of the orbicularis oris muscle.

The cavity is divisible into two portions, the *vestibule* and the *cavity proper* of the mouth, separated from one another by the alveolar ridges, gums, and teeth of the maxillæ and mandible.

Vestibulum Oris.—The vestibule of the mouth lies immediately internal to the aperture of the mouth, and occupies the interval between the lips and cheeks externally, and the teeth and gums internally.

In the normal resting condition, when the mouth is closed and the lips and the teeth are in contact, it becomes merely a slit-like interval, with a narrow roof and floor formed by the reflexion of the mucous membrane from the internal surface of the lips and cheeks to the corresponding gum. In the median plane is a small but prominent fold of the mucous membrane, the **frenulum**, which connects the back of each lip to the front of the gum. The upper frenulum is the better developed, and is readily brought into view by everting the lip. The frenulum of the lower lip is not always present.

On the outer wall of the vestibule, opposite the crown of the second upper molar, is a variably developed eminence, on whose summit is the small opening of the duct of the parotid gland.

When the teeth are in contact the vestibule communicates with the cavity of the mouth only through the small and irregular spaces left between the opposing teeth, and posteriorly, on either side, by a wider but variable aperture between the last molars and the ramus of the mandible.

Advantage is sometimes taken of the presence of this aperture for the introduction into the cavity of the mouth of liquid food in certain cases—trismus, anchylosis, etc.—in which the jaws are rigidly closed.

On the outer wall of the vestibule, the anterior border of the masseter can be distinctly felt with the finger, when the muscle is thrown into a state of contraction. Still further back, the front of the coronoid process, bearing the lower part of the insertion of the temporal muscle, can also be made out. The spheno-mandibular ligament, which corresponds to, and is felt along with, the anterior border of the internal pterygoid muscle, is distinguishable as a pliant ridge when the finger is carried from the front of the coronoid process behind the last molar tooth into the cavity of the mouth.

In addition to the duct of the parotid, the ducts of numerous small glands which are embedded in the lips and cheeks open into the vestibule.

Under normal conditions, as pointed out above, the lips and cheeks lie against the teeth and gums, obliterating the cavity of the vestibule, and helping, with the aid of the tongue, to keep the food between the grinding surfaces of the molar teeth during mastication. In facial palsy, however, owing to the paralysis of their muscles, and particularly of the buccinator muscle, the lips and cheeks fall away from the dental arches, and allow the food to pass out from between the teeth and to accumulate in the vestibule.

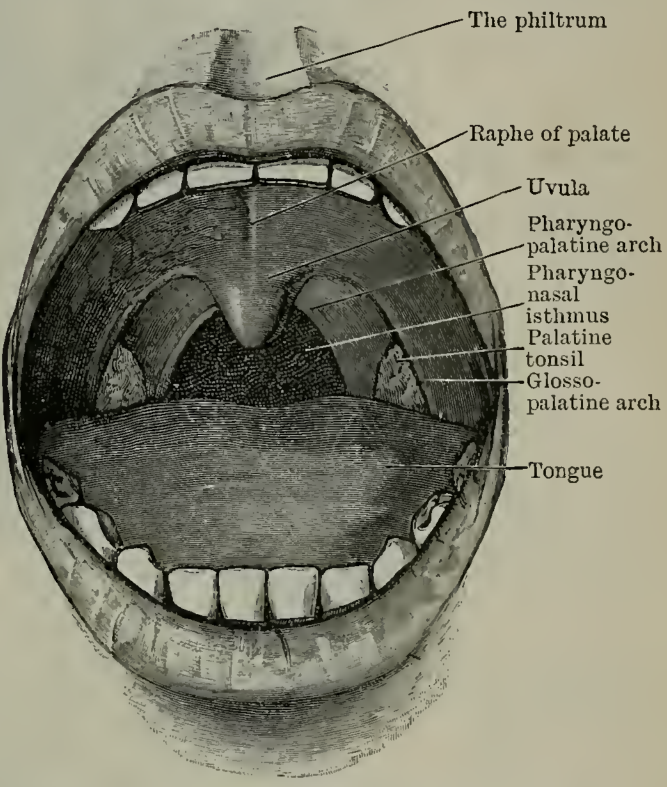


Fig. 850.—Open Mouth showing Palate and Palatine Tonsils.

It also shows the two palatine arches, and the pharyngo-nasal isthmus, through which the naso-pharynx, above, communicates with the oral portion of the pharynx, below.

Cavum Oris Proprium.—The **cavity proper of the mouth** is the space situated within the arches of the teeth and gums, extending backwards to the glosso-palatine arches (O.T. anterior pillars of the fauces)—two folds of mucous membrane which pass from the palate to the side of the tongue, and mark the junction of the mouth and the pharynx. The roof is formed by the **hard palate** and the anterior portion of the **soft palate**, the floor by the anterior part of the tongue in the middle, and on each side by the reflexion of the mucous membrane from the side of the tongue to the gums.

If the tongue is raised, there is exposed a limited space termed the sublingual space (Fig. 867), or floor of the mouth.

The term "floor of the mouth" is frequently applied to the muscular and other structures, especially the mylo-hyoid muscles, which fill in the interval between the two halves of the body of the mandible, and, with the hyoid bone, form the basis upon which the tongue and the mucous membrane of the sublingual space are supported, extending from the symphysis menti, in front, to the body of the hyoid bone, behind.

The floor of the sublingual region (Fig. 867) is formed by the mucous membrane between the gums and the inferior aspect of the tongue. When the tip of the tongue is raised the membrane forms in the median plane a prominent fold, the **frenulum linguæ**, stretching from the floor of the mouth to the inferior surface of the tongue. On each side of the frenulum, near its junction with the floor, is a prominent soft papilla, the **caruncula sublingualis**, on which opens the **duct of the submaxillary gland** (Fig. 867). Running laterally and posteriorly, on each side, from the frenulum, is a well-marked ridge, **plica sublingualis**, due to the projection of the underlying sublingual gland. Most of the ducts of this gland open near the crest of the ridge on each side. Another fold, called the **plica fimbriata**, lies medial to each of the others, on the inferior surface of the tongue.

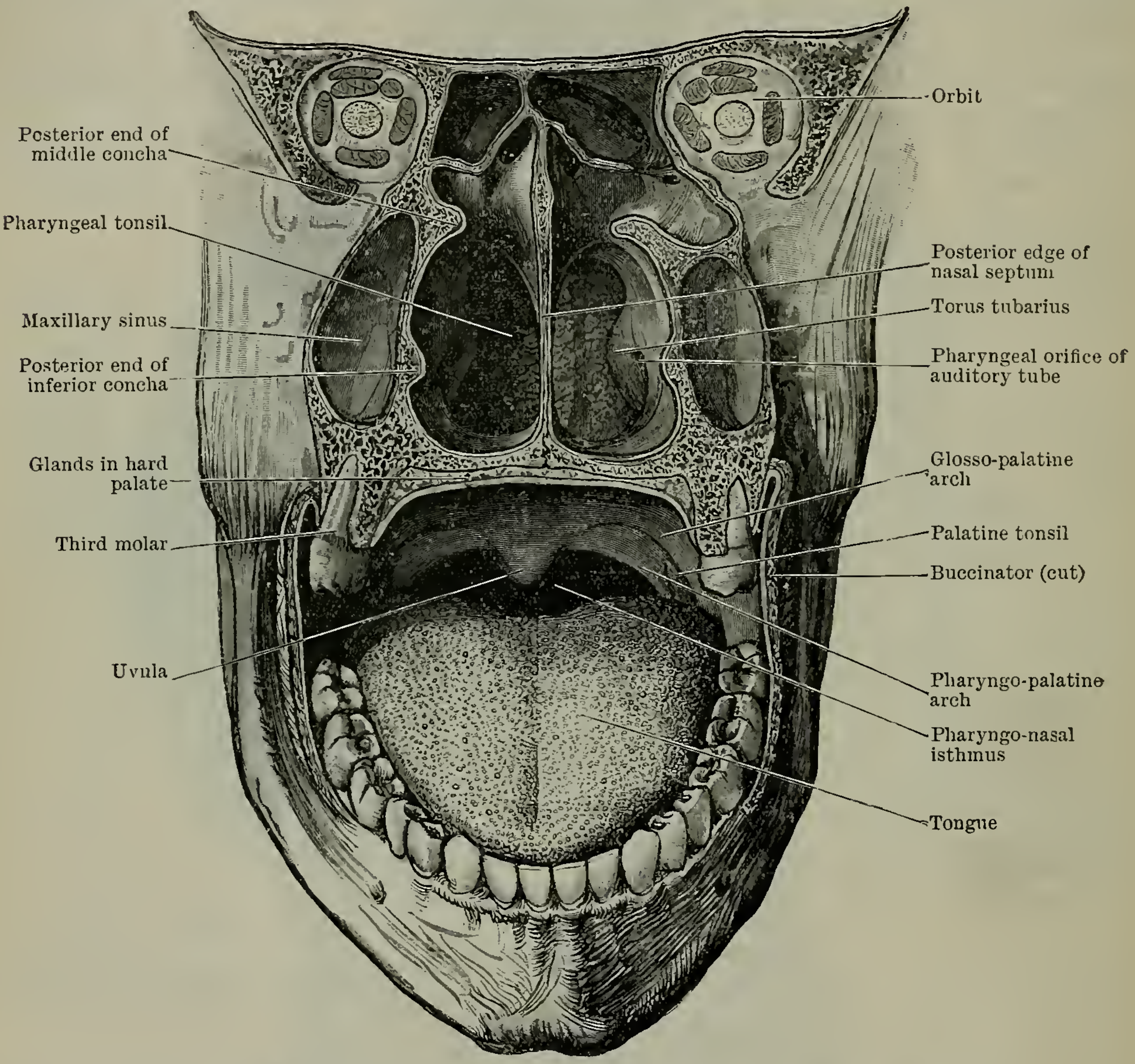


Fig. 851.—The Mouth and the Nasal Part of the Pharynx from the Front.

A frontal section was made through the upper part of the head; the section passed immediately in front of the posterior edge of the nasal septum, and extended into the mouth below. Through the choanæ, the nasal part of the pharynx is seen. The prominence of the posterior margin of the ostium pharyngeum of the auditory tube, and the lymph nodules constituting the pharyngeal tonsil, should be noted. The palatine arches and tonsils, and an unusually wide pharyngo-nasal isthmus, are also seen.

This fold represents the under-tongue of some mammals, in whom it is a sort of fringe, stated to be of service in cleaning the incisor teeth (F. W. Jones).

Labia Oris.—The lips are the two mobile folds, covered superficially by skin, and on their deep surface by mucous membrane, which surround the rima oris. Laterally, they are prolonged into the cheeks, and below into the chin. The junction of the lips and cheek is marked on the surface by the **sulcus naso-labialis**, a slight groove which passes downwards and laterally from the margin of the nose towards the angle of the mouth, while the **sulcus mento-labialis** separates the lower lip from the chin. At the middle of the upper lip is a shallow vertical groove, the **philtrum**, bounded by two distinct ridges descending from the columella nasi (Fig. 852); inferiorly the groove widens out, and terminates opposite a slight projection on the free edge—the *labial tubercle.* This tubercle is particularly well developed in children, and is chiefly responsible for the characteristic curve of the rima oris. The lower lip is usually longer and more movable than the upper lip.

For the manner in which the various muscles enter into the formation of the lip, see section on the Muscles (pp. 450-453).

In each lip the following series of structures can be recognised from the external to the internal surface:—(1) The **skin**, which is closely beset with hairs, small and fine in the child and female, long and stout in the adult male. (2) A layer of fatty **superficial fascia** continuous with the fascia of the face generally. (3) The **orbicularis oris muscle**, continuous at its periphery with the various muscles converging towards the mouth. A number of its fibres, or those of the muscles joining it, pass through the superficial fascia and are attached to the skin. (4) The **submucous tissue**, which is occupied by an almost continuous layer of racemose glands—the **labial glands**. These form a mass of small nodular glands, each about the size of a grape seed, closely packed together, and lying immediately external to the mucous membrane of the upper and lower lips. Each nodule is a small racemose gland, lined by mucous secretory cells, with a short duct opening through the mucous membrane. (5) The **mucous membrane** of the mouth, covered by stratified squamous epithelium. Between the orbicularis and mucous membrane, in the deeper part of the submucosa, the labial artery is found, a short distance from the free margin of the lip, running to meet its fellow of the opposite side.

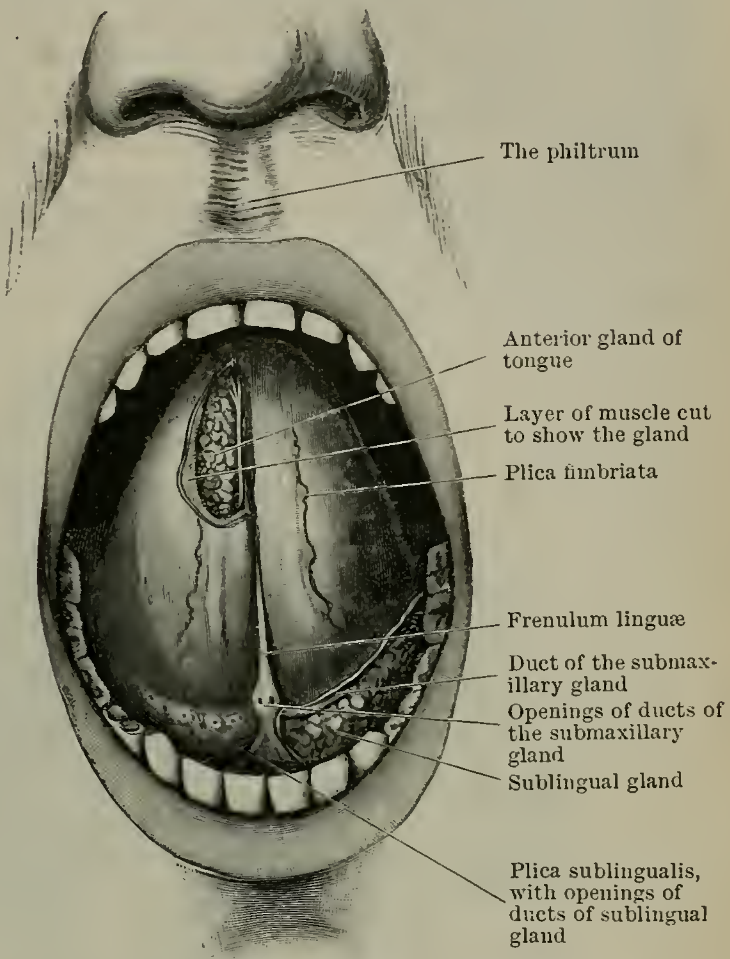

The philtrum
Anterior gland of tongue
Layer of muscle cut to show the gland
Plica fimbriata
Frenulum linguæ
Duct of the submaxillary gland
Openings of ducts of the submaxillary gland
Sublingual gland
Plica sublingualis, with openings of ducts of sublingual gland

Fig. 852.—Open Mouth with Tongue raised, and the Sublingual and Anterior Glands exposed.

The sublingual gland of the left side has been laid bare by the removal of the mucous membrane; to expose the anterior lingual gland of the right side a thin layer of muscle, in addition to the mucous membrane, has been removed. A branch of the lingual nerve is seen running on the medial aspect of the gland. The profunda vein also is faintly indicated on this side.

The free margin of the lip is covered with a dry and otherwise modified mucous membrane. It begins where the integument changes colour at the outer edge of the lip, and ends posteriorly just behind the line along which the two lips meet when closed, where it passes into the ordinary moist mucous membrane of the vestibule. It presents numerous simple vascular papillæ, and its nerves terminate in special end organs, hence the acute sensitiveness of this part. In the child, at birth, the margin of the lip is divided by a very pronounced groove or fissure into an outer and an inner zone, differing considerably in their appearance.

Blood-vessels, Nerves, and Lymph-vessels.—The lips receive a free blood supply, the lower lip from the inferior labial, and the upper from the superior labial branches of the *external maxillary artery.*

The sensory nerve supply of the lips is derived from the **trigeminal nerve,** that of the upper through the *infra-orbital branch* of the maxillary division, and that of the lower from the *mental branch* of the inferior alveolar branch of the mandibular division, while the **buccinator** branch of the mandibular division supplies the region of the angle. The lymph-vessels of the upper lip pass with the external maxillary artery to the **submaxillary lymph-glands** lying in the submaxillary triangle, while those from the lower lip pass in part to the same glands, and in part to the *submental glands* lying on the mylo-hyoid muscles, above the hyoid bone.

Buccæ.—The **cheeks** resemble the lips in structure, and are formed of corresponding layers, but the place of the orbicularis oris muscle is taken by the buccinator muscle. They are covered externally by the skin and internally by the mucous membrane. Under the skin lies the fatty superficial fascia of the face, much looser in texture than in the lips, through which the **parotid duct** (of Stensen) runs inwards to pierce the buccinator. Near the end of the duct are found four or five mucous glands, as large as hemp-seeds, known as the **molar glands**; their ducts pierce the cheek and open into the vestibule. Beneath the superficial fascia lies the *buccinator muscle*, covered by the thin bucco-pharyngeal fascia. Deeper still is the submucosa, which, like that of the lips, contains numerous racemose **buccal glands.** And finally the mucous membrane is reached.

The **corpus adiposum buccæ** (O.T. **sucking pad**) is an encapsuled mass of fat, distinct from the surrounding superficial fascia, which lies on the outer side of the buccinator, and passes backwards into the large recess between that muscle and the overlying part of the masseter. This fatty mass is relatively more developed in the child than in the adult, and strengthens the cheek to resist the effects of atmospheric pressure during the act of sucking. In the adult the remains of the pad can be distinctly made out under the anterior border of the masseter.

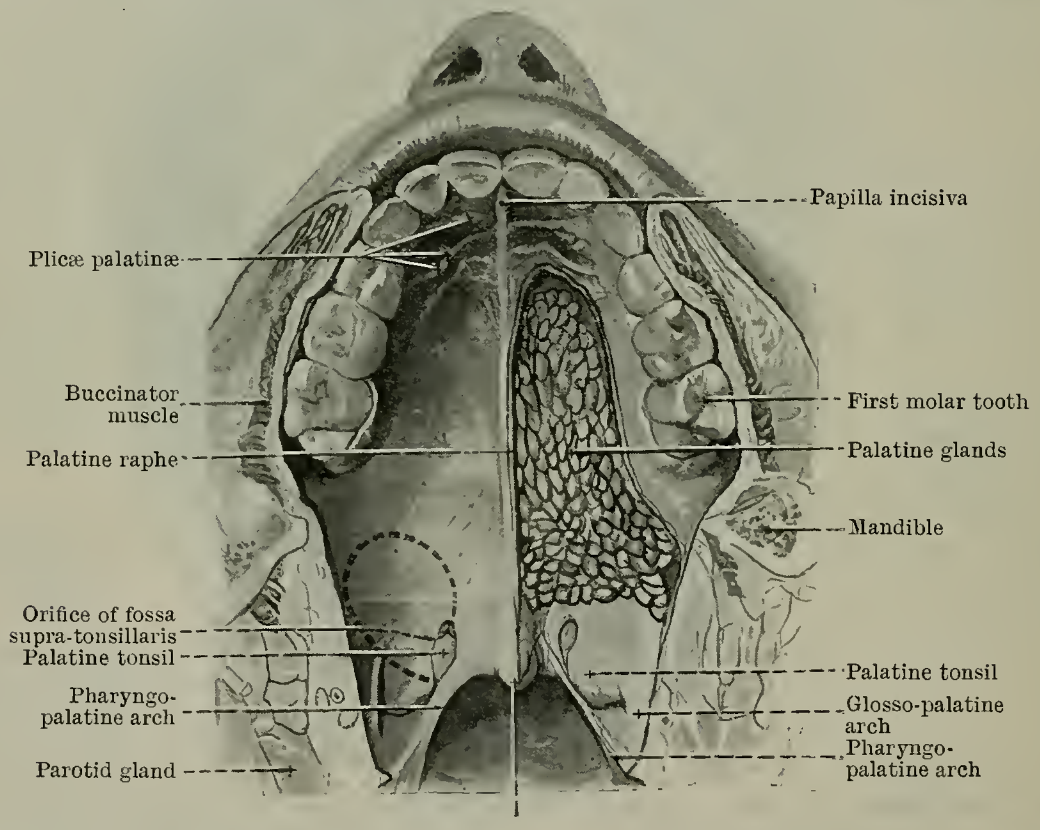


Fig. 853.—Palate from below. The mucous membrane has been removed over an area on the left side. From a child of ten years. The glosso-palatine arch was largely adherent to the anterior surface of the tonsil, and its free margin was thus obscured. The dotted line shows the extent of the supra-tonsillar fossa.

Some small superficial lymph-glands lie on the superficial surface of the buccinator, communicating with the vessels of the lips, while their efferent vessels pass onwards towards the parotid region.

Palatum.—The **palate** forms the roof of the mouth, and separates the mouth from the nasal cavities and nasal part of the pharynx. From the mouth it extends backwards into the cavity of the pharynx, forming the division between the oral and the nasal parts of the pharynx. It terminates behind in a free conical projection, the **uvula.**

It consists of two portions, an anterior, forming the anterior two-thirds, which has a bony foundation, and a posterior, forming the posterior third, with a fibrous basis; and they are termed the hard and the soft palate respectively. The palate is arched antero-posteriorly, and also transversely. The latter curvature is the more pronounced in the hard palate, but the shape and curvature of this portion depend upon the configuration of its bony foundation.

The hard palate is, on the whole, horizontal in direction, both transversely and antero-posteriorly. The soft palate is, on the other hand, during rest, as, for instance, in quiet nasal breathing, very oblique in direction, and it shuts off the mouth from the nasal and largely from the oral parts of the pharynx. When, however, the soft palate is raised, as in swallowing, it continues backwards the plane of the hard palate, and projects across the cavity of the pharynx, forming a nearly complete partition between the oral and the nasal parts of the pharynx. In this position it prevents food from passing upwards into the nasal part of the pharynx and nose.

Along the middle of the palate is a faint median ridge or **raphe** (Fig. 853), indicating its original development from two halves. This raphe is continued posteriorly along the soft palate to the base of the uvula, and in front it ends in a slight elevation, the **papilla incisiva**. From the anterior end of the raphe a series of transverse ridges of mucous membrane, about six in number, run laterally, just behind the incisor teeth; they are known as the **plicæ palatinæ**, and are composed of dense fibrous tissue. Sometimes a small pit, which will admit the point of a pin, is seen, on each side, immediately posterior to the central incisor teeth, and about 2 mm. from the median plane. These pits correspond to the inferior openings of the incisive canals, with which they are occasionally continuous.

Palatum Durum.—The **hard palate** consists of a horizontal plate formed by the palatine processes of the maxillæ and the horizontal parts of the palatine bones, covered on each surface, superior and inferior, by periosteum. The periosteum of the inferior surface is thick, and is in turn covered by a quantity of dense fibrous tissue firmly united both to the periosteum and to the mucous membrane. This dense tissue contains in its posterior half a large number of racemose palatine glands, and it also contains the larger nerves and blood-vessels of the palate. The mucous membrane covering the superior surface is largely ciliated in character, and forms the floor of the nasal cavity, while that on the inferior surface is a stratified squamous epithelium.

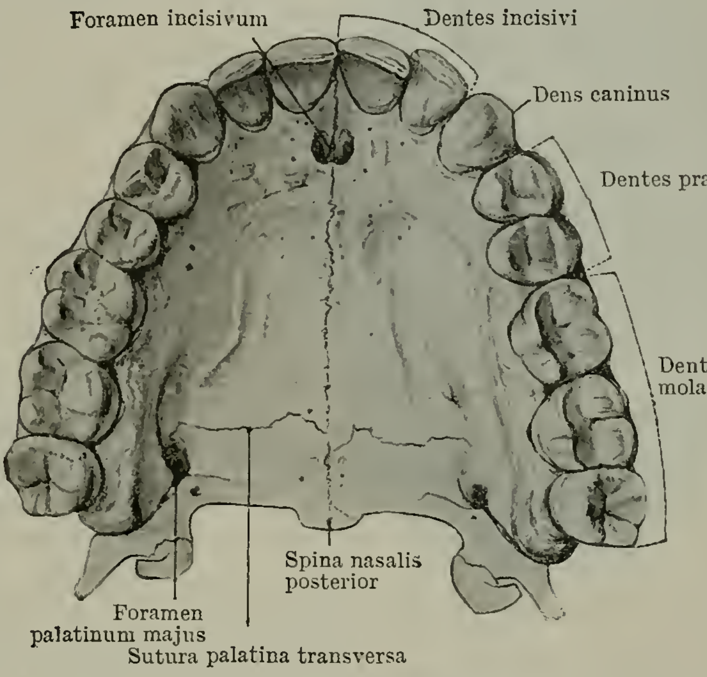


Fig. 854.—The Hard Palate and Upper Permanent Teeth, seen from below.

Palatum Molle.—The **soft palate** is attached anteriorly to the posterior margin of the hard palate. Its lower and posterior margin is free, and forms an arch, extending from one side of the pharynx to the other, but the arch is interrupted in the centre by the conical projection of varying size, called the uvula. Laterally the soft palate is intimately connected on each side with two prominent folds, called the palatine arches.

The more anterior, termed the **glosso-palatine arch** (O.T. **anterior pillar of the fauces**), passes below into the side of the tongue. Traced upwards, it runs on to the inferior surface of the soft palate, and is continuous with the margin of the uvula. The free posterior margin of the soft palate passes into the **pharyngo-palatine arch** (O.T. **posterior pillar of the fauces**), which passes downwards for some distance on the side wall of the pharynx.

The two palatine arches on each side are 7-8 mm. apart, and on the side wall, between each pair, there is a fossa, occupied in part by the palatine tonsil. This region belongs properly to the pharynx, and will be described in detail when that part is dealt with.

The superior surface of the soft palate forms a continuation backwards and downwards of the floor of the nasal cavity, and constitutes the floor of the nasal part of the pharynx. It is covered by a prolongation of the nasal mucous membrane, partly ciliated in character.

In the fœtus the whole of the epithelial covering of the soft palate is ciliated, but after birth the ciliated epithelium is largely replaced by stratified squamous epithelium, except at the margin of the palate.

Structure.—The framework of the soft palate is formed of a strong, thin, flat, fibrous sheet, called the palatine aponeurosis, which is confined to the anterior part of the soft palate, constituting a common tendon for the palatine muscles. Its anterior margin is united to the posterior edge of the horizontal parts of the palatine bones. With the exception of the aponeurosis of the tensor veli palatini which passes into its lateral part, the muscles do not, as a rule, reach further forwards than to within 8 or 10 mm. of the posterior edge of the hard palate.

The muscles entering into the formation of the soft palate are the mm. pharyngo-palatini, uvulæ, levatores veli palatini, tensores veli palatini, and glosso-palatini. For the details of the attachments and arrangement of these muscles, see p. 466.

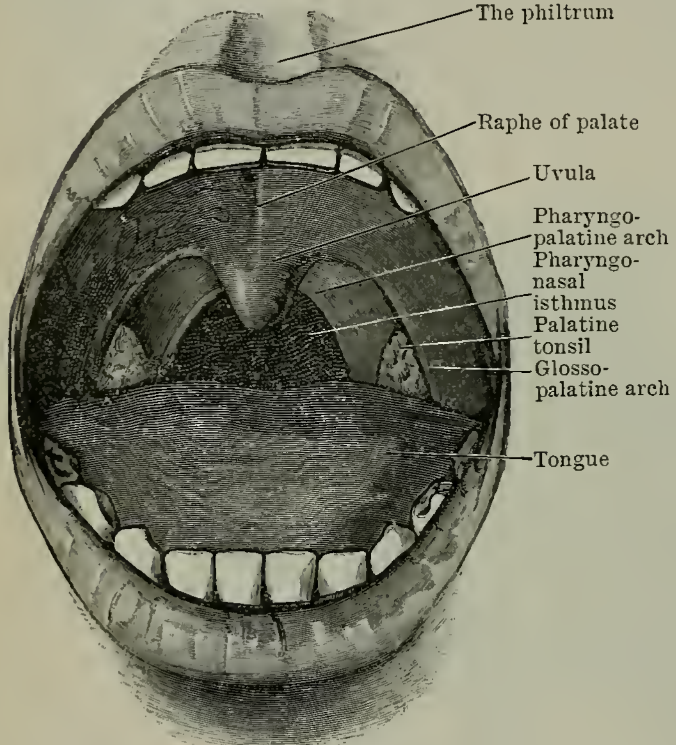


Fig. 855.—Open Mouth showing Palate and Palatine Tonsils.

It also shows the two palatine arches, and the pharyngo-nasal isthmus, through which the nasal part of the pharynx, above, communicates with the oral portion of the pharynx, below.

The anterior part of the soft palate for 8 or 10 mm. ($\frac{1}{3}$ in.) contains practically no muscular fibres; it is composed of the palatine aponeurosis, covered by an extremely thick layer of glands on the inferior surface and by mucous membrane on both surfaces. This anterior portion is much less movable than the rest of the soft palate, and forms a relatively horizontal continuation backwards of the hard palate, stretching across between the two medial pterygoid laminæ. Upon this portion chiefly the tensores veli palatini muscles act. The posterior and larger part contains muscular fibres in abundance, slopes strongly downwards, and is freely movable, and upon it the remaining palatine muscles act.

The **mucous membrane** of the inferior surface of the palate, which is covered by stratified squamous epithelium, is firmer and more closely adherent in front, near the rugæ, than behind, near the soft palate.

Mucous glands, the orifices of which can be seen as dots with the naked eye, are extremely abundant in the soft palate, and in the posterior half of the hard palate, except near the raphe. They are wanting in the anterior part of the palate, where the mucous membrane is particularly dense.

The **plicæ palatinæ** (which correspond to more strongly developed ridges in carnivora, etc.) are very well marked in the child at birth, although, perhaps, relatively less distinct in the fœtus of five or six months; in old age they become more or less obliterated and irregular. At birth, also, and in the fœtus, the incisive pad at the anterior end of the raphe is continued over the edge of the gum into the frenulum of the upper lip.

The **uvula** is composed chiefly of a mass of racemose glands and connective tissue covered by mucous membrane, and containing a slender prolongation of the uvular muscle in its upper part.

The **vessels** of the palate are :—

(1) Branches from the **descending palatine artery**, a branch of the internal maxillary artery.

Of these, some small vessels, the **lesser palatine arteries**, emerge from the smaller palatine foramina, and are distributed to the palatine tonsil and palate, and anastomose with branches of the ascending pharyngeal artery.

The largest branch, **greater palatine artery**, emerges through the great palatine foramen, and runs forwards over the lateral margin of the hard palate, about $\frac{1}{4}$ in. from the alveolar margin, as far as to the incisive foramen, where it anastomoses with the naso-palatine artery.

(2) **Posterior nasal septal artery**, a small vessel which enters through the incisive foramen.

(3) **Ascending palatine artery**, from the external maxillary, which anastomoses by a ramus tonsillaris with the descending palatine.

(4) Branches from the **ascending pharyngeal artery**, which enter the soft palate.

(5) Branches from the **rami dorsales linguæ** of the lingual artery, which pass in the glosso-palatine fold to the palatine tonsil and soft palate.

The **nerves** are all derived from branches from the spheno-palatine ganglion.

(1) **Nervi palatini.** The most important of these is the **nervus palatinus anterior,** which passes through the great palatine foramen, and divides in the roof of the mouth into branches which run in grooves on the hard palate and extend forwards nearly to the incisor teeth.

The others are the **nn. palatini medius** and **posterior,** which emerge from the smaller palatine foramina, and are distributed to the hard and soft palate.

(2) **N. nasopalatinus** (Scarpæ). This nerve sends branches to the palate through the incisive foramen, which join with branches from the anterior palatine nerves.

For the **motor** nerves to the muscles of the soft palate, see p. 467.

The **lymph-vessels** of the palate pass lateral to the tonsil and the isthmus of the fauces to the upper deep cervical lymph-glands.

Isthmus Faucium.—The **isthmus of the fauces** is the aperture through which the mouth communicates with the oral part of the pharynx (Fig. 855). It is bounded at the sides by the glosso-palatine arches, above by the inferior surface of the soft palate, and below by the dorsum of the tongue; in width it corresponds pretty closely to the cavity of the mouth.

The **arcus glosso-palatini** (O.T. **anterior pillars of the fauces**) are two prominent folds of mucous membrane which bound the isthmus of the fauces on each side (Fig. 855). Each contains a glosso-palatine muscle in its interior. They are continuous above with the inferior surface of the soft palate, a little way (about 8 mm.) anterior to its free edge, and near the base of the uvula, and they pass downwards and slightly forwards to join the side of the tongue a little behind its middle.

The **pharyngo-palatini arches** (O.T. **posterior palatine arches**) are two vertical folds of mucous membrane which pass from the soft palate to the side wall of the pharynx. Each contains a muscle, the pharyngo-palatinus. The pharyngo-palatine arches are described in connexion with the palatine tonsil (p. 1138).

Gingivæ.—The **gums** are composed of the firm connective tissue which covers the alveolar borders of the maxillæ and mandible and surrounds the necks of the teeth. In structure they consist of dense fibrous tissue, inseparably united to the periosteum, covered by mucous membrane. They are richly supplied with blood-vessels, but sparsely with nerves, and are covered by stratified squamous epithelium. Around the neck—or more correctly the base of the crown—of each tooth, the gum forms a free overlapping collar, and at this part particularly it is closely studded with small papillæ, visible to the naked eye.

In thickness it usually measures from 1 to 2 mm.

DENTES.

The teeth are hard structures, rooted in the alveoli of the upper and lower jaws, of different form and shape, and appearing in two sets, a deciduous (milk teeth) and a permanent.

General Form and Structure.—Each tooth consists (Fig. 856) of (1) the **corona dentis** or **crown,** the portion projecting above the gum. It varies in shape in the different teeth, and may be chisel-shaped, conical, or flattened and broad. It bears on its masticating surface a number of tubercles, the **tubercula coronæ** (O.T. **cusps**), varying in number from two to five in the different teeth; (2) the **collum dentis** or **neck,** the faintly constricted part which is surrounded collar-wise by the gum, and connects the crown with (3) the **radix dentis** or **root,** the portion of the tooth embedded in the alveolus of the jaw. In the majority of teeth, the root is single, or nearly so, and consists of a long, tapering, conical, or flattened piece, perfectly adapted to the alveolus in which it lies. In the molar teeth (and in some of the others occasionally) the root is divided into two or three tapering or flattened roots or fangs. At the apex of each root there can be made out, even with the naked eye, a minute opening, the **foramen apicis,** through which the vessels and nerves enter the tooth.

Within each tooth is a cavity of some size, the **cavum dentis** or **tooth cavity,** which is filled in the natural state by the loose vascular and connective tissue known as the **pulpa dentis** or **tooth pulp**. The tooth cavity gradually narrows, and is prolonged into each root of the tooth as a slender tapering passage, the **canalis radicis** (root-canal), which opens at a minute foramen, the **foramen apicis**. Through these foramina and root-canals the vessels and nerves pass to the interior of the tooth.

Short diverticula of the pulp cavity are prolonged into the bases of the tubercles in the molar and premolar teeth, and in the incisors also there are similar slight prolongations of the cavity towards the angles of the crown.

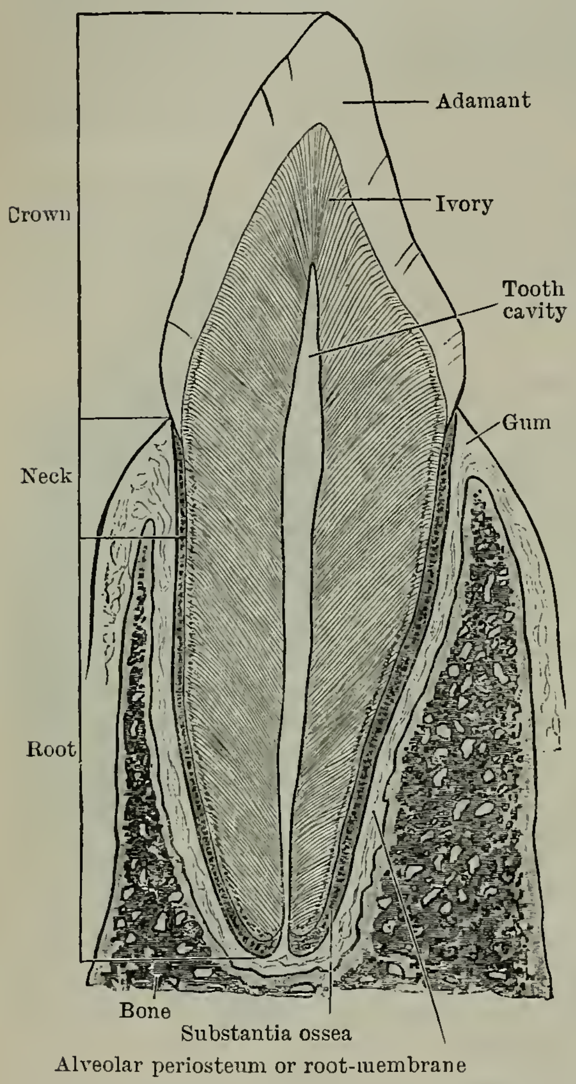


Fig. 856.—Vertical Section of Canine Tooth to illustrate its various parts and its structure.

The roots of the teeth are embedded in the **alveoli** of the jaws, to which they are firmly united (Fig. 856) by a highly vascular layer of connective tissue—the **periosteum alveolare**. This is attached to the wall of the alveolus on the one hand and to the root of the tooth on the other, whilst above it is continuous with the connective tissues of the gum.

So accurately are the root and the alveolus adapted to each other over their whole extent, and so firmly does the periosteum bind them together, that, under normal conditions, the tooth is quite firmly fixed in the bone, and no movement of the root within the alveolus can take place; the vessels and nerves entering at the apex are thus secured against pressure or strain.

When, however, the alveolar periosteum is inflamed it becomes swollen and exquisitely sensitive; the tooth, as a result of the swelling, is pushed partly out of its socket, its crown projects above those of its neighbours, and strikes against the opposing tooth when the mouth is closed, giving rise to much pain and discomfort.

The **neck** can scarcely be recognised as a distinct constriction in the permanent teeth; it corresponds to the line along which the gum and alveolar periosteum meet, or along which the gum is united to the tooth; but, as already pointed out, the gum does not stop at the neck, but forms a free fold which surrounds the base of the crown collar-wise for a short distance. The outline of the margin of the gum opposite the labial and lingual surfaces of the crown is usually concave, but opposite the contact surfaces of the tooth it is convex, and reaches much nearer to the edge of the crown than on the other surfaces.

Tartar is a hard calcareous deposit from the saliva (salivary calculus), often found on the teeth near their necks. It is composed of lime salts, and its deposit is largely determined by the presence of organisms (leptothrix, etc.) in the mouth.

Structure of the Teeth.

Each tooth consists of two chief portions—namely, the **substantia eburnea** (**ivory, O.T. dentine**) derived from the connective tissue, and the **substantia adamantina** (**adamant, O.T. enamel**) from the epithelial layer of the mucous membrane. The **substantia eburnea** constitutes the chief mass of the tooth, whilst the **substantia adamantina** forms a cap for the crown. There is also found in the teeth another special tissue—the **substantia ossea** (**O.T. cement**), a form of modified bone—encasing the roots. The cement is in turn united to the alveolar wall by a layer of periosteum like connective tissue, the periosteum alveolare (periodontal membrane).

Both **ivory** and **adamant**, but particularly the latter, are the hardest and most resistant structures in the body, and are thus specially fitted for the functions which they have to perform.

The **substantia adamantina** is the dense, white, glistening layer which forms a cap, thickest over the tubercles, for the crown of each tooth (Fig. 856). At the neck it ceases gradually, being here slightly overlapped by the substantia ossea.

It is composed chiefly of phosphate and carbonate of lime. "The **substantia adamantina** is to be regarded as an inorganic substance composed of lime salts, which have been deposited in particular patterns and formed under the influence of organic tissues, which have themselves disappeared during its formation" (Tomes).

The adamantine substance consists of minute, solid, calcified hexagonal prisms, **prismata adamantina**, radiating from the surface of the ivory to the surface of the crown, on which they terminate by free ends, and most of them reach from the ivory to the surface of the crown without interruption. The prisms are held together by the smallest possible amount of calcified matrix (Tomes). In old teeth the cap of adamant is often worn away over the tubercles, the ivory is then exposed, and is easily recognised by its yellowish colour, which contrasts strongly with the whiteness of the adamant.

Whilst adjacent adamantine prisms are in general parallel to one another, they do not usually take a straight, but rather a wavy course, and in alternate layers they are often inclined in opposite directions, thus giving rise to certain radial striations seen by reflected light (Schreger's lines). Certain other pigmented lines, more or less parallel to the surface, are also seen in the adamant (brown striæ of Retzius). They are due to true pigmentation (Williams), and mark the lines of deposit of the adamant during its development. The adamantine prisms are more or less tubular in certain animals—viz., in all marsupials except the wombat, in the hyrax, certain insectivora, and certain rodents.

Cuticula dentis (O.T. **Nasmyth's membrane**) is an extremely thin (1·5 μ) cuticular layer which covers the adamant of recently-cut teeth, and is very indestructible, resisting almost all reagents. Two chief views are held as to its origin. One that it is the last formed layer of adamant, which has not yet been calcified, and therefore the final product of the adamant cells. The other that it is produced by the outer layer of cells of the adamant organ. This latter seems to be the more probable view.

Substantia eburnea (ivory) is the hard and highly elastic substance, yellowish white in colour, which forms the greater part of the mass of every tooth (Fig. 856). Like the adamant it is highly calcified, but it differs from it in containing a very considerable amount of organic matter and water incorporated with its salts, which are chiefly phosphate and carbonate of lime.

Fresh human ivory contains 10 per cent of water, 28 per cent of organic and 62 per cent of inorganic material. The organic matter is composed chiefly of collagen, and to a less extent of elastin. The inorganic matter consists of (1) calcium phosphate (with a trace of fluoride), (2) calcium carbonate, and (3) magnesium phosphate, the percentages present in dried dentine being 66·72, 3·36, 1·08, respectively.

Ivory consists of a homogeneous, highly calcified, organic matrix, everywhere traversed by tubes—the **canaliculi dentales**—which give to this tissue a finely striated appearance, the striæ usually running in wavy lines. The canaliculi begin by open mouths on the wall of the pulp cavity, whence they run an undulating and spiral course, towards the periphery of the ivory. They give off fine anastomosing branches, and occasionally divide into two.

The canaliculi dentales are generally described as being lined by special sheaths (dentinal sheaths of Neumann) which are composed of a most resistant material, and possibly are calcified.

The canaliculi dentales are occupied by processes, prolonged from the outermost cells of the pulp—called after their discoverer, **Tomes' fibrils** (dentinal fibrils), and they are probably sensory in function.

The concentric **lines of Schreger**, frequently seen in the ivory, are due to bends in successive canaliculi along regular lines running parallel to the periphery of the ivory. Other lines (the incremental lines of Salter), due to imperfect calcification, are found arching across the substance of the ivory, chiefly in the crown. There must also be mentioned the **interglobular spaces**, intervals left in the ivory, as a result of imperfect calcification, bounded by the fully calcified surrounding tissue, the contour of which is in the form of a number of small projecting globules. These interglobular spaces are very numerous in the outer or "granular layer" of the ivory, particularly beneath the osseous substance.

The **substantia ossea** (O.T. **cement**) is a layer of modified bone which encases the whole of the tooth except its crown. It begins as a very thin stratum, slightly overlapping the adamant at the neck. From there it is continued, increasing in amount, towards the apex, which is formed entirely of this substance. It is relatively less in amount in the child, and increases during life. In places the ivory seems to pass imperceptibly into the substantia ossea, the "granular layer" marking the junction of the two, and some of the canaliculi dentales are continuous with the lacunæ of the substantia ossea. Like true bone, it is laminated, it possesses lacunæ, canaliculi, and, when in large masses, it may even contain a few Haversian canals.

The **pulpa dentis** is composed of a number of branched connective tissue cells, the anastomosing processes of which form a fine network, containing in its meshes a jelly-like material, in addition to numerous vessels and nerves, but no lymph-vessels. The most superficial of these cells are arranged in the young tooth as a continuous layer of columnar, epithelium-like cells, lying on the surface of the tooth pulp against the ivory; they are known as **odontoblasts**, for they are the active agents in the formation of the ivory. The vessels of the tooth pulp are numerous, and form a capillary plexus immediately within the odontoblasts. The nerves form rich plexuses throughout the pulp, but their exact mode of ending is unknown.

The **periosteum alveolare** is a layer of connective tissue free from elastic fibres, but well supplied both with blood-vessels and nerves, which fixes the root of the tooth in the alveolus, being firmly united by perforating fibres of Sharpey, to the substantia ossea on the one hand, and to the bone of the alveolus on the other. It establishes a communication between the bone of the jaw and the substantia ossea, and it is continuous with the tissue of the gum. Its blood comes chiefly from the arteries, which subsequently enter the apical foramina for the supply of the tooth pulp, but in part also from the vessels of the surrounding bone and of the gum (hence the relief obtained in dental periostitis by lancing the gum).

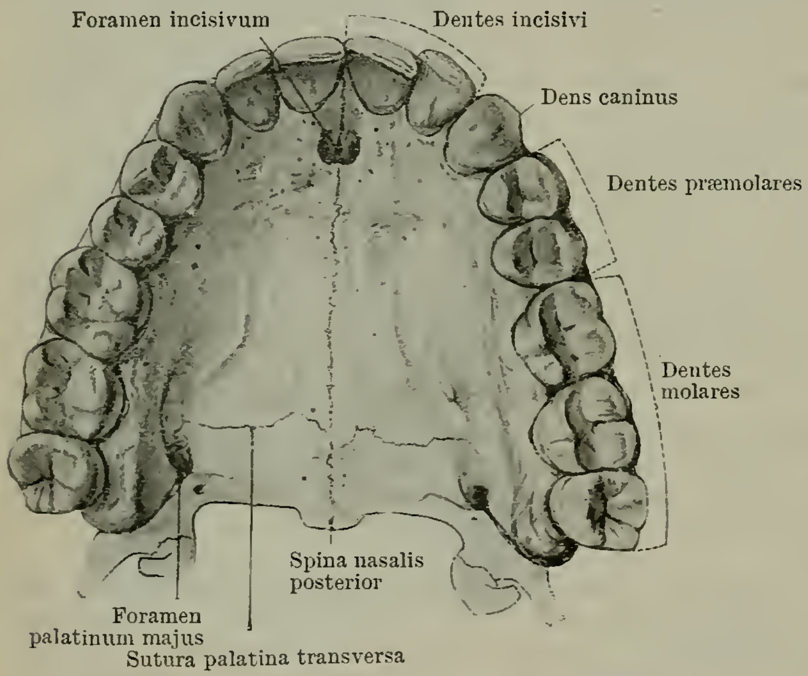


FIG. 857.—THE HARD PALATE AND UPPER PERMANENT TEETH, VIEWED FROM BELOW.

DENTES PERMANENTES.

Names and Numbers of the Teeth.—The two rows, upper and lower, contain the same number of teeth, and of similar varieties. The permanent teeth are thirty-two in number, eight above and eight below on each side. Each set of eight consists of two incisor teeth (dentes incisivi), a medial and a lateral, a single canine (dens caninus), two premolars (dentes præmolares, anterior and posterior), and three molars (dentes molares, first, second, and third), arranged in that order from the median plane. When the dentition is perfect each set is bilaterally symmetrical. The "dental formula" showing the number of teeth of each class above and below on one side is therefore in man :—

$$i.\ \tfrac{2}{2},\ c.\ \tfrac{1}{1},\ pm.\ \tfrac{2}{2}\ m.\ \tfrac{3}{3}.$$

Descriptive Terms.—The part of a tooth which comes in contact with the teeth of the opposite jaw is known as the **facies masticatoria** (grinding or masticating surface) (Fig. 857). The surface in contact with or looking towards its predecessor in the row is known as the **facies medialis** in incisors and canines, **facies anterior** in premolars and molars; the opposite surface is known as the **facies lateralis** in incisors and canines, **facies posterior** in molars and premolars. The surface which looks towards the tongue is the **facies lingualis** (lingual surface), and that towards the lips and cheek, the **facies labialis** (labial surface) or **facies buccalis** (buccal surface). The portion of a tooth which touches its neighbour in the same row is known as the **facies contacta** (contact surface).

Dentes Incisivi (Figs. 858 and 859).—In the incisor teeth the **crown** is chisel-shaped, the labial surface convex in all directions, the lingual surface concave, the edge chisel-like and, when first cut, surmounted by three small tubercles separated by two grooves. These tubercles, however, are soon worn down, and the edge becomes straight or nearly so. The upper incisors usually overlap the lower ones and hence the cutting edge is bevelled, on the lingual aspect of the former, and on the labial aspect of the latter. The upper, and particularly the central upper incisors, are of large size, and slope somewhat forwards; whilst the lower incisors, all of nearly equal size, are much smaller—being the smallest of all the teeth—and are placed vertically. The roots of the incisors are single, though a groove is occasionally seen on each side, suggesting a division.

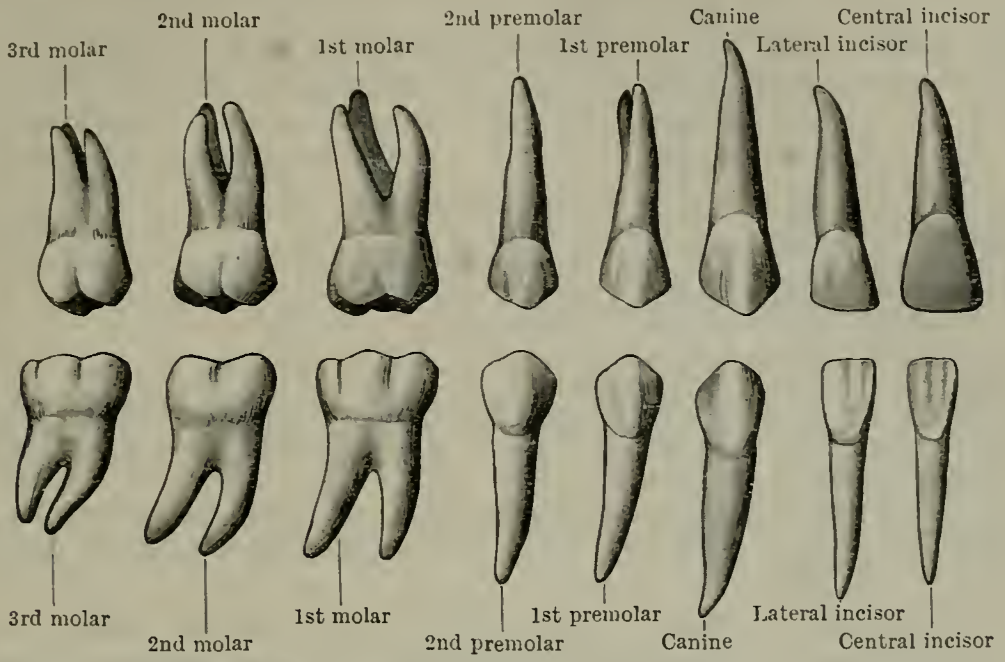


FIG. 858.—THE PERMANENT TEETH OF THE RIGHT SIDE, LABIAL OR BUCCAL SURFACES.

The upper row shows the upper teeth, the lower row the lower teeth. The wide vertical "labial ridge" is distinct on the upper canine and premolar teeth.

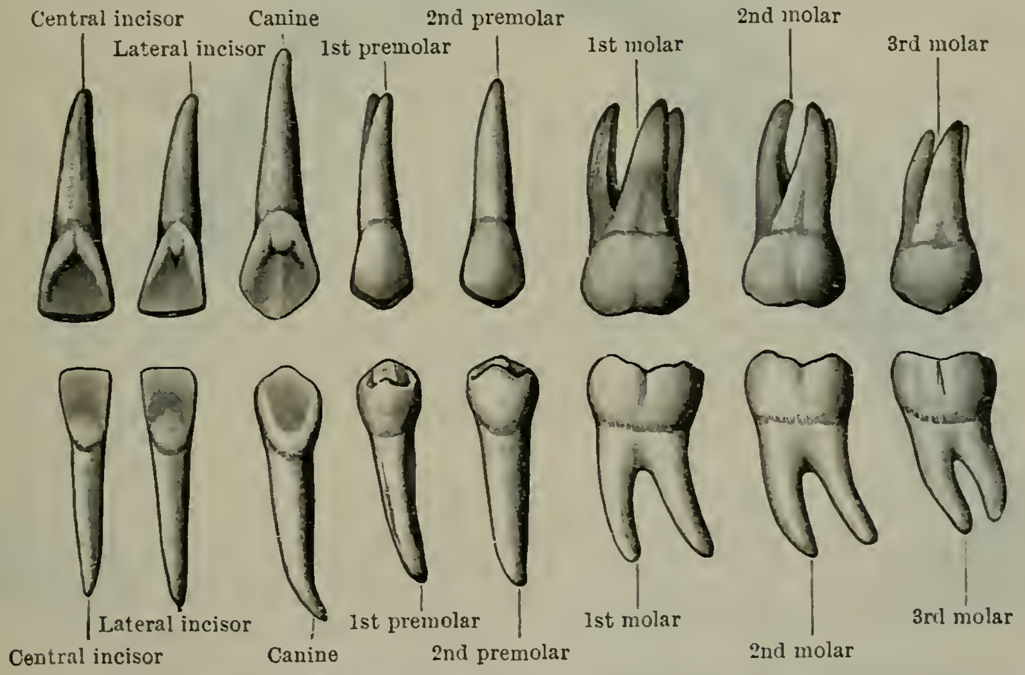


FIG. 859.—THE PERMANENT TEETH OF THE RIGHT SIDE, LINGUAL SURFACES.

The upper row shows the upper teeth, the lower row the lower teeth. The cingulum is distinct on the upper incisors and both canines, the lingual tubercle on the upper lateral incisor and the upper canine.

The central upper incisors are very much larger than the lateral upper incisors (Fig. 858), but in the mandible the opposite is the case, the lateral incisors being slightly the larger. In all incisors the lateral angle of the crown is more rounded than the medial. The concave lingual surface of the crown in the upper incisors is usually limited towards the gum by a Λ-shaped ridge (Fig. 859), known as the **cingulum**. The two limbs of the Λ are continued up along the sides of the lingual surface, whilst the apex is turned towards the gum; and here, particularly in the lateral incisor, there is often developed a small **lingual tubercle** (Fig. 859). The cingulum is rarely found on the lower incisors.

The roots of the upper incisors and canines are conical and rounded (the lateral incisors and canines not so distinctly as the central incisors) (Fig. 858), whilst those of the mandible are flattened from side to side (medio-laterally).

Dentes Canini.—In the four **canine teeth** (Figs. 858 and 859) the **crown** is large and conical, corresponding closely in general form to a very large central incisor with its angles cut away. The labial surface is convex, the lingual usually somewhat concave, and both surfaces show a slight ridge extending from the base of the crown to the point. The root is single and long, particularly in the upper canine, the root of which is longer than that of any other tooth, and produces the canine eminence on the anterior surface of the maxilla. The upper canines are larger than the lower ones, and are known as the "eye teeth."

The upper canine presents on its lingual surface a well-marked cingulum, and often a distinct lingual tubercle; in addition, there is usually a median ridge running from the point of the crown to the apex of the cingulum, which is separated from the lateral part of the cingulum on each side by a slight depression. These points are neither so well marked, nor so constant, in the lower as in the upper canine.

Of the two margins sloping away from the apex of the crown, the lateral is the longer in both teeth. After it has been a little worn the lower canine is less distinctly pointed than the upper; its root is also more flattened.

Dentes Præmolares (Figs. 858 and 859). — The **crown**, unlike that of the incisors and canines, is flattened antero-posteriorly, and shows a flat chewing surface, which is characterised by the presence of two tubercles (O.T. cusps) (Fig. 860), one, the larger, placed on the buccal, the other on the lingual side. The buccal and lingual surfaces are both convex. The **root** is single, but is, as a rule, flattened antero-posteriorly and grooved, showing in this a tendency to division, which often actually takes place in the first upper premolar. In the upper premolars the two tubercles are large and are separated from one another by a distinct antero-posterior fissure (Fig. 857); in the lower premolars, on the other hand, the separation between the two tubercles is not a continuous fissure, but two dimple-like depressions separated by a ridge which joins the two tubercles (Fig. 860). In the upper premolars, therefore, the two tubercles are separated by a fissure, in the lower they are united by a central ridge.

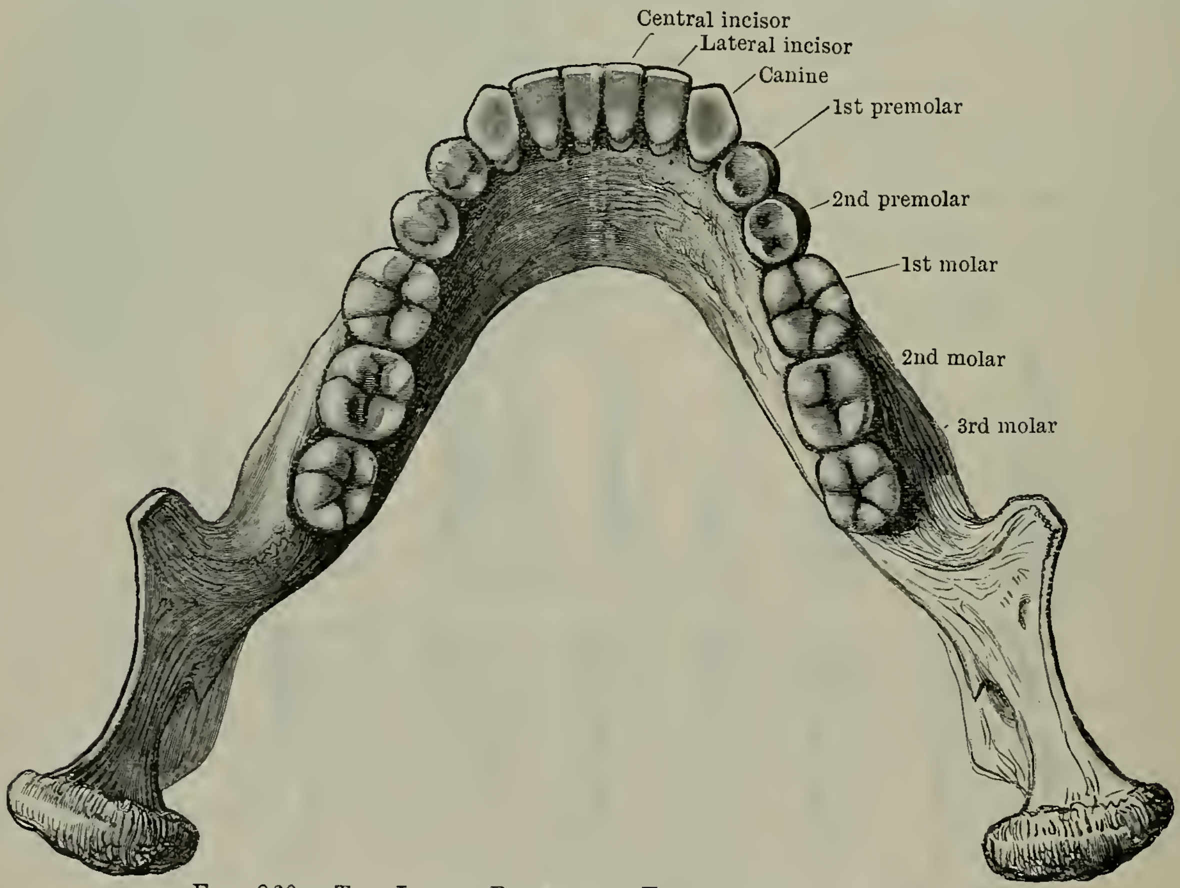


Fig. 860.—The Lower Permanent Teeth, viewed from above.

The first premolar is occasionally slightly larger than the second, in the upper but not in the lower set. The labial surface of the crown is usually somewhat larger than the lingual surface in all premolars. As a general rule, in the lower premolars the labial surface of the crown is sloped medially near the masticating surface. The first can usually be distinguished from the second by the fact that, while the lingual tubercle and surface are smaller than the labial in the first premolar, they are nearly of the same size in the second. In addition, the root of the first upper premolar is bifid or nearly so, and its labial ridge is fairly distinct, but is indistinct in the second. In the first lower premolar the lingual tubercle and surface are very small, in fact the tubercle is quite rudimentary. It should, however, be added that it is often extremely difficult to identify the various premolars.

Dentes Molares.—The **molar teeth** are distinguished as first, second, and third molars. The last in each jaw is also known as the **dens serotinus**, late appearing (*sēro* = late). All the molars are characterised by the large size of the crown and the possession of three or more trihedral tubercles on the masticating surface (Figs. 858 and 859). They are the largest of all the teeth. They diminish in size, as a rule, from the first to the third. In shape the crown is more or less quadrangular, with convex labial and lingual surfaces. The roots are either two or three in number, but frequently in the last molars they are united to a varying degree.

The molars of the maxilla and mandible differ considerably in detail. Normally the **upper molars** possess three roots (Figs. 858 and 859), whilst the **lower molars** have two at most. The number of tubercles, though not so reliable a guide as the form of the root, is also generally sufficient to distinguish them. In the upper molars there are either three or four tubercles, whilst in the lower the number is most commonly five.

In the **upper molars**, the **crown** (Fig. 857) is rhomboidal in shape (*i.e.* quadrangular with the angles not right angles). The labial and the lingual surfaces are convex. The number of **tubercles** is either four or three. On the *first* there are invariably four—two on the labial and two on the lingual side—the anterior lingual of these being connected with the posterior labial by an oblique ridge. The *second* upper molar has either four or three tubercles in about an equal proportion; in the third the number is much more frequently three. The **roots** in the upper molars are three in number, two buccal, and the third lingual, but are occasionally confluent in the third molar.

In the **lower molars**, the **crown** is somewhat cubical. The labial and lingual surfaces are convex, as in the upper molars. The *first*, as a rule, bears five tubercles, two labial, two lingual, and the fifth behind and buccal. The *second* has usually only four tubercles; a fifth, however, is sometimes present. The *third* has either four or five, the former number more frequently than the latter.

The **roots** of the lower molars are two in number, one root anterior, the other posterior, each wide, grooved, and flattened antero-posteriorly, and both are usually recurved in their lower portions. As in the corresponding teeth of the maxilla, the roots of the lower last molars are often more or less united into a single mass.

The upper molars are directed downwards and laterally; whilst the lower molars, which the former partly overlap, slope upwards and medially, with the result that the labial tubercles of the lower molars lie in the groove separating the lingual from the labial tubercles of the upper teeth. As a result of this overlapping, the labial edge of the crown is sharp and the lingual edge rounded in the upper molars; whilst the lingual edge is sharp and the labial edge rounded in the lower set.

The fissures which separate the cusps on the grinding surfaces of the molar teeth are generally continued as faint grooves on the labial and lingual surfaces.

The anterior and posterior surfaces of the upper molars are not in transverse but in oblique planes, sloping strongly postero-medially, and converging in that direction.

Lower Molars.—The **crowns** are more massive than those of the upper molars, and are elongated antero-posteriorly (Fig. 860). A crucial groove separates the four chief tubercles from one another; this bifurcates behind to enclose the fifth, which lies slightly to the labial side of the middle of the tooth.

The **roots** of the lower molars (Fig. 859), two in number, are flattened from before backwards, and very wide. The anterior of these has two root-canals; the posterior but one (Fig. 863). The dens serotinus has commonly two roots like its fellows; occasionally the two are united. In determining the side to which a lower molar belongs, it should be remembered that the deep part of the root is generally curved backwards, and also that the blunter margin of the crown (see above) and the fifth tubercle, if present, are on the labial side.

DENTES DECIDUI.

The **deciduous teeth** are twenty in number, ten above and ten below, or five in each half of each jaw—namely, two incisors, one canine, and two molars. They may be distinguished from the permanent teeth by their smaller size, their well-marked and constricted necks, and, in the case of the molars, by the wide divergence of their roots (Fig. 861). Otherwise they correspond closely to the same-named teeth of the permanent set. The first upper molar has, however, but three tubercles on its crown—two labial and one palatal; the first lower molar has four—two labial and two lingual; and the crowns of both are flattened from side to side. The second molars of the maxilla have four, those of the mandible five tubercles each. In every case the second are much larger than the first molars. The tubercles are sharper and are separated by deeper fissures or fossæ than those of the permanent teeth, whilst the roots of the deciduous molars, except for their greater divergence, agree with those of the permanent set.

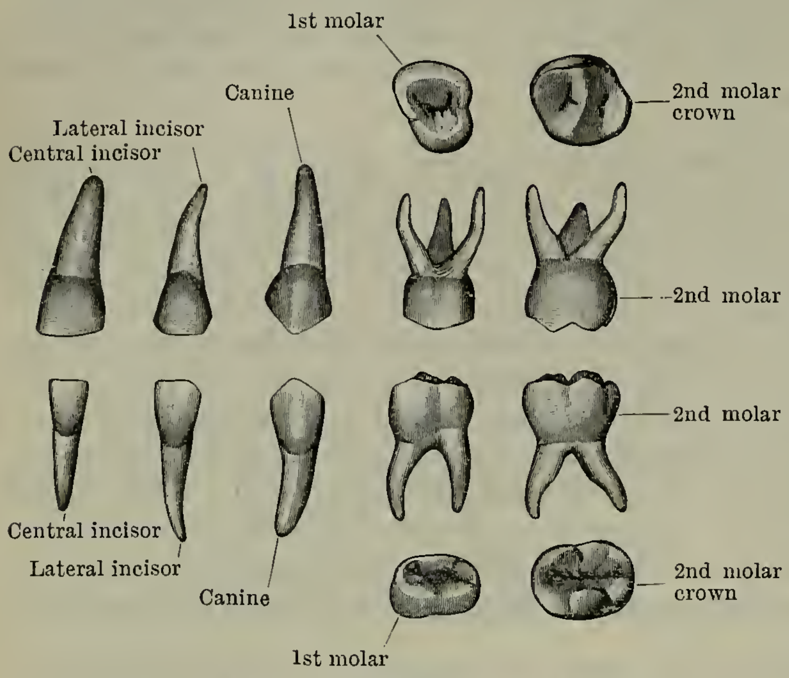


FIG. 861.—THE DECIDUOUS TEETH OF THE LEFT SIDE.

The masticating surfaces of the two upper molars are shown above. In the second row the upper teeth are viewed from the outer or labial side. In the third row the lower teeth are shown in a similar manner; and below are the masticating surfaces of the two lower molars. In the specimen from which the first upper molar was drawn the two labial tubercles were not distinctly separated, as is often the case.

The marked constriction at the neck of the deciduous teeth (Fig. 861) is due to a great thickening of the cap of adamant on the crown, and its abrupt termination as the neck is reached. The **adamant**, too, is much whiter as a rule than in the permanent teeth. It should be added that the labial surface of the canines and molars slopes strongly outwards towards the mouth cavity from the neck to the crown, which latter is, as a result, much reduced in width.

The divergence of the roots in the deciduous molars allows the crowns of the permanent premolars to fit in between them before the former molars are shed.

Dentes Decidui and Dentes Permanentes (Deciduous and permanent teeth).—The mouth of the infant at birth contains no teeth, although a number, partly developed, lie embedded in the jaws beneath the gum. Some six months later teeth begin to appear, and by the end of the second year a set, known as the **deciduous teeth** (O.T. **milk teeth**), twenty in number, has been "cut." The individual teeth of this set usually appear at the following ages: the lower central incisors between six and nine months, the upper incisors between eight and ten months, lower lateral incisors and first molars between fifteen and twenty-one months, the canines between sixteen and twenty months, the second molars between twenty and twenty-four months.

Then follows a pause of about four years, during which no visible change takes place in the mouth, although active preparation for further development is going on beneath the gum.

At about the sixth year the next stage in the production of the adult condition begins. It consists in the eruption of four new teeth—the first permanent molars—one on each side, above and below, behind those of the deciduous set. This is followed by the gradual falling out of the twenty deciduous teeth, and the substitution for them of twenty new teeth, which take up, one by one, the vacancies created by the dropping out of each of the deciduous set in the following order:—

First, at about the age of seven the central deciduous incisors fall out; then follow the remaining teeth in the following order: lateral incisors, 1st premolars, 2nd premolars, canines. It will be observed that the eruption of the canine is delayed until the two premolars, which succeed it in the row, are cut, so that it breaks the otherwise regular order of eruption. Finally, the adult condition is attained by the eruption of eight additional teeth—the 2nd and 3rd molars—two on each side, above and below, behind those which have already appeared. All of these—the **permanent teeth**—have appeared by the end of the twelfth or thirteenth year, except the four **dentes serotini** (**O.T. wisdom teeth**), which are usually cut between the seventeenth and twenty-fifth year, but are often delayed until a very much later period, and occasionally never appear. The 1st molar is sometimes popularly known, owing to the date of its eruption, as the "six-year-old tooth," and the 2nd molar as "the twelve-year-old tooth."

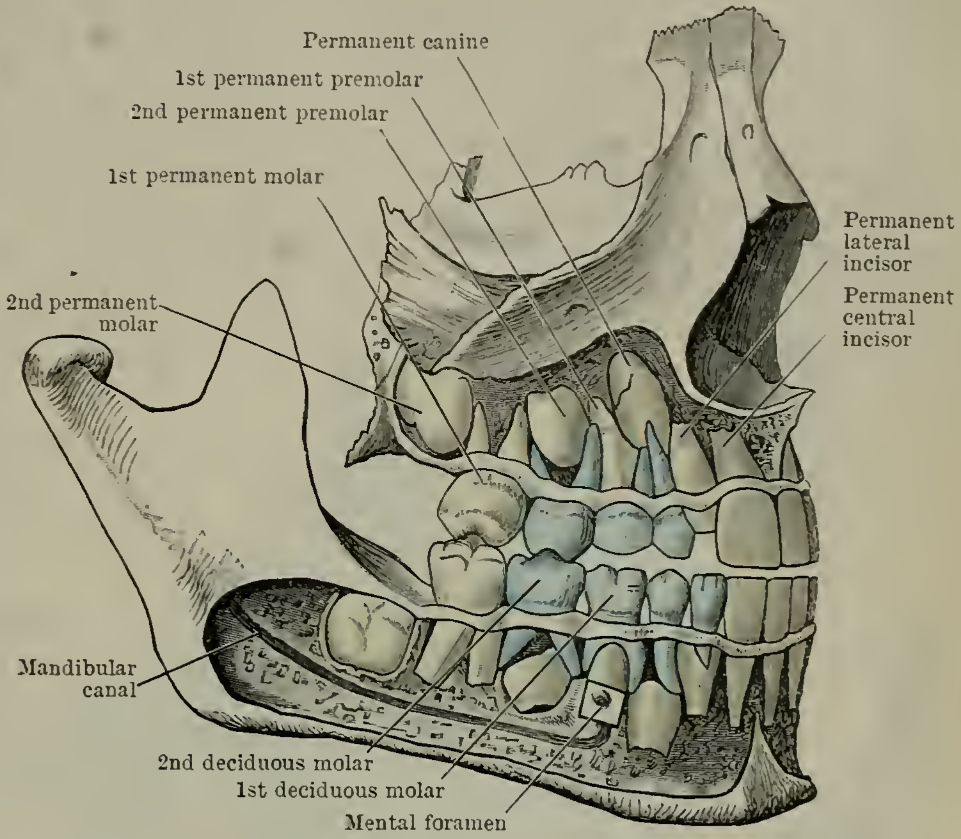


Fig. 862.—Teeth of a Child over Seven Years old. (Modified from Testut.)

By the removal of the bony outer wall of the alveoli, the roots of the teeth which have been erupted, and the permanent teeth which are still embedded in the mandible and maxilla, have been exposed. The deciduous teeth are coloured blue, the permanent teeth yellow. It will be seen that the first permanent molars have appeared, the central and lateral deciduous incisors have been replaced by the corresponding permanent teeth in the maxilla, but the deciduous canine and molars have not yet been shed. In the mandible the central deciduous incisor has been replaced by the permanent central; the lateral has not yet been shed, but its permanent successor is making its way up to the surface on its lingual side. In addition, the canine and two molars of the deciduous set persist. The position of the crowns of the permanent teeth between the roots of the deciduous molars, and the deep situation occupied by the permanent canines, should be noted. Observe also the absorption of the root of the lower lateral incisor.

The dates at which the eruption usually takes place may be simply stated as follows for the lower teeth; those of the upper jaw appear a little later:—

1st molars appear soon after the 6th year.
Central incisors appear soon after the 7th year.
Lateral ,, ,, ,, 8th ,,
1st premolar ,, ,, 9th ,,
2nd ,, ,, ,, 10th ,,
Canine ,, ,, ,, 11th ,,
2nd molar ,, ,, 12th ,,
3rd ,, ,, from the 17th ,, to 21st year, or even later.

Variations in the Number of the Teeth.—The presence of an additional tooth is by no means uncommon. It may appear in connexion with the incisor, premolar, or the molar groups. A distinction is drawn between "supernumerary" or imperfect additions to the dentition and "supplemental" teeth which correspond in size with those with which they are associated. When a supplemental incisor appears it has an interesting bearing upon the solution of the much-debated point as to which incisor has disappeared from the primate dentition. A fourth molar is occasionally present.

Arrangement of the Teeth in the Jaws.—The teeth are arranged in each jaw in a curved row—the **arcus dentalis**—of approximately a semi-oval form (Figs. 857 and 860). The curve formed by the upper teeth, **arcus dentalis superior,** however, is wider than that formed by the lower set, **arcus dentalis inferior,** so that when the two are brought in contact the upper incisors and canines overlap their fellows in front, and the labial tubercles of the upper premolars and molars overlap the corresponding ones of the lower teeth (Fig. 135, p. 129). It will also be seen that, as a rule, the teeth in one jaw are not placed exactly opposite their fellows, but rather opposite the interval between two teeth, in the other jaw (Fig. 135). This arrangement is brought about largely by the great width of the upper central incisors as compared with their fellows of the mandible, which throws the upper canines and the succeeding teeth into a position behind that of the same-named teeth of the lower set. But as the lower molars are larger in their antero-posterior diameter than those of the upper row—and this remark applies particularly to the third molars—the two dental arches terminate behind at approximately the same point.

The upper dental arch is said to form an **elliptical**, the lower a **parabolic curve** (Figs. 857 and 860). The line formed by the masticating surfaces of the upper teeth, as seen on profile view (Fig. 135), is usually somewhat convex, owing largely to the failure of the third molar to descend into line with the others. Similarly the line of the lower teeth is as a rule concave.

In both jaws the crowns of the front teeth are higher (longer) than those of the molars.

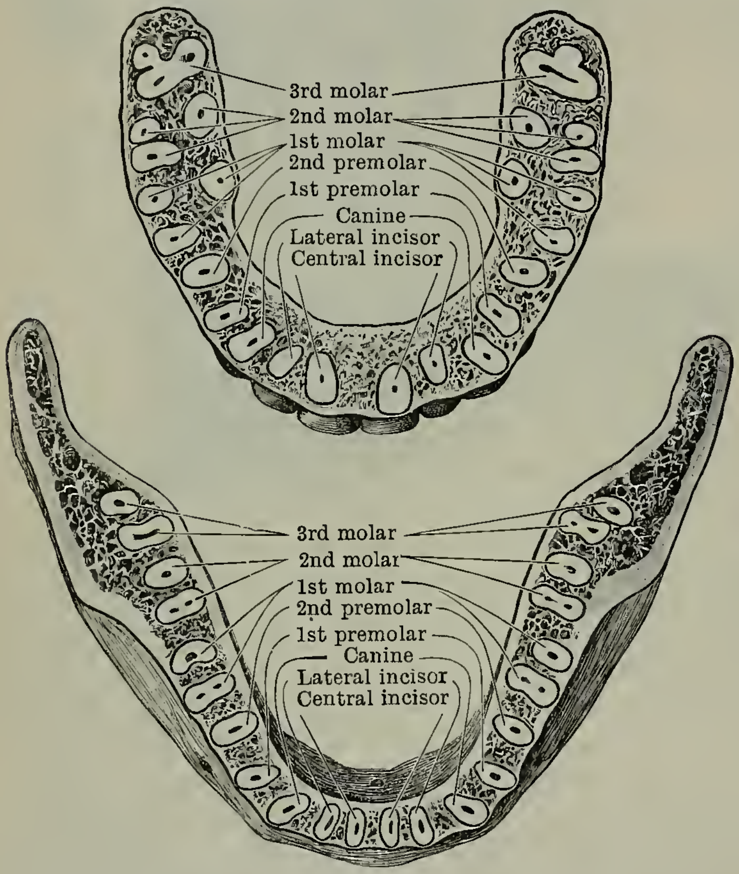


Fig. 863.—Horizontal Sections through both the Maxilla and Mandible to show the roots of the teeth. The sections were carried through the bones a short distance from the edge of their alveolar borders. The upper figure shows the upper teeth, the lower figure the lower teeth. Note the flattened roots of the lower incisors, the two root-canals in the anterior root of each lower molar, and the confluence of the three roots of the upper last molars.

LINGUA.

The **tongue** is a large mobile mass, which occupies the floor of the mouth and forms the anterior wall of the oral part of the pharynx (Fig. 865). It is composed chiefly of muscular tissue, and is covered by mucous membrane.

The sense organs of taste are found on its surface. It is an important organ of speech, and it assists in the mastication and deglutition of the food—functions which it is well fitted to perform, owing to its muscular structure and great mobility. In length it measures about three and a half inches (9 cms.) when at rest, but its length and width vary with every change in the condition of the organ.

In describing the tongue we distinguish the following parts: the **corpus linguæ** (body), made up chiefly of striped muscle, and forming the mass of the organ; the **dorsum linguæ** (Fig. 864), which looks towards the palate and pharynx, and is free in its whole extent; the **base,** the posterior wide end which is attached to the hyoid bone; the **apex linguæ,** the pointed and free anterior extremity; the **margo lateralis,** which is free in its anterior half or more, *i.e.* in front of the attachment of the anterior palatine arch (Fig. 864). Finally, the unattached portion on the inferior aspect, seen when the apex is turned strongly upwards (Fig. 867), constitutes the **facies inferior,** or inferior surface; whilst the thick posterior portion, fixed by muscles and mucous membrane to the hyoid bone and mandible, is known as the **radix linguæ** or root.

The **dorsum of the tongue**, when the organ is at rest, is strongly arched antero-posteriorly in its whole length (Fig. 865), the greatest convexity corresponding to the attachment of the glosso-palatine arch. When removed from the body the tongue, unless previously hardened *in situ*, loses its natural shape, and appears as a flat, elongated, oval structure, which gives a very erroneous idea of its true form and connexions.

Both in structure and in function, as well as in embryological history, the dorsum linguæ is divisible into two areas—an anterior or *oral part*, which lies nearly horizontally on the floor of the mouth, and constitutes about two-thirds of the length of the whole tongue (Fig. 865); and a posterior or *pharyngeal part*, the remaining third of the organ, which is placed nearly vertically, and forms the anterior wall of the oral pharynx (Fig. 865). The separation between these two parts, which differ in appearance as well as in direction, is indicated by a distinct V-shaped groove, called the **sulcus terminalis** (Fig. 864), the apex of which is directed backwards, and corresponds to a depression on the surface of the tongue, the **foramen cæcum**, whilst its diverging limbs pass laterally and forwards towards the attachments of the glosso-palatine arch. The foramen cæcum is the remains of a tubular downgrowth formed early in embryonic life, in the floor of the primitive pharynx, from which the thyreoid gland is developed (see p. 49).

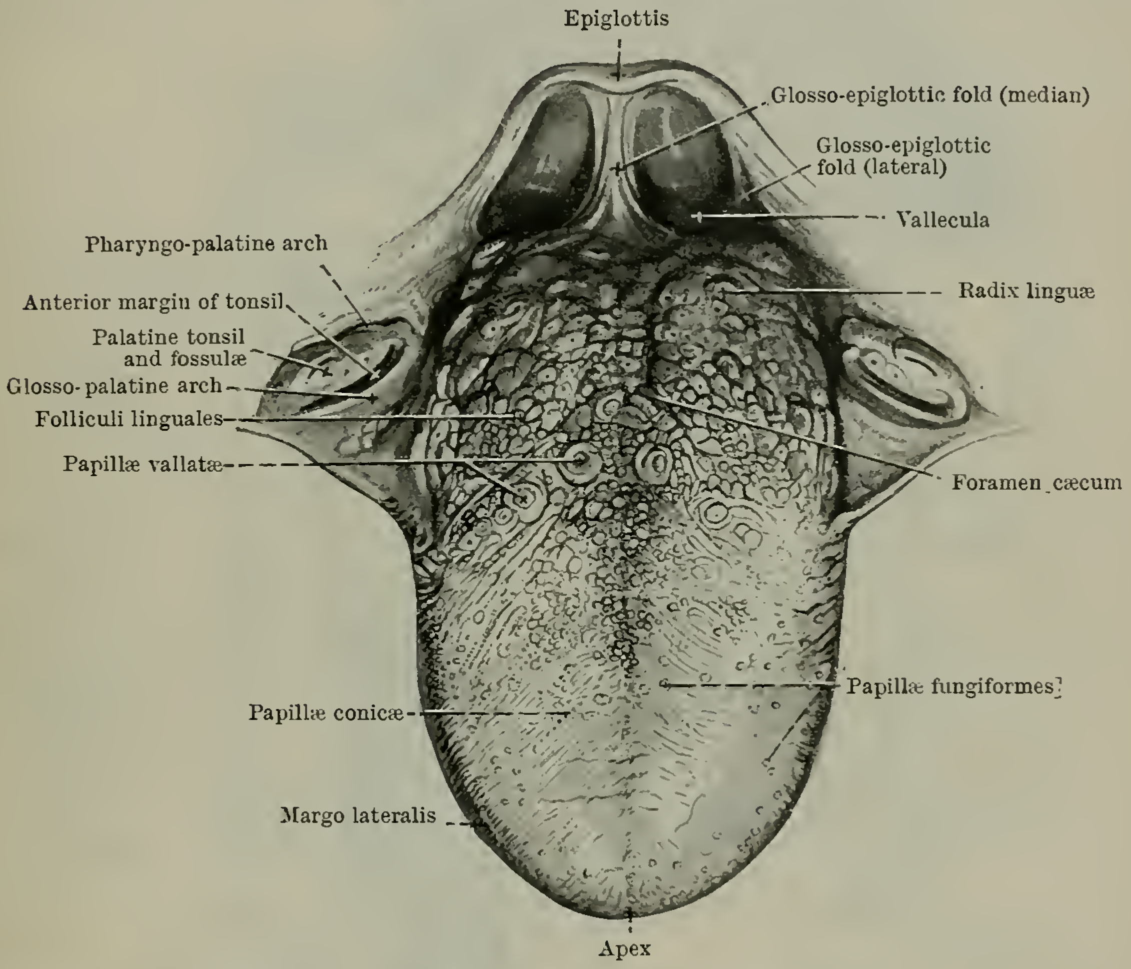


FIG. 864.—DORSUM OF TONGUE AND PALATINE TONSILS.

The **anterior or oral portion of the dorsum linguæ** (Fig. 864) usually presents a slight median depression, **sulcus medianus**, which ends posteriorly near the foramen cæcum.

Its surface is velvety and is covered with innumerable papillæ; the taste-buds are situated in it, and it is horizontal in position. It is developed from the tissues of the floor of the pharynx immediately behind the first visceral arch.

The posterior portion, on the other hand, has a smooth glistening surface, contains numerous serous glands and small lymph follicles, and is more vertical in position. It is developed from the tissue covering the ventral ends of the second and third visceral arches (see p. 50).

This **posterior portion** (Fig. 864) forms the greater portion of the anterior wall of the oral part of the pharynx (Fig. 865). Its surface is free from evident papillæ, but is thickly studded with rounded projections, each presenting, as a rule, a little pit, visible to the naked eye, at its centre; the great majority of these **folliculi linguales** (lingual follicles, Fig. 864) are similar to the lymph follicles found in the palatine tonsils; some few are said to be mucous glands; all are covered by a smooth mucous membrane, and they combine to give to this region a characteristic nodular appearance. To this collection of follicles the name **tonsilla lingualis** is applied.

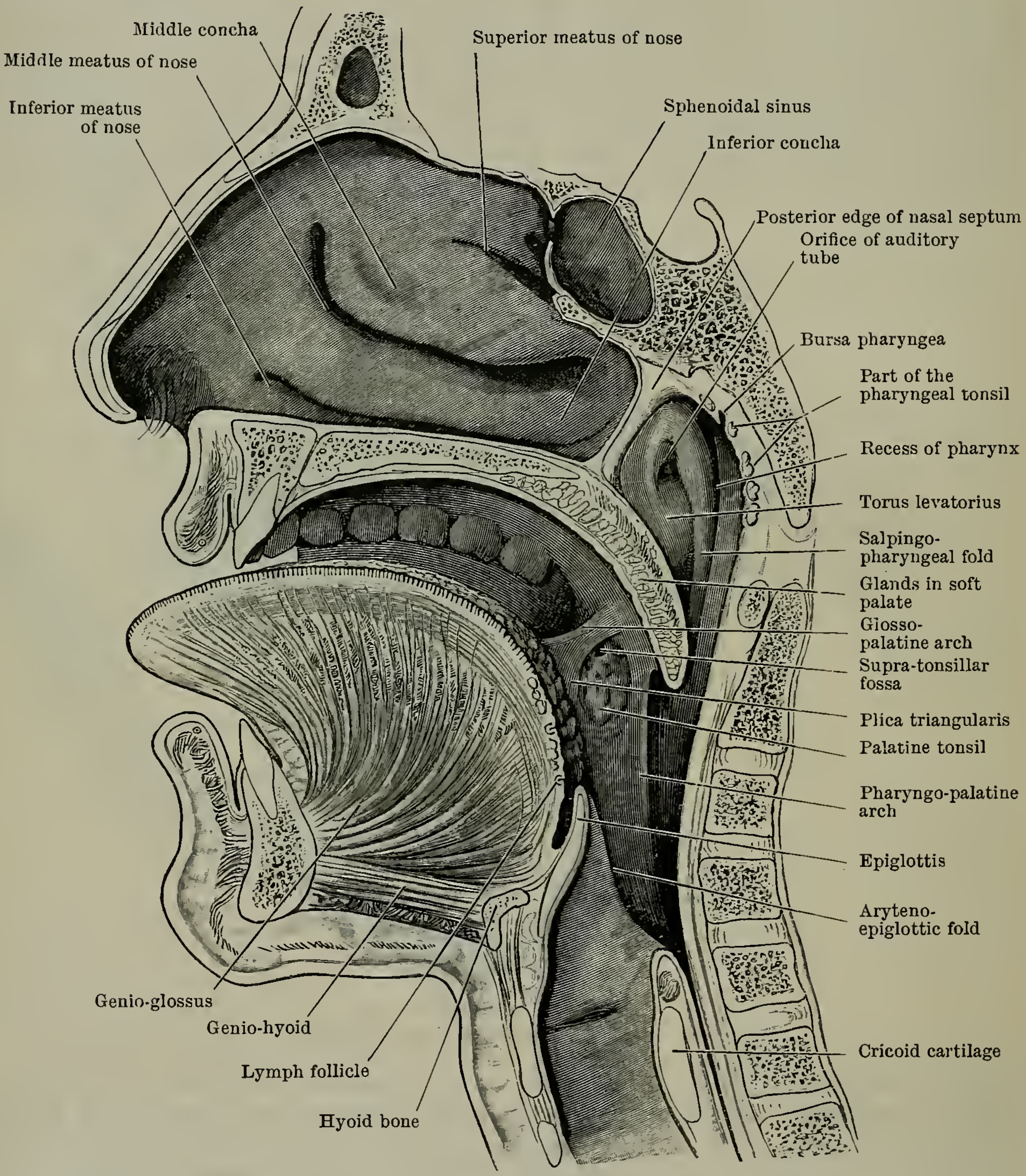


Fig. 865.—Sagittal Section through Mouth, Tongue, Larynx, Pharynx, and Nasal Cavity.

The section was slightly oblique, and the posterior edge of the nasal septum has been preserved. The specimen is viewed slightly from below, hence the apparently low position of the inferior concha.

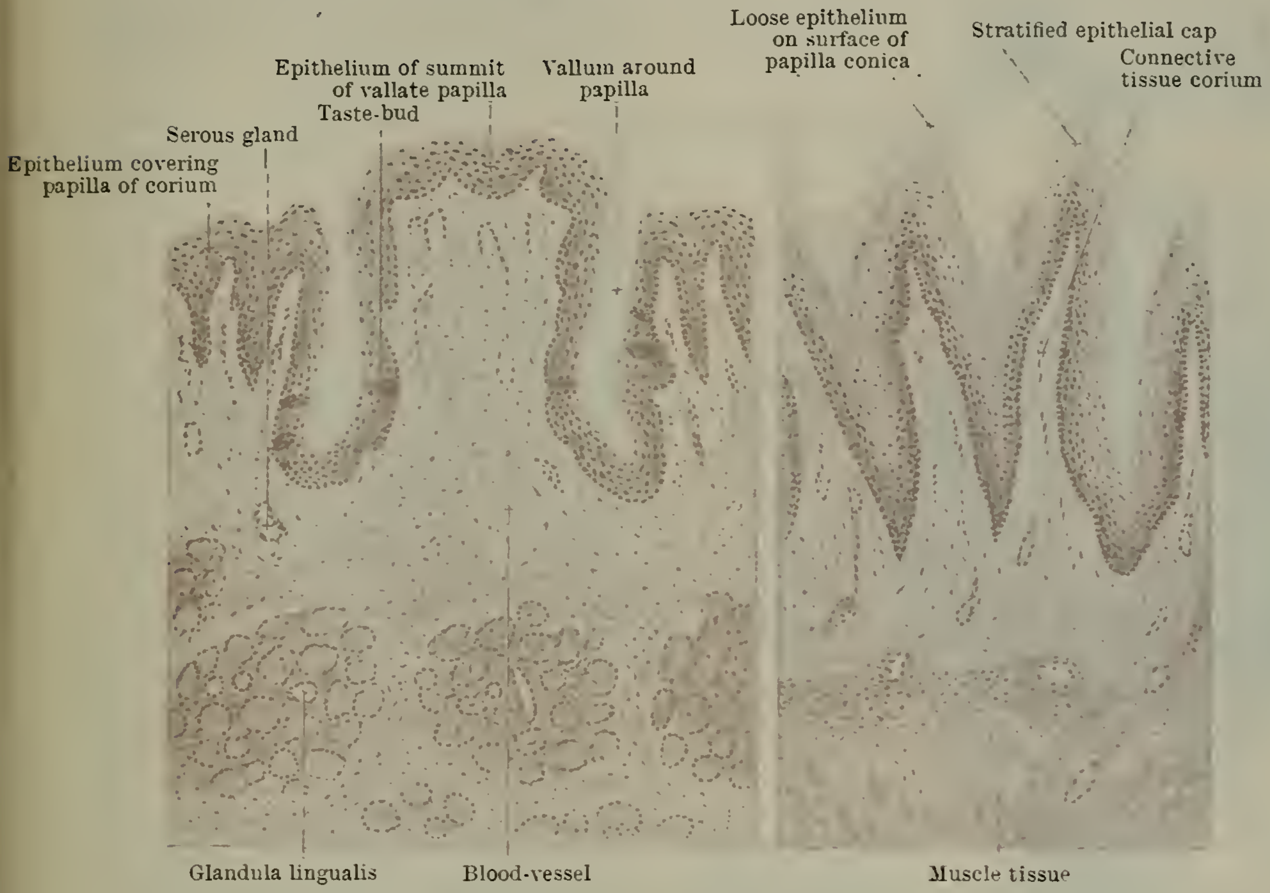
On the pharyngeal part of the tongue there are also small papillary projections of the corium, but the epithelium fills up all the intervals between the papillæ, and levels off the surface, so that none are visible to the eye as projections above the general level. Over the anterior part of the tongue, on the contrary, the projections of the corium are large and prominent, and the intervals between them are not filled up by the epithelium, so that the projections stand out distinctly and independently, and in places attain a height of nearly 2 mm. above the general surface.

The *mucous membrane* of this portion of the tongue is separated from the muscular substance by a submucous layer in which the lymph follicles and the mucous glands lie embedded (Fig. 868). At the sides it is continuous with the tunica mucosa covering the palatine tonsils and the side wall of the pharynx; whilst posteriorly it is reflected on to the front of the epiglottis, forming in the middle line a prominent fold, the **plica glosso-epiglottica** (Fig. 864), at each side of which is a wide depression, the **vallecula.**

On each side is a **pharyngo-epiglottic fold,** which passes from the side of the epiglottis, upwards along the wall of the pharynx, upon which it is soon lost.

Papillæ of the Tongue (Fig. 864).—These are formed by variously shaped projections of the corium of the mucous membrane, covered by thick caps of epithelium. They are of three main varieties: 1, Conical and filiform (*papillæ conicæ, p. filiformes*); 2, Fungiform and lenticular (*papillæ fungiformes et p. lenticulares*); and 3, Vallate and foliate (*papillæ vallatæ et p. foliatæ*).

The **conical and filiform papillæ** (Fig. 864) are the smallest and most numerous, forming as they do a dense crop of minute projections all over the anterior two-thirds of the dorsum, and also upon the superior part of the margin and tip, of the tongue. Posteriorly they are arranged in divergent rows running laterally and forwards from the raphe, parallel to the limbs of the sulcus terminalis. More anteriorly, the rows become nearly transverse, and near the tip irregular. Each papilla is composed of a conical projection of the corium, covered with microscopic papillæ like those of the skin, and covered by a thick long cap of stratified squamous epithelium.


Loose epithelium on surface of papilla conica
Stratified epithelial cap
Epithelium of summit of vallate papilla
Vallum around papilla
Connective tissue corium
Taste-bud
Serous gland
Epithelium covering papilla of corium
Glandula lingualis
Blood-vessel
Muscle tissue

A FIG. 866. B

A. Section of a papilla vallata of tongue. B. Section of papillæ conicæ of tongue.

In many of them the cap of epithelium is broken up into several long, slender, hair-like processes, giving rise to the variety known as *filiform papillæ.* The cap of epithelium is being constantly shed and renewed, and an excessive or diminished rate of shedding or renewal, coupled with the presence of various fungi, gives rise to the several varieties of "tongue" found in different diseases.

The conical papillæ are longer and larger than the filiform, and have a wider base. They are situated on the dorsum among the filiform papillæ, and resemble them in their structure.

The conical and filiform papillæ are probably of a prehensible or tactile nature, and are highly developed, and horny, in carnivora.

The **fungiform and lenticular papillæ** (Fig. 864) are larger and redder, but less numerous than the first variety, and they are found chiefly near the tip and margins of the tongue, comparatively few being present over the dorsum generally. Each is in shape like a "puff-ball" fungus, consisting of an enlarged rounded head, attached by a somewhat narrower base. As in the case of the conical papillæ, the corium is studded over with microscopic papillæ, which are buried in the covering of squamous epithelium and do not appear on the surface. Most of the fungiform papillæ, if not all, appear to be furnished with taste-buds, and they are probably intimately connected with the sense of taste. The lenticular papillæ are placed on the margin of the tongue. They are flatter than the fungiform papillæ, and do not contain taste-buds.

The **vallate papillæ** (O.T. **circumvallate**) (Fig. 864), much the largest of all the papillæ of the tongue, are confined to the region immediately in front of the sulcus terminalis and foramen cæcum. Usually about nine to fourteen in number, they are arranged in the form of the letter V, with the apex posteriorly, just in front of and parallel to the sulcus terminalis. One or two of the papillæ are usually placed at the apex of the V, immediately anterior to the foramen cæcum. In appearance a vallate papilla resembles very closely the impression left by the barrel of a small pen pressed on soft wax (Fig. 866). Each is composed of a cylindrical central part (1 to 2·5 mm. wide), slightly tapering towards its base, and flattened on its crown, which projects a little above the general surface of the tongue. This is surrounded by a deep, narrow, circular trench or **fossa**, the outer wall of which is known as the **vallum**. The vallum appears in the form of an encircling collar very slightly raised above the adjacent surface (Fig. 866).

As in the case of the other forms, the vallate papillæ are made up of a central mass of corium, studded with numerous microscopic papillæ on the crowns, but not on the sides, and covered over, as are the surfaces of the fossa and vallum, by stratified squamous epithelium. Into the fossæ open the ducts of some small serous glands (Fig. 866 A).

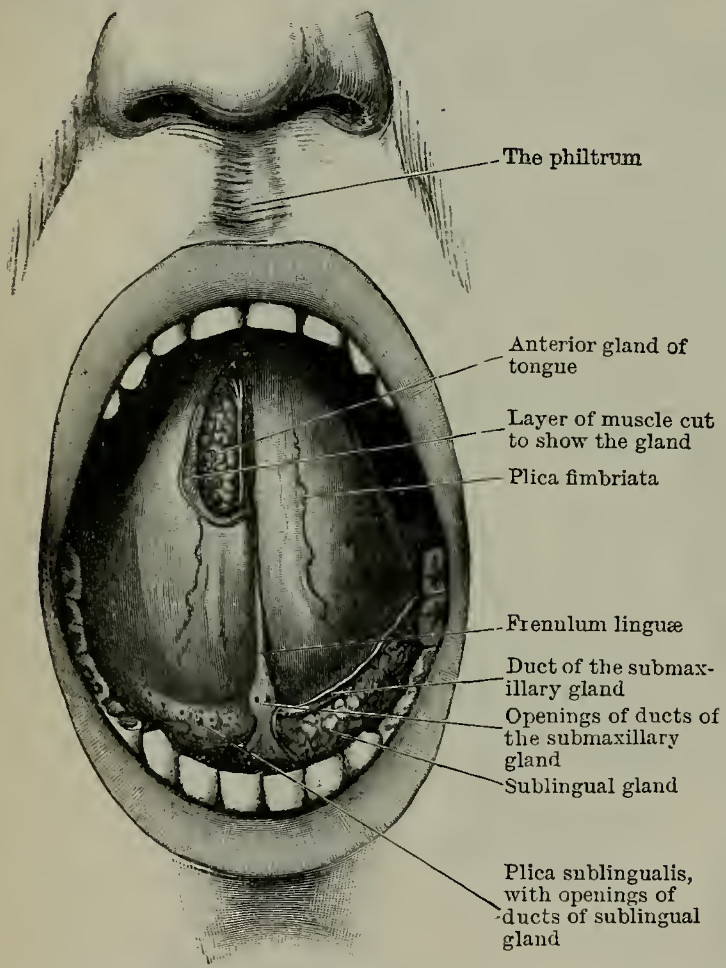

The philtrum
Anterior gland of tongue
Layer of muscle cut to show the gland
Plica fimbriata
Frenulum linguæ
Duct of the submaxillary gland
Openings of ducts of the submaxillary gland
Sublingual gland
Plica sublingualis, with openings of ducts of sublingual gland

FIG. 867.—OPEN MOUTH WITH TONGUE RAISED, AND THE SUBLINGUAL AND ANTERIOR LINGUAL GLANDS EXPOSED.

The sublingual gland of the left side has been laid bare by the removal of the mucous membrane; to expose the anterior gland of the right side a thin layer of muscle, in addition to the mucous membrane, has been removed. A branch of the lingual nerve is seen running on the medial aspect of the gland. The vena profunda linguæ is faintly indicated on this side also.

On the sides of the vallate papillæ, as well as upon the opposed surface of the vallum, are found, in considerable numbers, the structures known as **taste-buds**, the special end-organs of the nerves of taste.

Just anterior to the glosso-palatine arch, on the margin, are usually seen about five or six distinct vertical folds, forming the **folia linguæ**, which are studded with taste-buds. They correspond to the papillæ foliatæ on the side of the tongue in certain animals (rabbit, hare, etc.), in which they form an important part of the organ of taste.

The **apex** and the **margin** of the tongue in front of the attachment of the glosso-palatine arch are free, and lie in contact with the teeth when the tongue is at rest.

The **inferior surface** of the tongue, which is exposed by turning the apex of the organ upwards, is free from visible papillæ, the surface being covered by a smooth mucous membrane. Running along its middle, except near the tip, is a depression, from which a fold of mucous membrane, the **frenulum linguæ**, passes down to the floor of the mouth, and on towards the posterior aspect of the mandible. At each side of the frenulum, and a short distance from it, the large profunda linguæ vein is distinctly seen through the mucous membrane. Further out still are situated two indistinct, fringed folds of mucous membrane, the **plicæ fimbriatæ**, which converge somewhat as they are followed forward towards the tip, near which they are lost.

The **plicæ fimbriatæ** correspond pretty closely to the course of the deep lingual arteries as they run towards the tip; the arteries, however, are deeply placed in the substance of the tongue, at a distance of 3 to 6 mm. from the inferior surface.

The **root of the tongue** is the portion which is connected by muscles and mucous membrane to the mandible and hyoid bone. It is of very considerable extent, and is, with the base, the most fixed part of the organ.

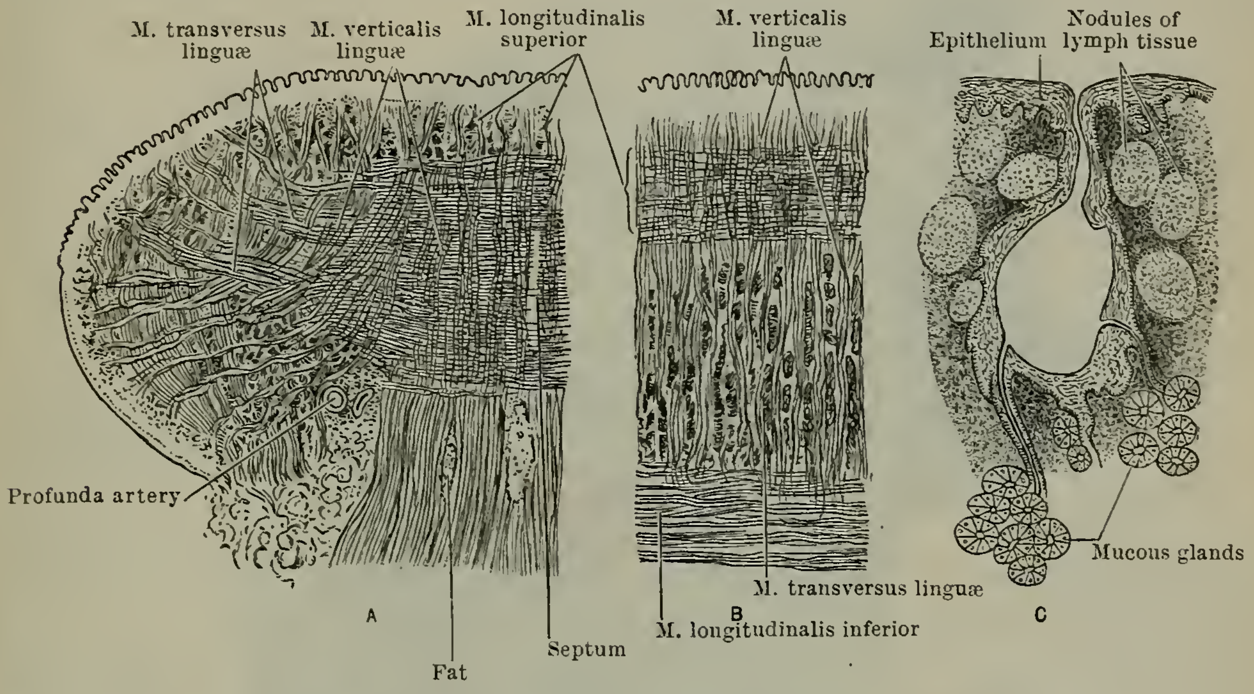


FIG. 868.—A, TRANSVERSE, AND B, LONGITUDINAL VERTICAL SECTION THROUGH THE TONGUE (Krause); C, A LYMPH FOLLICLE FROM POSTERIOR PART OF THE TONGUE. (Macalister, slightly modified.)

Structure of the Tongue.—The tongue is composed chiefly of striped muscular tissue, with a considerable admixture of fine fat. A median septum of connective tissue occupies the central part of the organ. In addition, there are vessels, nerves, glands, and lymph tissue, the whole being covered over by mucous membrane, except at the root (Fig. 868).

The muscular tissue is derived partly from the terminations of the extrinsic muscles—namely, the hyo-glossus, stylo-glossus, genio-glossus, glosso-palatinus, and chondro-glossus; and also largely from the intrinsic muscles—namely, the longitudinalis superior, the longitudinales inferiores, the transversus linguæ, and the verticalis linguæ. These are so arranged that they form a **cortical portion**, made up chiefly of longitudinal fibres—derived, above, from the longitudinalis superior and the hyo-glossus, at the sides, from the stylo-glossus, and, below, from the longitudinales inferiores. This cortex surrounds a central or **medullary portion**, divided into two halves by the median **septum**, and formed in great part by the transverse and vertical fibres, and also by the fibres of the genio-glossi ascending to the dorsum. The muscular fibres derived from these various sources end by being inserted into the deep surface of the mucous membrane.

The detailed description of the extrinsic and intrinsic muscles will be found on page 464.

The **septum** is a median fibrous partition found in the medullary portion only. Anteriorly it usually extends to the apex; whilst posteriorly it grows gradually narrower, and expanding transversely it passes into a broad sheet (the hyo-glossal membrane) which is united to the upper border of the hyoid bone, and gives attachment to the posterior fibres of the genio-glossus. From the sides of the septum the fibres of the transverse muscle of the tongue arise.

The **mucous membrane** on the anterior two-thirds of the dorsum, and on the free margins, is firm and closely adherent to the underlying muscular substance, the fibres of which are inserted into it. On the posterior third of the dorsum, and on the inferior surface, it is neither so firm nor so closely united to the muscular substance, from which it is separated in both of these situations by a layer of submucous tissue.

The mucous membrane of the tongue, like that of the rest of the mouth, is covered by stratified squamous epithelium.

Glandulæ Linguales.—Numerous small racemose glands are found scattered beneath the mucous membrane of the posterior third of the tongue; and a small collection of similar glands is present at the margin, opposite the vallate papillæ. Small serous glands are also found embedded in the dorsum near the vallate papillæ, into the fossæ of which their ducts open (Fig. 866).

The chief collections of glandular tissue in the tongue, however, are found embedded in the muscle of the under surface, a little way posterior to the apex, on each side of the middle line (Fig. 867). They are known as the **glandulæ linguales anteriores** of Blandin or Nuhn.

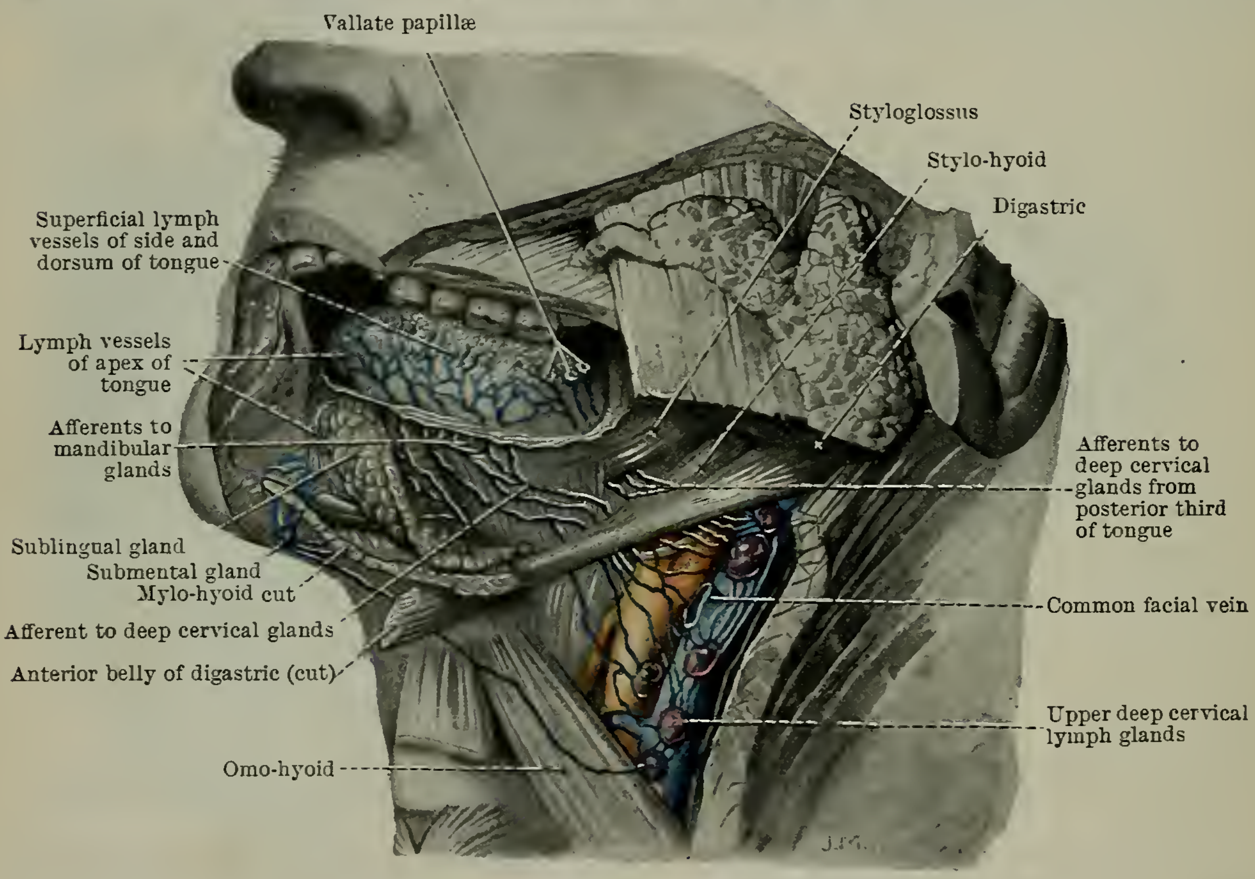

Vallate papillæ
Styloglossus
Stylo-hyoid
Digastric
Superficial lymph vessels of side and dorsum of tongue
Lymph vessels of apex of tongue
Afferents to mandibular glands
Sublingual gland
Submental gland
Mylo-hyoid cut
Afferent to deep cervical glands
Anterior belly of digastric (cut)
Omo-hyoid
Afferents to deep cervical glands from posterior third of tongue
Common facial vein
Upper deep cervical lymph glands
J.T.G.

FIG. 869.—LYMPH-VESSELS OF THE TONGUE. (After Poirier and Cuneo, modified.)

These glands are displayed after the removal, from the under surface of the tongue, of the mucous membrane and a layer of muscle fibres about 2 mm. thick which is composed of fibres of the stylo-glossus and the longitudinalis inferior muscles a little distance behind the apex. The anterior lingual glands are oval in shape, often partly broken up by muscular fibres, and they measure from $\frac{1}{2}$ to $\frac{3}{4}$ in. (12 to 19 mm.) in length. They are mixed serous and mucous glands, and they open by three or four very small ducts on the inferior surface of the tongue.

Vessels.—The chief *artery* is the **lingual**. This vessel passes forwards, on each side, medial to the hyo-glossus muscle, and then is continued on to the apex—between the genio-glossus on the medial side and the longitudinalis inferior laterally—under the name of the **a. profunda linguæ.** Anteriorly it is covered by the fibres of the longitudinalis inferior, and lies $\frac{1}{8}$ to $\frac{1}{4}$ in. from the surface. Near the apex the arteries of opposite sides are connected by a branch which pierces the septum; but otherwise, with the exception of capillary anastomosis, they do not communicate. The **rami dorsales linguæ** of the lingual artery are distributed to the pharyngeal part of the tongue, whilst some twigs of the **ramus tonsillaris** of the external maxillary artery are also distributed in the same region.

The **veins** are: The **v. profunda linguæ**, the chief vein, which lies beneath the mucous membrane at the side of the frenulum, and runs backwards over the hyoglossus with the hypoglossal nerve; two **venæ comites**, which accompany the lingual artery; and two **dorsales linguæ veins** from the back of the tongue. These either unite and form a common trunk, or open separately into the internal jugular vein.

The **lymph-vessels** of the tongue take their origin in an extensive lymph network in the submucous coat, and a smaller network connected with the first, in the muscular substance of the tongue. The network at the apex, including the tip, margins, and front of the dorsum, is drained by some two to four vessels on each side, which pass downwards by the margin of the genio-glossus muscle and pass laterally to the inferior deep cervical lymph glands. These vessels may be connected with the submental lymph glands also.

From the margins and dorsum of the tongue, behind the former area, and extending back to the vallate papillæ, lymph-vessels pass to the submaxillary lymph glands, and also, on the hyo-glossus muscle, to the upper deep cervical lymph glands, especially to some glands near the bifurcation of the common carotid artery. From the posterior part of the tongue the lymph-vessels pass laterally on each side below the palatine tonsil, and thence follow the course of the tonsillar lymph-vessels to the upper deep cervical lymph glands. Some central vessels, from the median portion of the tongue, pass downwards to the submaxillary glands, and also to the upper deep cervical glands, on the lateral side of the internal jugular vein.

Nerves. — The nerves which supply the tongue are: (1) The **hypoglossal nerve**, the motor nerve of the tongue, which enters the genio-glossus and passes up in its substance to the intrinsic muscles, in which it ends. (2) The **lingual nerve**, a branch of the mandibular nerve, which is accompanied by the **chorda tympani branch** of the facial nerve. The lingual, after crossing the hyo-glossus, breaks up and enters the longitudinalis inferior and genio-glossus muscles, and thus makes its way upwards to the mucous membrane of the anterior two-thirds of the tongue—the lingual itself conferring common sensation on this part, the chorda tympani probably carrying to it taste fibres. (3) The **glosso-pharyngeal nerve** passes forwards beneath the upper part of the hyo-glossus muscle, and sends its terminal branches to the mucous membrane of the posterior third of the tongue, supplying the papillæ vallatæ, and the part of the tongue behind these, with both gustatory and common sensory fibres. (4) The **internal laryngeal nerve** also distributes a few fibres to the posterior part of the base of the tongue, near the epiglottis.

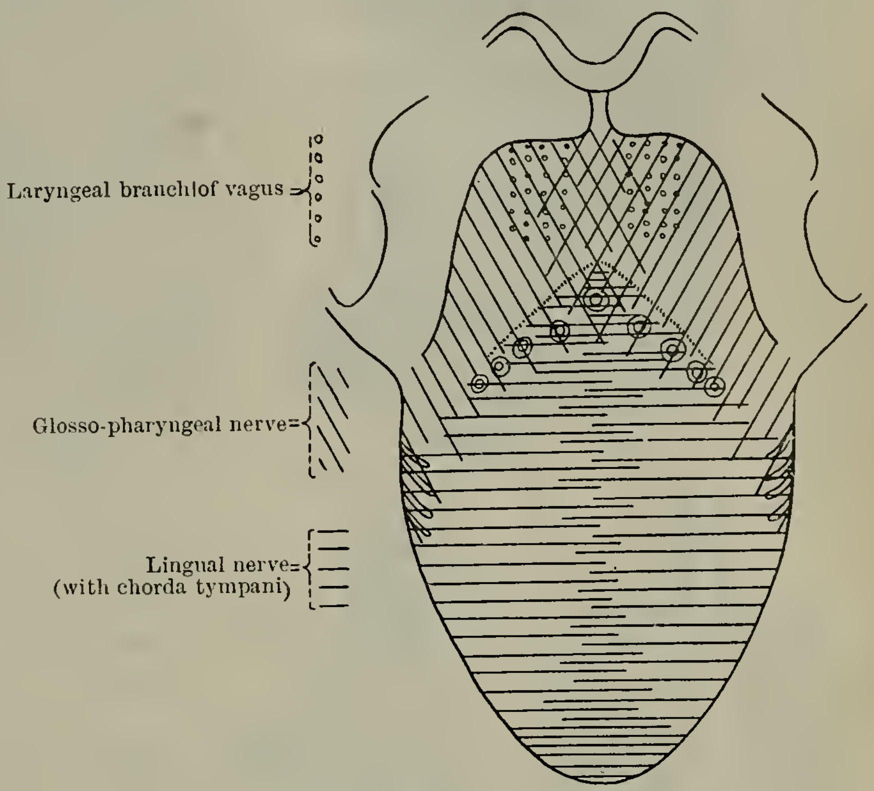


FIG. 870.—AREAS OF AFFERENT NERVE SUPPLY OF TONGUE.

GLANDULÆ.

Numerous organs, differing widely in structure, function, and development, are commonly included under the term **gland**. It may indicate any of the following types:—

(1) Glands producing a visible fluid or semi-fluid secretion, which is discharged from the cells of the gland, either directly or by a duct, on to a free surface, where it is useful chemically or mechanically, or by which it is drained away. Glands of this type connected with the alimentary canal are serous and mucous glands, salivary glands, gastric and intestinal glands, and the liver and pancreas.

(2) The so-called **ductless glands**, which possess no ducts, but secrete some substances, which are directly and gradually transmitted from the cells of the gland to the blood or lymph stream, and are of use in the general metabolism of the body. Such structures are the thyreoid gland, the suprarenal glands, the parathyreoids, and the hypophysis cerebri.

(3) **Cytogenic** or cell-producing glands, not always epithelial, and usually with no distinct duct, consist of aggregations of special cells, enclosed in a more or less definite framework of connective tissue, freely supplied with blood- and lymph-vessels. Glands of this type are concerned in the production, from the cells

in the glands, of special cells, which are liberated from the gland tissue, and pass away from it. Such glands are lymph glands, the bone marrow, and the reproductive glands—testes and ovaries.

Glands may also be classified according to their development, and on this basis the following groups are recognised:—

(1) **Glandulæ epitheliales**, developed from epithelial cells. These may (*a*) possess a duct, in which case they are termed **glandulæ evehentes**; or (*b*) they may be constituted as ductless glands, and they are then termed **glandulæ clausæ**. To this last group belong the thyreoid gland, the hypophysis, and the suprarenal glands.

(2) **Glandulæ vasculares**, developed in connexion with vessels, and not containing epithelial cells. This group includes all the lymph glands, the lymph nodules found in the intestine, the tonsils, the thymus, and the spleen.

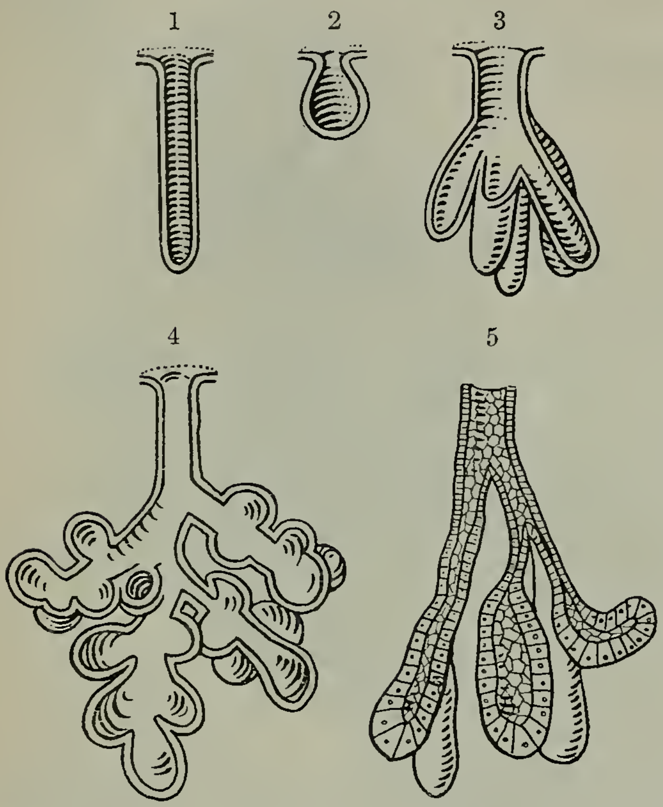


Fig. 871.—Diagram of the Structure of Various Types of Glands.

1. Simple tubular gland.
2. Simple alveolar.
3. Compound tubular.
4. Gland acinus (racemose gland).
5. Section of secreting portion of gland and ducts.

In the following paragraphs only the true glands of the alimentary system — namely, the glands of epithelial origin, characterised by the possession of ducts—are considered.

Such glands may be defined as epithelial organs used for the secretion or excretion of some particular substance or substances from the body. They usually consist of a number of cells, and there may be different kinds of cells in a gland.

The simplest form of this type of gland is an involution of an epithelial surface, which may be of various forms.

The simplest form is a single pocket, of uniform size throughout, forming a simple tubular gland. Of this kind are the intestinal glands in the wall of the small intestine.

In other cases the end of the gland may be widened, forming a sort of pocket, called an alveolus (*alveolus*, small stomach or bag), and this type of gland is known as the simple alveolar gland. It does not exist in the alimentary canal.

In some cases the lower part or fundus of the gland does all the secretion, and the upper part forms a tube or duct that carries the secretion to the surface.

When the outgrowth forming the gland remains undivided, the gland is known as a **simple gland**. It may, on the other hand, break up into two or more branches, and it then is known as a **compound gland**, and this compound gland may be tubular, alveolar, or of a mixed tubular and alveolar form.

When the fundus of the gland at the extremities of the ducts becomes a highly differentiated saccular region, consisting of several enlargements (alveoli) at the end of a duct, it is called an **acinus** (*ăcĭnus*, a berry), from the fancied resemblance it presents to a cluster of grapes at the end of a stalk. A gland formed of several such structures collected together is often called a **compound acinous** or **racemose gland** (*racemus*, a cluster).

General Structure of Glands.—Whilst the small glands, such as those of the mouth and pharynx, are placed in the mucosa or submucosa close to the point at which their ducts open on the surface, the large glands forming distinct masses, often lie at a considerable distance from the points at which their ducts open, and are generally surrounded by special capsules.

Each of these large glands of the acinous type, such as the parotid or submaxillary, presents the following general arrangement. The gland is made up, as can be seen with the unaided eye, of a number of masses, often as large as peas, which are surrounded and held together by connective tissue. These are known as lobes, and to each a branch of the duct passes. The lobes are in turn made up of a number of smaller masses—lobules—each having a special branch of the lobar duct. These again are composed of smaller lobules, and finally the smallest are made up of a terminal branch of the duct, with a cluster of acini or alveoli leading into it.

The **acini** or **alveoli** are composed of a basement membrane, often fenestrated or basket-like, formed of flattened cells, on the outer side of which the blood- and lymph-vessels lie. The inner surface of this membrane is lined by the secreting epithelial cells, usually polygonal in shape, which almost completely fill the alveolus. A small lumen, however, is left, into which the secretion of the cells is shed; thence it passes into the duct of the lobule, and thus to the main duct.

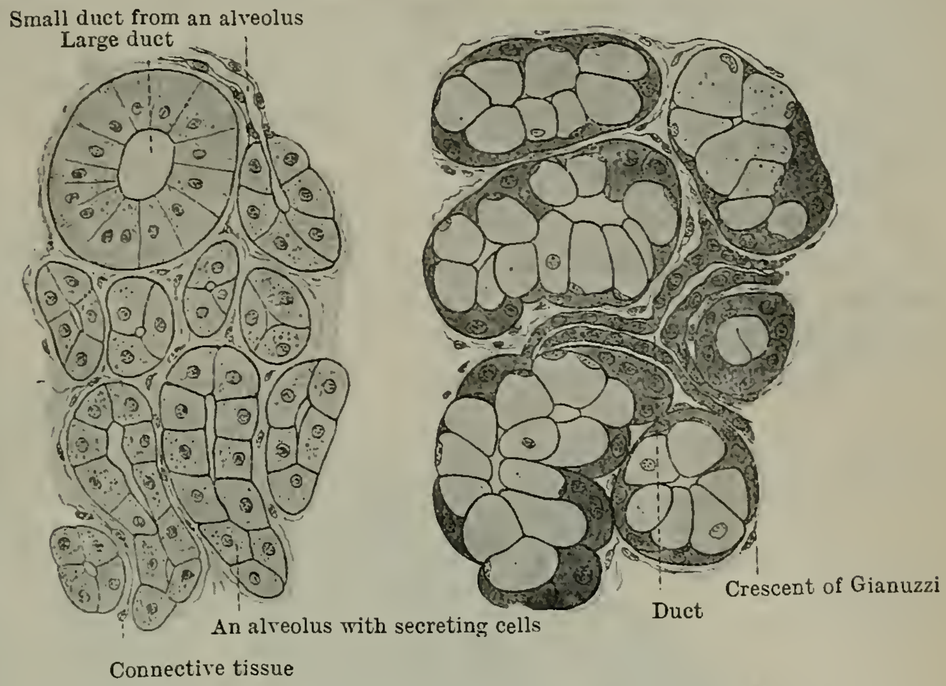


Fig. 872.—Section of a Serous Gland on the left, a Mucous Gland on the right side. (Böhm and v. Davidoff.)

In the serous gland the granular secreting cells and the centrally-placed nucleus should be noted. The relatively clear cells, with the dark crescents of Gianuzzi, are distinctive in the mucous gland.

The blood- and lymph-vessels, on entering the gland, break up and run, branching as they go, in the connective tissue which conveys them to all parts of the gland.

Glandulæ Salivales.

Saliva is a clear watery fluid poured by a number of glands into the mouth cavity. It moistens the tongue and the walls of the mouth, and facilitates movements of the tongue in speaking. Mixed with food by mastication it helps in swallowing. It also contains a ferment which plays an important part in digestion, and can transform starch into dextrin.

The glands which secrete it include the small glands of the lips, cheeks, and tongue, and also three large paired glands, the parotid, submaxillary, and sublingual glands. These last alone are usually included in the term salivary glands.

Glandula Parotis.—The **parotid gland**, the largest of the salivary glands, lies on the side of the face, below and in front of the ear, the mastoid process and sterno-mastoid muscle.

It forms a lobulated mass, of a yellowish or light reddish-brown colour, with a large triangular superficial surface. From this mass a process of the gland passes medially behind the ramus of the mandible, almost to the side wall of the pharynx. It is known as the **processus retromandibularis**.

Shape and Relations of the Parotid Gland.—In shape the parotid gland with its deep process is three-sided (Fig. 873), the three surfaces being superficial, anterior, and posterior.

Superficial Surface.—This surface is somewhat triangular in form, though irregular in outline. Its long posterior border lies in front of the external acoustic meatus and the sterno-mastoid muscle, and extends down to the angle of the jaw and the posterior belly of the digastric muscle. Its superior border lies below the zygomatic arch, and the inferior border passes irregularly upwards and anteriorly to join it. The apex, directed anteriorly, forms the facial process of the gland, and lies on the masseter muscle, and the duct of the gland issues from it, or just below it.

This superficial surface is frequently prolonged downwards over the digastric muscle. It may descend beyond the angle of the mandible, and come into immediate relation with the posterior part of the submaxillary gland, from which it is separated merely by a thin layer of the deep cervical fascia.

Embedded in the superficial surface there are usually found several small rounded lymph glands, which can be distinguished from the gland tissue by the difference in their colour.

The **facial process** of the gland—often of considerable size—is a flat and somewhat triangular portion which runs forwards from the upper part of the front of the gland, and overlaps the masseter muscle to a varying extent. A separated portion of this process, often found lying immediately above the duct, is known as the **glandula parotis accessoria.**

Processus Retromandibularis.—This portion of the gland occupies a deep fossa, called the parotid fossa, of considerable size, which has two nearly vertical sides, an anterior and posterior. These sides converge towards one another and meet deeply, and so form the apex of the fossa. This fact is well brought out by a horizontal section through the head about the middle of the gland (Fig. 874).

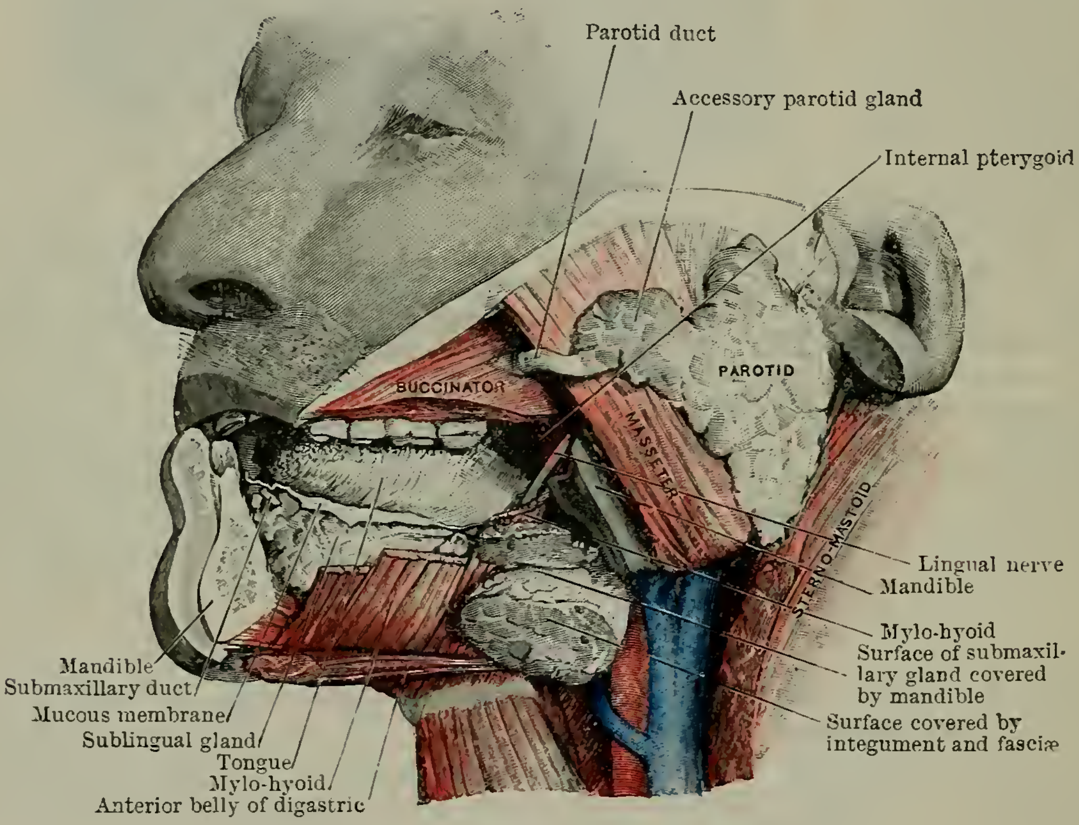


FIG. 873.—THE SALIVARY GLANDS AND THEIR DUCTS.

From this it will be seen that the posterior wall of the fossa is formed, medial to the sterno-mastoid muscle, by the posterior belly of the digastric and the stylohyoid muscles, with the occipital artery, and more deeply still, by the root of the styloid process and the carotid sheath and its contents, and especially by the internal jugular vein, separating the fossa from the vertebral column.

The anterior wall of the fossa is formed by the ramus of the mandible and the masseter and internal pterygoid muscles.

The portion of the gland lying in this fossa—the retro-mandibular or deep process — presents an anterior surface looking forwards, deeply concave, and a posterior surface, irregular in outline, directed backwards and medially.

These surfaces meet medially at the medial border, which may lie so deeply as to be in contact with the side wall of the pharynx. The superior and inferior borders, at the union of the anterior and posterior surfaces, are irregular in outline, and indefinite.

The relations of these two surfaces are as follows:—

The anterior surface is wrapped round the ramus of the mandible, and extends on to the muscles which cover this portion of the bone laterally and medially, that is, on to the masseter and internal pterygoid muscles respectively.

The posterior surface is in contact with the structures which form the posterior wall of the fossa, viz., from the surface medially, with the sterno-mastoid muscle, the mastoid process, the external acoustic meatus, the posterior belly of the digastric muscle, the internal jugular vein, and the root of the styloid process and the styloid muscles. It is often deeply grooved by the posterior belly of the digastric.

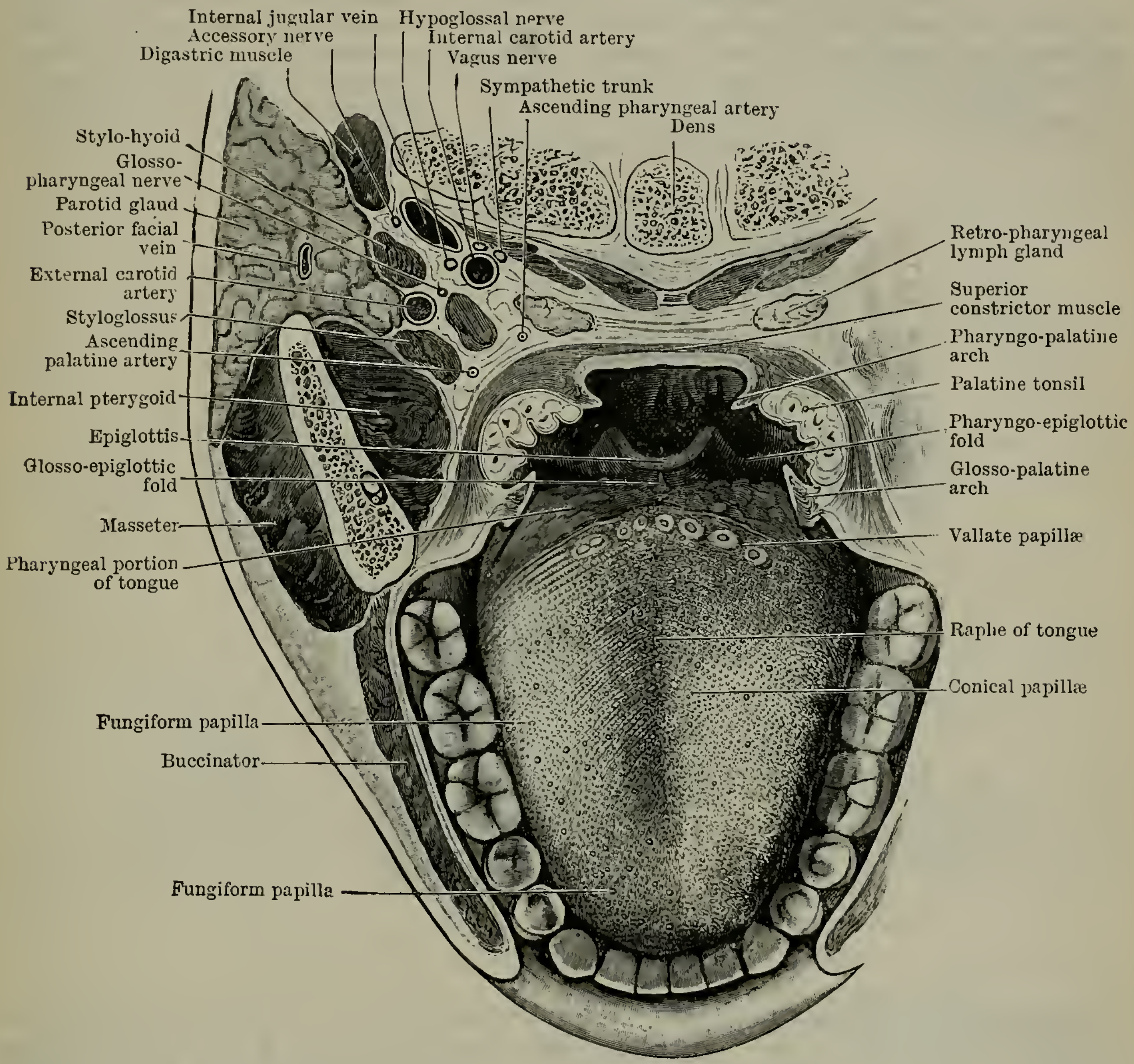


FIG. 874.—HORIZONTAL SECTION THROUGH MOUTH AND PHARYNX AT THE LEVEL OF THE PALATINE TONSILS.

The prevertebral muscles and the stylopharyngeus (which is shown just at the medial side of the external carotid artery) are not indicated by reference lines.

The posterior surface is occasionally prolonged medially beyond the lower portion of the styloid process, towards the pharynx. In such cases, the lower part of the styloid process lies in a groove on the posterior surface of the gland.

The gland frequently gives off processes which pass into the intervals between the structures bounding the fossa. Occasionally from its superior end a small process termed the *glenoid lobe* is found, passing into the posterior or tympanic part of the mandibular fossa.

Another runs into the interval between the sterno-mastoid and digastric muscles; and a pharyngeal process is occasionally found extending medially, anterior to the styloid process, towards the side of the pharynx.

A pterygoid extension, between the two pterygoid muscles, cannot properly be said to exist.

Fascia Parotideomasseterica.—The parotid recess is covered over on the one hand, and lined on the other, by fascia. The covering layer is specially known as the **fascia parotideomasseterica**, and both it and the lining layer are derived from the deep cervical fascia, which divides to enclose the gland. The parotideo-masseteric fascia is connected, on the surface, above to the zygoma; posteriorly, to the acoustic meatus and anterior border of the sterno-mastoid; below, it is continuous with the deep cervical fascia, and anteriorly it passes over the masseter, and blends with the fascia buccopharyngea. The fascia forms a lining for the recess, and is united above to the periosteum over the acoustic meatus and posterior part of the glenoid fossa; medially it is connected to the styloid process; whilst below it joins the deep cervical fascia. Taken together, the two layers form a definite capsule which completely encloses the gland. In connexion with the lower and anterior part of this capsule is developed a special flat band, the **stylo-mandibular ligament**, which passes downwards and laterally from the styloid process to the angle of the mandible. It separates the anterior part of the parotid gland from the posterior border of the internal pterygoid muscle; perhaps occasionally, also, from the upper and posterior part of the submaxillary gland.

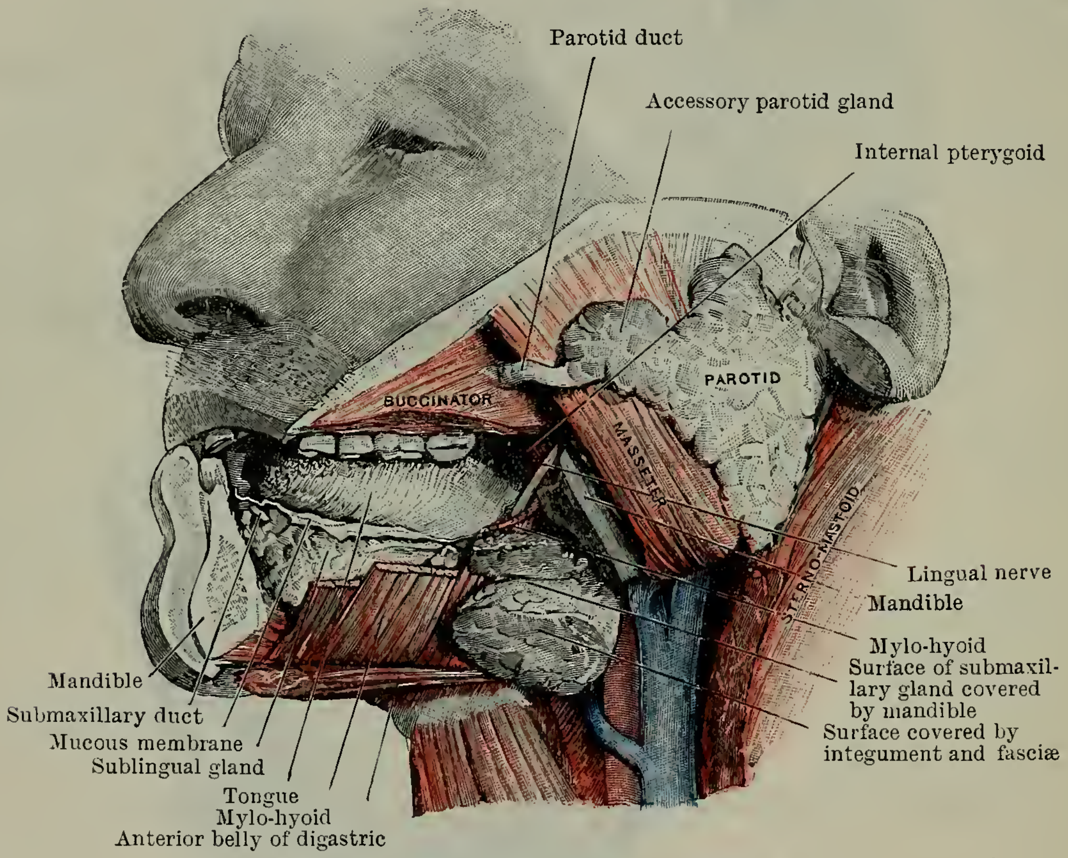


Fig. 875.—The Salivary Glands and their Ducts.

Ductus Parotideus (Stensen).—The **parotid duct** (O.T. Stensen's) leaves the anterior border of the gland at its most prominent part (Fig. 875). It first runs forwards across the masseter, below the accessory parotid gland, accompanied by branches of the facial nerve, and the transverse facial artery, which is commonly some distance above, though its relation is variable. Having crossed the masseter, the duct turns abruptly round the anterior border of this muscle and runs inwards through the fat of the cheek, practically at right angles to the first part of its course, to reach the buccinator, which it pierces. Then passing for some distance (5 to 10 mm.) between the buccinator and the mucous membrane, it opens into the vestibule of the mouth by a very small orifice, on a variably developed papilla, opposite the crown of the second upper molar tooth.

The course of the duct can be marked on the side of the face by drawing a line from the inferior edge of the acoustic meatus to a point midway between the ala of the nose and the red of the lip; the middle third of this line corresponds fairly accurately, on the surface, to the course pursued by the duct.

The duct measures from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches (38 to 62 mm.) in length, and $\frac{1}{8}$ inch (3 to 4 mm.) in diameter. The calibre of the duct is very much greater than that of its orifice, which admits only a fine bristle, and for this reason the duct may, to some extent, be looked upon as a reservoir for the saliva, as well as a duct for its conveyance. In the child it pierces the "sucking pad" on its way to the mouth.

A number of vessels and nerves are found in intimate relation to the parotid gland.

These are: (1) The external carotid artery and its two terminal branches. This artery lies at first in a groove in the inferior and deep aspect of the gland. It then enters the gland substance and lies deeply in it, as far up as to the neck of the mandible, where it divides into its two terminal branches. The superficial temporal artery emerges from the superior superficial part of the gland, and the internal maxillary artery turns inwards and emerges from the deep part of the anterior surface.

The transverse facial artery is given off in the substance of the gland, and emerges from it between the zygomatic arch and the duct.

The posterior facial vein descends in the substance of the gland superficially, and divides in it into the two terminal branches which emerge from the inferior part of the gland.

The facial nerve enters the posterior surface of the gland, slightly below its middle, and runs forwards and laterally, dividing into its main branches within the gland, and lying superficial to the external carotid artery and posterior facial vein. Communicating branches from the auriculo-temporal and great auricular nerves to the facial also traverse the gland substance.

Vessels and Nerves.—The **arteries** which supply the gland arise from the external carotid artery, and from the branches of this artery in relation to the gland.

The **veins** join the posterior facial vein and its tributaries. The **lymph vessels** pass to both the superficial and the deep cervical glands; there are also a few small parotid lymph glands, which lie on the surface of the superior and inferior part of the parotid beneath the capsule. Some are said to be embedded in the substance of the parotid itself.

The **nerves** are derived (*a*) from the auriculo-temporal, great auricular, and facial, and (*b*) from the plexus caroticus externus. The fibres of the sympathetic are mainly vaso-constrictor.

The secretory fibres to the gland, arising in the brain-stem, pass out through the glosso-pharyngeal nerve, and pass from it through the lesser superficial petrosal nerve to the otic ganglion, and from that ganglion to the gland in the auriculo-temporal nerve.

Glandulæ Submaxillares.—The **submaxillary glands** are next in size to the parotid, and resemble them in their lobulation and colour. Each is placed largely in the submaxillary triangle under cover of the mandible (Fig. 875).

In each gland two portions may be recognised, a somewhat superficial larger part, the body, lying in the submaxillary triangle, and a smaller deep part, the deep process, which springs from the middle of the deep surface of the body.

The superficial part, like the parotid, presents a superficial convex surface, which projects below the mandible, in the submaxillary triangle, but it frequently extends beyond the limits of that space, and overlaps the digastric muscle.

This surface is covered by the deep cervical fascia and the platysma and is crossed superficially by the anterior facial vein.

The *body of the gland* is wedged upwards, between the medial surface of the mandible and the mylo-hyoid and hyo-glossus muscles. It thus presents two surfaces, a lateral, which is in contact with the submaxillary fossa of the mandible, and a medial, related to the mylo-hyoid, hyo-glossus, the posterior belly of the digastric, and the stylo-hyoid muscles.

The deep process passes around the posterior free margin of the mylo-hyoid muscle, and comes to lie between the mylo-hyoid and hyo-glossus muscles.

Embedded in the substance of the gland are found a few submaxillary lymph glands, which are of importance from the connexion they have with the lymph vessels of the lip and of a portion of the tongue.

The external maxillary artery lies embedded in a groove in the superior and posterior part of the gland.

The gland is enclosed in a delicate capsule of connective tissue derived from the deep cervical fascia.

In considering the relations of the gland, it is well to remark that there is in this region a three-sided space bounded laterally by the medial surface of the mandible below the mylo-hyoid line, medially and above by the mylo-hyoid muscle, and below by the skin and fascia passing from the margin of the jaw to the side of the neck. In this space the gland lies with lateral, medial, and inferior surfaces corresponding to the walls of the space.

The *posterior end* of the gland, which is its most bulky portion, either abuts against, or lies very close to, the sterno-mastoid, and is often overlapped by the inferior end of the parotid gland.

Ductus Submaxillaris.—The **submaxillary duct** (Wharton) leaves the deep surface of the gland about its middle, and runs forwards beneath the mylo-hyoid muscle, along the superior and medial aspect of the deep process of the gland (Fig. 876). Pursuing its course forwards beneath the floor of the mouth, on the medial side of the sublingual gland, the duct crosses the hyo-glossus and the genio-glossus muscles, and finally opens on the floor of the mouth at the side of the frenulum linguæ, on the summit of a soft papilla (**caruncula sublingualis**) close to its fellow of the opposite side.

While running forward beneath the floor of the mouth the duct, which is about two inches long (50 mm.), is crossed by the lingual nerve near the anterior border of the hyo-glossus, that is opposite the 2nd molar tooth. The nerve passes from the posterior end of the mylo-hyoid ridge (against which it lies) forwards and medially in order to reach the inferior surface of the tongue, and it passes below the duct at the point indicated.

As in the case of the parotid duct, the calibre of the submaxillary duct is much greater than that of the orifice by which it opens ; for this reason it likewise may be looked upon as forming, to some extent, a reservoir for the saliva secreted by the gland.

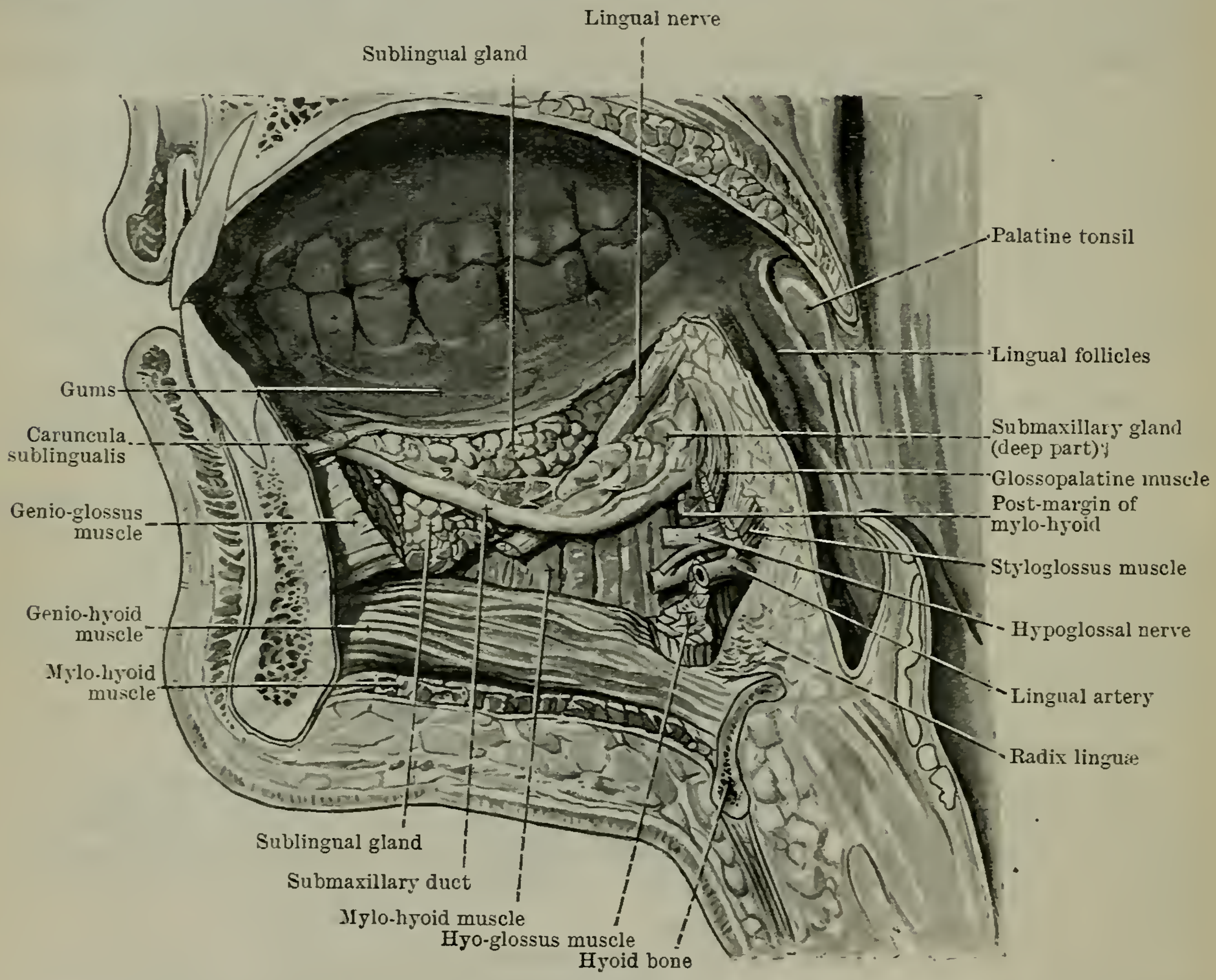


FIG. 876.—SIDE WALL AND FLOOR OF MOUTH, AFTER REMOVAL OF TONGUE AND MUCOUS MEMBRANE.

Vessels and Nerves.—The **arteries** come chiefly from the external maxillary artery and its submental branch: the **veins** accompany the arteries. The **nerves** are derived through the submaxillary ganglion (which lies above the deep process of the gland), from the chorda tympani and lingual, and from the sympathetic plexus around the external maxillary artery. The lymph vessels pass to the submaxillary lymph glands.

Glandulæ Sublinguales.—The **sublingual glands**, the smallest of the principal salivary glands, are situated more deeply than the others.

Each lies immediately below the mucous membrane of the floor of the mouth, in the interval between the sublingual fossa (on the inner surface of the mandible above the mylo-hyoid line) and the genio-glossus muscle, which passes from the mandible to the tongue. Below, it rests upon the deep surface of the mylo-hyoid muscle.

In shape it is almond-like, flattened from side to side, but is much wider (from above downwards) anteriorly than posteriorly. It is usually from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches (37 to 45 mm.) in length, whilst its bulk is about equal to that of two or three almonds.

Its detailed relations are as follows :—Its *lateral surface* rests against the inner aspect of the body of the mandible above the mylo-hyoid line. Its *medial surface* is in contact with the genio-glossus, stylo-glossus, and hyo-glossus muscles, as well as with the submaxillary duct, which runs forwards between the gland and the muscles. *Below*, it rests on the mylo-hyoid, and at its posterior part on the deep process of the submaxillary gland; whilst its *upper prominent border* is covered only by the mucous membrane of the mouth, and the plica sublingualis (Fig. 867). The anterior portion of the gland is much deeper and more bulky than the posterior half, and it meets its fellow in the median plane beneath the frenulum linguæ. The posterior extremity grows gradually more slender, but may extend to the posterior part of the mylo-hyoid ridge, where it lies above the deep process of the submaxillary gland.

The **ducts, ductus sublinguales minores** (O.T. **ducts of Rivinus**), are about twelve in number and of small size; they leave the superior part of the gland, and, after a short course, open on a series of papillæ, visible to the naked eye, which are placed along the summit of the plica sublingualis.

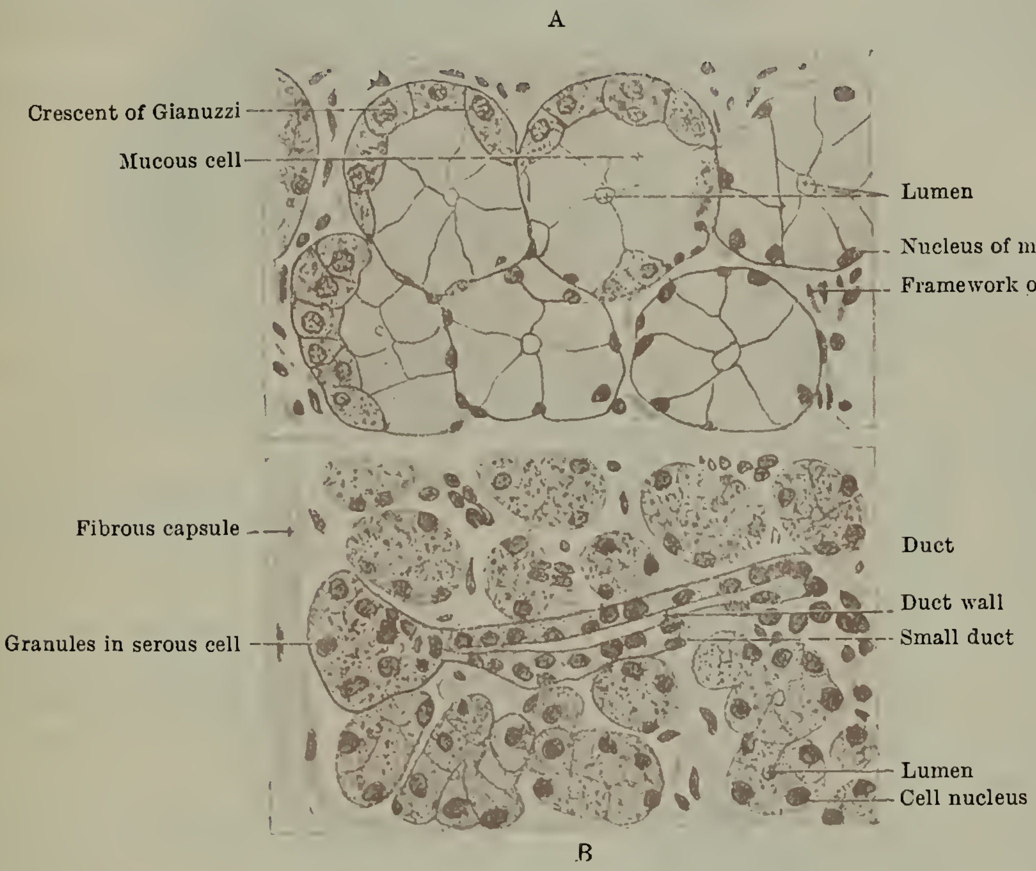


FIG. 877.

A. Section of human submaxillary gland × 400. B. Section of human parotid gland × 400.

The gland is not enclosed in a distinct capsule, thus differing from the parotid and submaxillary glands; but its numerous lobules, which are smaller than those of the glands just mentioned, are held together by fine connective tissue, loosely, but still in such a manner as to make one more or less consolidated mass out of what was, in the embryo, a number of separate glands.

As a rule all the ducts open separately on the summit of the plica sublingualis, and apparently none of them join the submaxillary duct. Frequently some of those from the anterior and more bulky part of the gland are larger than the others, but the presence of a large duct running alongside of the submaxillary duct, and opening with or beside it, **ductus sublingualis major (Bartolin)**, is very rare, and must be considered as an exceptional condition in man, although normal in the ox, sheep, and goat. The same may also be said of ducts from the sublingual, which are described as opening into the submaxillary duct.

Vessels and Nerves.—The **arteries** are derived from the sublingual artery, a branch of the lingual, and from the submental, a branch of the external maxillary. The **nerves** come from the lingual, chorda tympani, and the external maxillary plexus, through a branch of the submaxillary ganglion which joins the lingual, and is conveyed by it to the gland. The secretory fibres run in the chorda tympani nerve, and thence through the submaxillary ganglion to the gland.

The **glandula lingualis anterior** (Blandini, Nuhni) has been described with the tongue.

Structure of the Salivary Glands (Fig. 877).—Each of the principal salivary glands consists of a number of lobules, loosely united together by connective tissue. From each of them one or more ducts emerge. Each duct when traced onwards divides into branches, which terminate in a group of saccular or tubular alveoli.

The epithelium lining the ducts is columnar in character, but becomes flattened at the junction with the alveoli.

The epithelium lining the alveoli shows different characters in different glands. In the parotid, and the small salivary glands of the vallate papillæ in which the secretion is watery or albuminous, the cells are uniform in character, and of small size. When the gland is at rest, the cells are filled with small granules, which when the secretion is poured out are transformed into the gland ferment (ptyalin). After secretion, only the deeper parts of the cells show the presence of granules. The nuclei are rounded, and lie near the centre of the cells. In the sublingual, labial, buccal, and other glands of the mouth and palate the secretion is of a mucous character and the cells are larger, and the nuclei are placed deeply. The cells appear clear and swollen unless special methods of preparation are employed. In such cases, *e.g.*, when examined in serum, the cells are seen to contain large and distinct granules of mucigen which in secretion are transformed into mucus.

In the submaxillary gland and the anterior lingual gland both varieties of cells are present. In these cases, the larger clear mucus cells line the cavity of the alveolus, and the smaller granular serous cells are arranged upon the basement membrane, deep to the former cells, in crescentic masses, termed the crescents or demilunes of Gianuzzi. They communicate with the cavity of the alveolus by small channels between adjacent mucous cells.

After secretion, the mucus cells become smaller, and stain more deeply than when loaded with mucigen before secretion.

PHARYNX.

The **pharynx** lies posterior to and communicates with the mouth, the larynx, and the nasal cavities, and is continuous inferiorly with the superior end of the œsophagus or gullet (Fig. 878).

It extends from the base of the skull, above, to the level of the sixth cervical vertebra (Fig. 878) and the lower border of the cricoid cartilage, below.

Its total length varies from 5 to 5½ inches (12·5 to 14·0 cm.).

The inferior portion alone, opposite and inferior to the opening of the mouth, is functionally a part of the alimentary canal, for the portion above the level of the soft palate is used for respiration only. It is, however, convenient to study the structure and relations of the whole of the pharynx at once.

Structurally the pharynx is a fibro-muscular bag, lined with mucous membrane, of conical form, wide above and narrow below. The wall of the superior part of the pharynx is firmly attached to the base of the skull, especially around the orifice of the choanæ, and hence in this superior portion there is a permanent cavity containing air.

The lower portion gradually assumes a more tubular form, and the anterior and posterior walls approach one another, so that below the level of the opening of the larynx they are in contact with one another, and the cavity is reduced to a slit, except during the passage of food.

Dimensions of the Pharynx.—From the highest part of the roof, to the superior surface of the soft palate at its junction with the hard palate, measures about 1¼ inches, or 3 cm. The vertical extent of the oral part of the pharynx is about 2¼ inches, or 6 cm., and that of the laryngeal part is about 2¾ inches, or 7 cm.

The inferior end of the pharynx is usually about 5½ to 6½ inches from the margins of the incisor teeth, in a line passing through the cavities of the mouth and of the oral and laryngeal parts of the pharynx.

The other diameters are as follows: the antero-posterior diameter (depth) of the superior segment (nasal portion), from the posterior margin of the septum of the nose at its inferior part horizontally backwards, measures 15 to 18 mm., and that of the middle segment, from the glossopalatine arches to the posterior wall, about 10 mm.

The transverse width of the pharynx also varies considerably. Immediately below the base of the skull the cavity is wide, as there is on each side a deep recess, and it measures 45 mm., or nearly 2 inches.

Opposite the middle of the soft palate the cavity narrows, and measures transversely 25 mm., or 1 inch.

It again widens out below this level, and expands to a width of 35 mm., opposite the inferior margin of the laryngeal opening, where on each side there is a wide recess, called the piriform recess.

Cavum Pharyngis.—The **cavity of the pharynx** is partially intersected by the soft palate, which cuts into the cavity of the pharynx (Fig. 878), and incompletely divides it into two, namely, an upper part, **pars nasalis**, and a lower part or pharynx proper. This lower portion is further subdivided into the **pars oralis**, lying behind the mouth and tongue, and the **pars laryngea**, behind the larynx.

The aperture left between the margin of the soft palate and the posterior wall of the pharynx, by which the nasal part of the pharynx communicates with the inferior divisions of the cavity, is called the **isthmus pharyngonasalis.**

The pharynx presents *seven openings* by which it communicates with neighbouring cavities (Fig. 878). These are the two **choanæ** (O.T. **posterior nares**) on the anterior wall of the pars nasalis, and the two **tubæ auditivæ** on its side walls; the isthmus of the fauces, leading into the mouth from the oral part; the orifice of the larynx on the anterior wall of the laryngeal part of the cavity; and finally, the opening of the œsophagus at its inferior end.

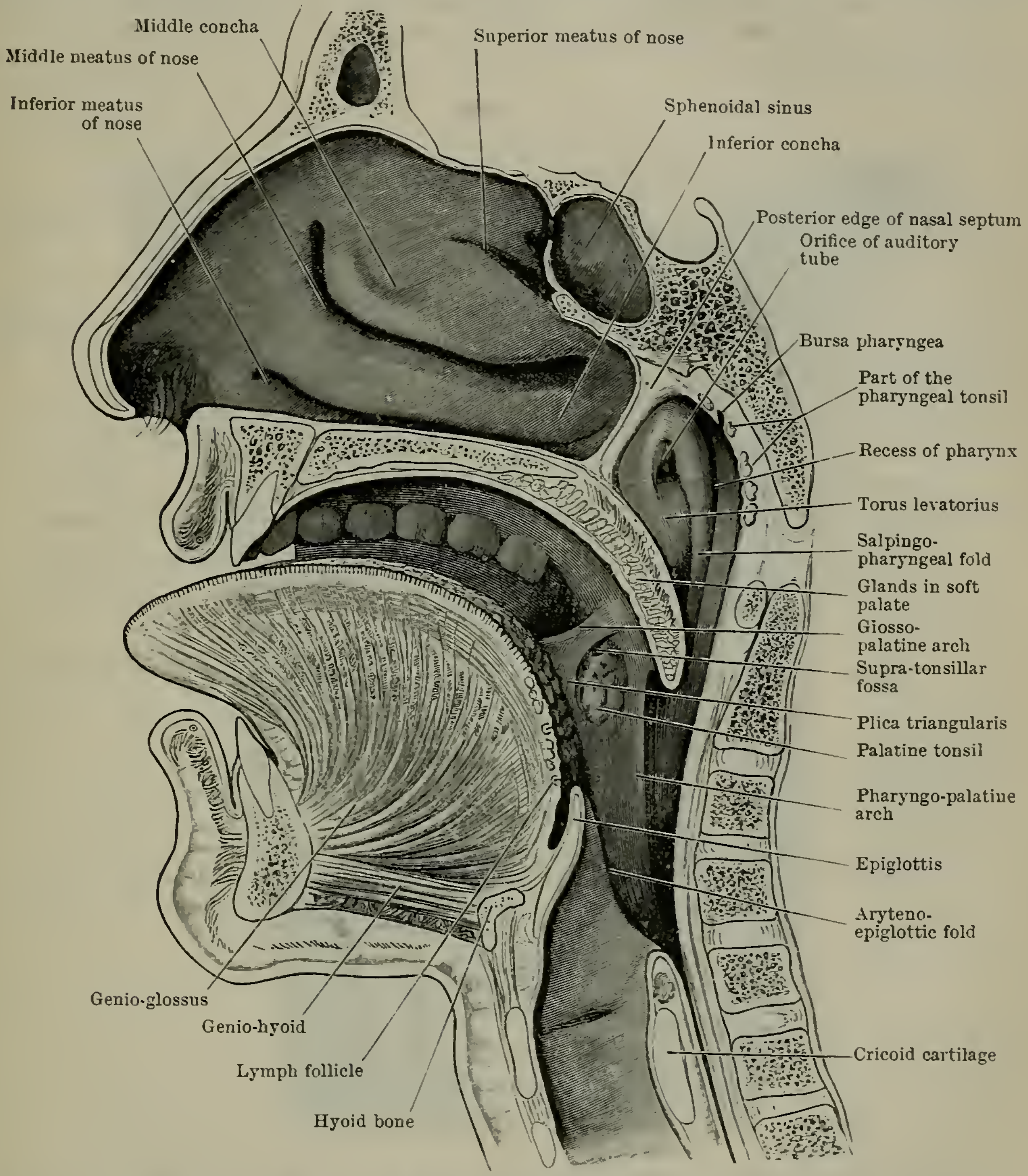


FIG. 878.—SAGITTAL SECTION THROUGH MOUTH, TONGUE, LARYNX, PHARYNX, AND NASAL CAVITY.

The section was slightly oblique, and the posterior edge of the nasal septum has been preserved. The specimen is viewed slightly from below, hence the apparently low position of the inferior concha.

Pars Nasalis (Figs. 851 and 878).—Although morphologically and developmentally this is a portion of the true pharynx, it is functionally an annexe to the respiratory portion of the nasal cavities, and both anatomically and functionally it is distinctly marked off from the digestive tube. It differs from the rest of the pharynx in that its cavity remains, under all conditions, a distinct open chamber incapable of obliteration, owing to the fact that all its walls, with the single exception of the floor, are practically immovable.

The cavity of the pars nasalis is irregular in shape, and is enclosed by *six walls*—namely, anterior and posterior, right and left, a floor and a roof or vault.

These walls all merge into one another, and the lines of separation between them are arbitrary. Through the *anterior wall,* which slopes upwards and backwards, open the **choanæ**, separated from each other by the nasal septum. The margins of the choanæ form the line of separation between the pars nasalis and the cavity of the nose. This separation is occasionally marked by a furrow or fold on the side wall, called the naso-pharyngeal furrow.

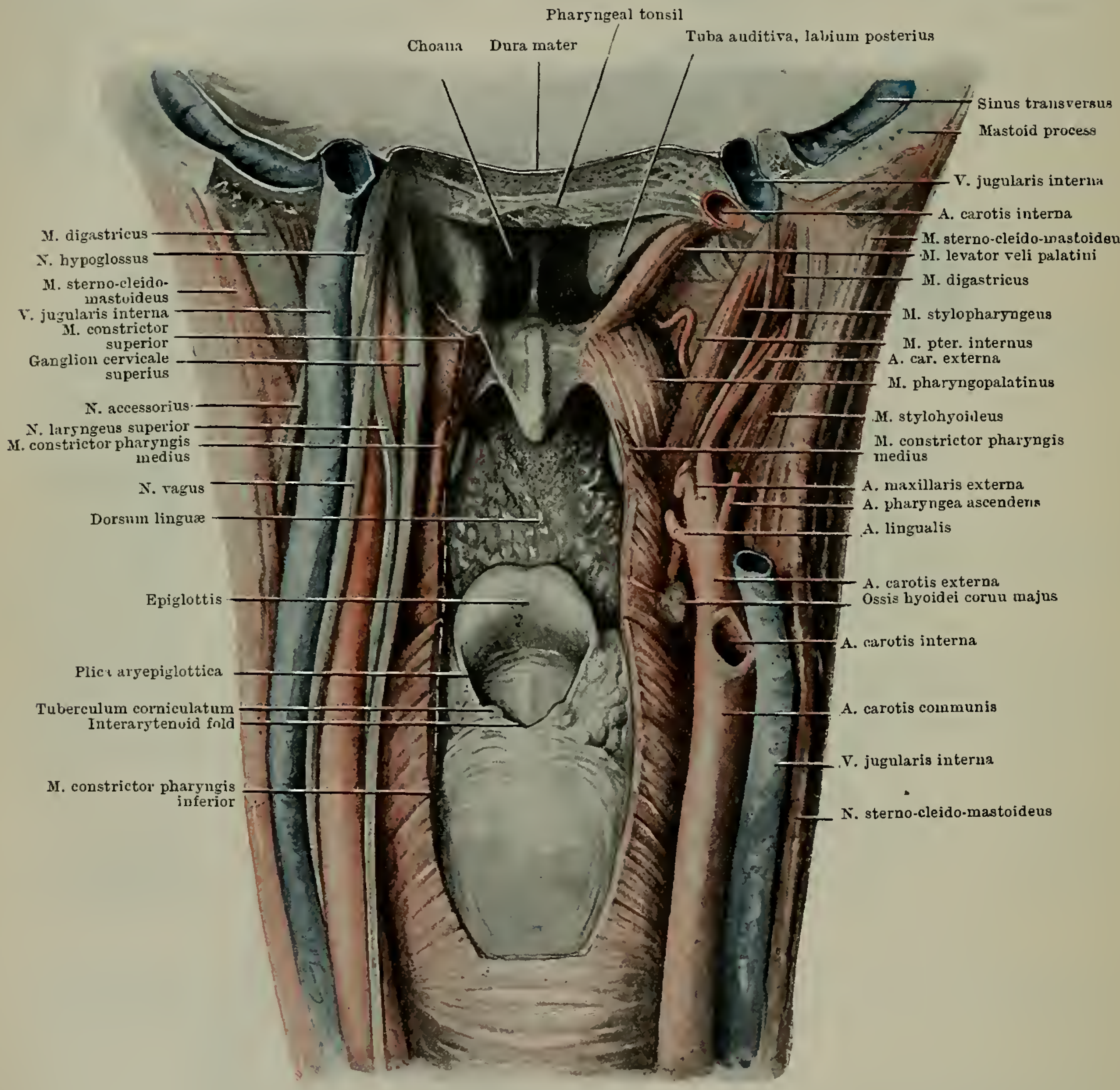


FIG. 879.—INTERIOR OF PHARYNX AND STRUCTURES IN RELATION TO ITS SIDE WALLS, VIEWED FROM BEHIND.

The *posterior wall* is nearly vertical; it corresponds in extent to the basi-occipital bone and the upper six cervical vertebræ.

The *roof* lies under the body of the sphenoid, and on each side it extends downwards to the superior margin of the orifice of the auditory tube. It slopes from in front downwards and backwards to meet the posterior wall at the junction of the basilar part of the occipital and sphenoid bones.

The lateral walls are occupied by the pharyngeal opening of the auditory tube, and posterior to them, by a vertical slit-like depression leading into a recess, called the **recessus pharyngeus** (Rosenmülleri).

The *floor* is formed by the upper surface of the soft palate.

In the posterior part of the roof, and superior part of the posterior wall, there is a considerable accumulation of lymph tissue, known as the **pharyngeal tonsil.** It is most distinct in the child, and becomes indistinct, or entirely disappears, in adult life. It extends from the body of the sphenoid down as far as to the margin of the occipital bone, and, laterally, as far as to the superior part of the side wall. The mucous membrane which covers it is thickened and thrown into transverse folds.

A similar collection of lymphoid tissue, a lateral prolongation of the pharyngeal tonsil, lies behind the mouth of the auditory tube, and it is known as the "*tubal tonsil.*"

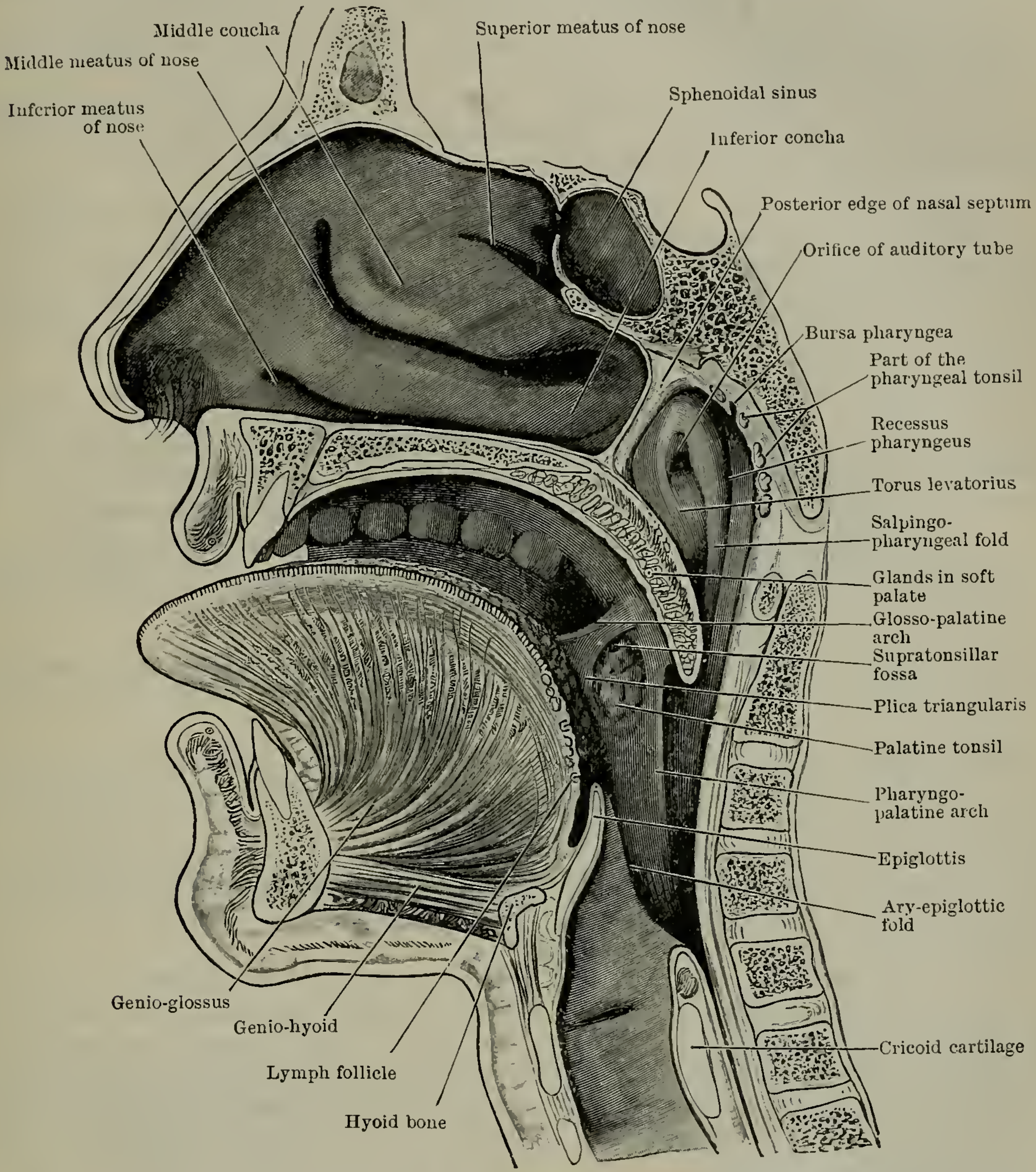


Fig. 880.—Sagittal Section through Mouth, Tongue, Larynx, Pharynx, and Nasal Cavity.

The section is slightly oblique, and the posterior edge of the nasal septum has been preserved. The specimen is viewed slightly from below, hence, in part, the low position of the inferior concha.

In connexion with the inferior part of the pharyngeal tonsil, there is found, constantly in the child and occasionally in the adult, a small median recess which runs upwards and backwards in the wall of the pharynx for some distance, and is known as the **bursa pharyngea** (Fig. 880).

Enlargement of the lymph tissue here occurs frequently in children, and the swollen lymph nodules are known as adenoids. The enlargement may become so great as to fill up a great part of the cavity of the nasal part of the pharynx.

Embedded in the tissue of the roof of the pharynx, near the orifice of the cranio-pharyngeal canal, is a nodule of tissue which in structure resembles the anterior lobe of the hypophysis cerebri. It is termed the **pharyngeal hypophysis**, and is composed of strands of epithelial cells, some follicles containing colloid material, and a few chromatin cells. Its size and its exact position are variable.

Ostium Pharyngeum Tubæ Auditivæ.—The **pharyngeal orifice** of the **auditory tube** is oval or triangular, and funnel-like in appearance (Fig. 880). It is bounded superiorly and posteriorly by a prominent rounded ridge, the **torus tubarius** (O.T. **Eustachian cushion**), formed by the cartilage which surrounds the auditory tube superiorly and posteriorly. The prominence of the posterior margin (labium posterius) as contrasted with the anterior margin (labium anterius) of the orifice, and the direction of the tube itself, which runs posteriorly and laterally (from the pharynx to the tympanum), greatly facilitate the introduction of a Eustachian catheter.

The orifice is situated on the side wall of the pars nasalis, a short distance (about $\frac{1}{3}$ to $\frac{1}{2}$ inch) behind the posterior end of the inferior concha, and immediately above the level of the hard palate (Figs. 851 and 880).

A slight ridge of the mucous membrane, the **plica salpingopharyngea**, descends from the inferior end of the torus tubarius on the side wall of the pharynx. Another less-developed ridge, the **plica salpingopalatina**, passes from the anterior border of the ostium pharyngeum downwards and forwards to join the palate. In front of the latter lies the indistinct groove, the **naso-pharyngeal groove**, which indicates the separation of the nasal cavity from the nasal part of the pharynx.

The levator veli palatini in descending runs parallel to the tuba auditiva, and along its lower border. As it enters the palate, it produces, particularly when in a state of contraction, an elevation just below the pharyngeal orifice of the tube, known as the **torus levatorius** (Fig. 880), which in its upper portion abuts against the lower part of the orifice, and forms its base when that opening assumes its usual triangular shape.

Immediately posterior to each osteum pharyngeum is the **recessus pharyngeus** (O.T. **lateral recess of the pharynx** or **fossa of Rosenmüller**), a nearly vertical depression of considerable depth (Fig. 880).

The pharyngeal recesses project laterally over the superior margin of the superior constrictor, below the petrous portion of the temporal bone, and correspond in position to the sinus of Morgagni on each side (cf. description of pharyngeal wall, p. 1142).

Pars Oralis.—The oral part of the pharynx lies behind the mouth, between the soft palate above and the superior aperture of the larynx below. On its *anterior aspect* is the isthmus of the fauces, leading into the mouth. Below this the vertical pharyngeal portion of the tongue forms the anterior wall. Its *side wall* (Fig. 880) presents a triangular area, **sinus tonsillaris**, occupied in the greater part of its extent by the **tonsil**. Above the tonsil there is a depression, the **fossa supratonsillaris** (Fig. 880).

The **arcus pharyngopalatinus** (O.T. **posterior pillar of the fauces**) is a fold of mucous membrane, containing in its interior the pharyngopalatinus muscle. It springs from the posterior edge of the soft palate, and, passing downwards and slightly backwards, ends inferiorly on the side wall of the pharynx (Fig. 880). The two pharyngo-palatine arches form the right and left boundaries of the pharyngo-nasal isthmus, and the orifice can be modified in size by the contraction of the pharyngo-palatine muscles.

The arcus **glossopalatinus** is described on p. 1109.

By the contraction of the pharyngo-palatine muscles, which are enclosed within the pharyngo-palatine arches, the sides of the isthmus can be approximated, like two curtains, and its size correspondingly diminished. When, at the same time, the uvula and soft palate are elevated, and the whole pharynx in this region is narrowed by the contraction of the superior constrictor, the aperture can be completely closed, and the oral separated from the nasal part of the pharynx, as in the acts of swallowing and vomiting.

Tonsillæ Palatinæ.—The **palatine tonsils** are two large, oval masses of lymph tissue which are embedded in the side walls of the oral part of the pharynx in the lower part of a triangular recess, the sinus tonsillaris.

The tonsillar sinus is bounded anteriorly by the glosso-palatine arch, posteriorly it is bounded by the more vertical pharyngo-palatine arch; the inferior boundary is formed by the margin of the tongue, while the narrow apex above passes up to the side of the soft palate.

From the posterior surface of the glosso-palatine arch a thin triangular fold of mucous membrane, called the **plica triangularis**, passes backwards. Its base corresponds to the glosso-palatine arch, its superior border is free, and passes downwards and backwards, frequently overlapping the tonsil. Its lower border is attached to the side of the tongue. It covers, medially, the inferior part of the tonsillar fossa.

The palatine tonsil presents very different forms in different individuals.

It may project from the fossa into the cavity of the pharynx, or it may be flat and limited to the tonsillar fossa. In some cases the plica triangularis is fused with the free surface of the tonsil, and the lymph tissue may in some cases be developed on the medial surface of that plica.

The palatine tonsils are oval in shape, with the long axes directed vertically, and each presents a medial and a lateral surface, and a superior and inferior pole, and an anterior and posterior margin.

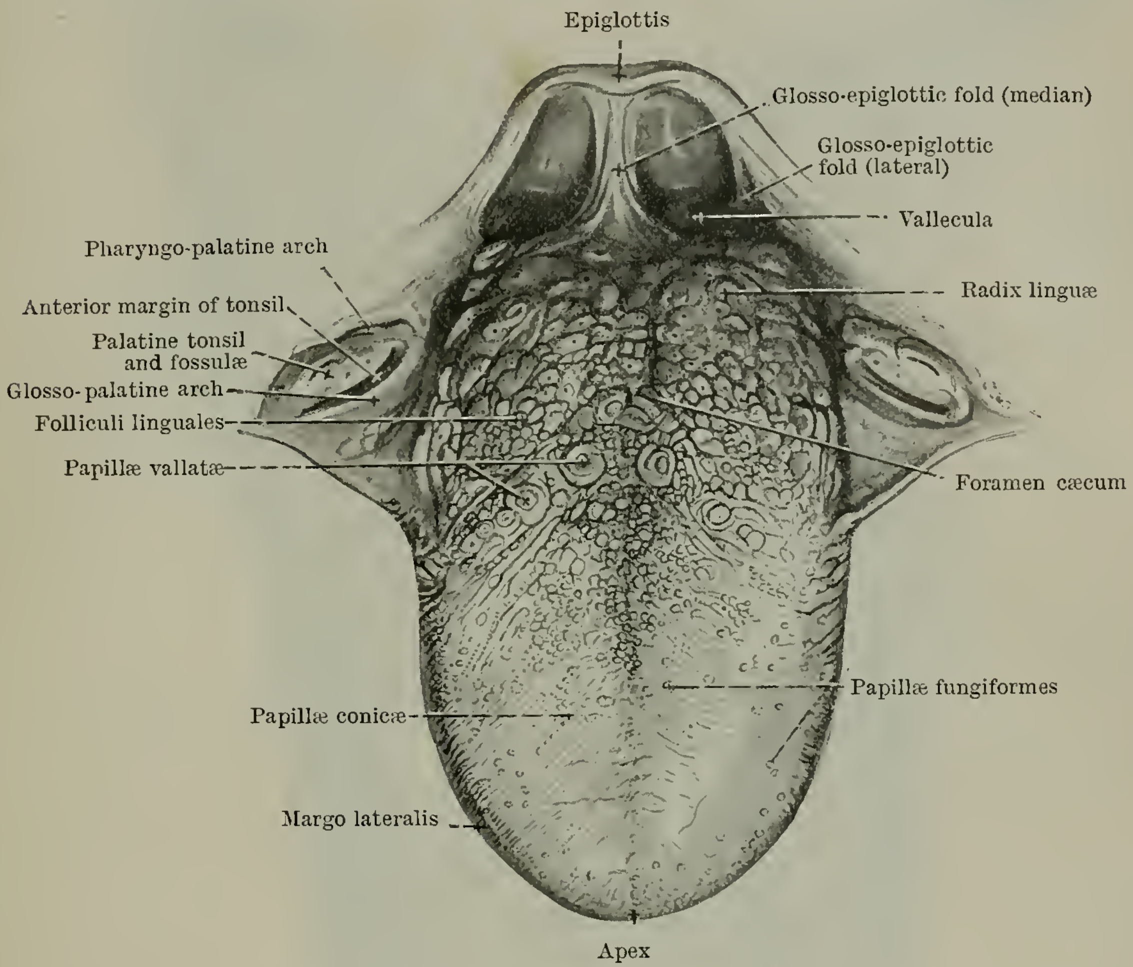


FIG. 881.—DORSUM OF TONGUE AND PALATINE TONSILS.

The medial surface is prominent and free, studded with small pit-like depressions called the fossulæ or crypts of the tonsil.

The lateral, or attached surface, is enclosed in a distinct fibrous capsule, connected with the pharyngo-basilar fascia, and this capsule separates the tonsil from the superior constrictor muscle of the pharynx.

The superior pole is rounded and blunt, and presents numerous fossulæ. The inferior pole projects downwards towards the tongue. The anterior margin looks towards the glosso-palatine arch, and is often overlapped by the plica triangularis; the posterior margin is directed towards the pharyngo-palatine arch.

The supra-tonsillar fossa is a recess of considerable size, which extends into the soft palate, and opens by a narrow orifice into the upper part of the tonsillar sinus (Figs. 880 and 881).

Relations of the Tonsil.—The lateral relations of the tonsil consist of the fibrous capsule and the superior constrictor muscle. Lateral to the pharyngeal wall lies the internal pterygoid muscle, and behind it a region filled with connective tissue, containing blood-vessels and nerves.

The nearest and most important vessel is the external maxillary artery, which, especially if tortuous, has a very close relation to the pharyngeal wall at this level.

The ascending palatine and tonsillar branches of the artery are also in close relation.

The internal carotid artery and internal jugular vein lie considerably further back (¾ to 1 inch) and to the lateral side, and the external carotid artery is still more lateral.

The ascending pharyngeal artery is well behind the tonsil.

The size of the palatine tonsils is extremely variable, but as a rule, in early life, they measure something under 1 inch (20 to 22 mm.) from above downwards, about ¾ inch (18 to 20 mm.) antero-posteriorly, and ½ inch (12 to 15 mm.) medio-laterally.

The arteries of the palatine tonsil are derived from the ascending palatine and tonsillar branches of the external maxillary artery, the ascending pharyngeal branch of the external carotid, and the dorsalis linguæ of the lingual. The **veins** pass to the tonsillar plexus, on the lateral side of the tonsil, which is an offshoot of the pharyngeal venous plexus.

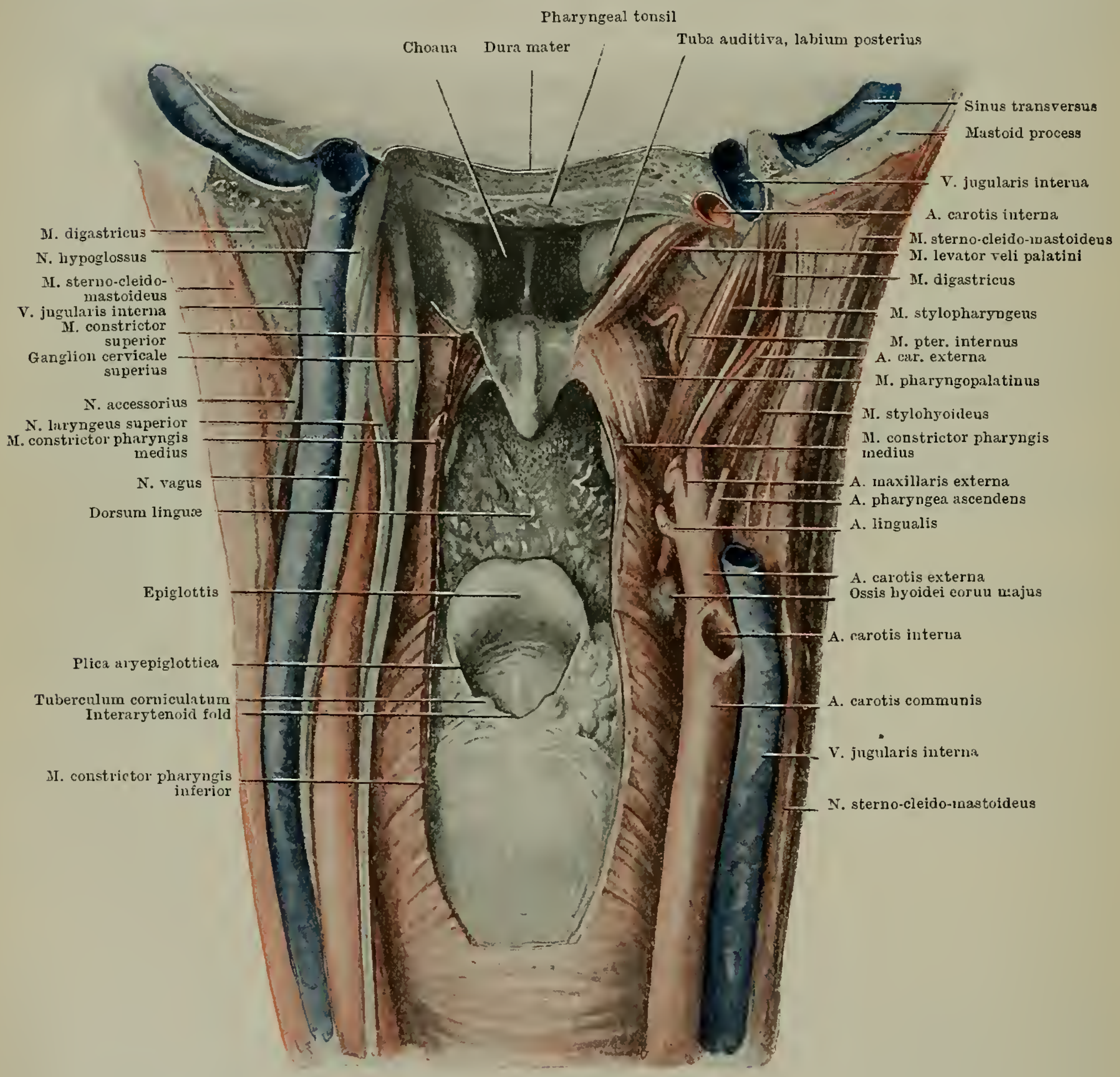


Fig. 882.—Interior of Pharynx and Structures in relation to its Side Walls, viewed from behind.

Nerves.—The palatine tonsil receives a special branch from the glosso-pharyngeal ; this unites with branches from the pharyngeal plexus to form a small **plexus tonsillaris** which supplies the organ.

The **lymph vessels** are extremely numerous. They begin in a plexus which surrounds each follicle, whence vessels pass to the lateral surface of the tonsil. Thence they pass through the wall of the pharynx, and pass to the deep cervical glands in the neighbourhood of the greater cornu of the hyoid bone, behind and inferior to the angle of the mandible.

Structure of the Palatine Tonsils.—Each palatine tonsil is composed of masses of small rounded lymph cells with a delicate connective tissue reticulum. These resemble in structure the folliculi linguales, *q.v.*

Upon its medial surface it is covered with epithelium, continuous with the epithelium covering the adjacent parts of the wall of the pharynx. This surface is very irregular, and on section crypts, termed fossulæ tonsillares, are seen to be formed by deep infoldings of the epithelial wall. On its lateral surface, the lymph tissue is invested by a connective tissue capsule.

Pars Laryngea.—The **laryngeal part** of the pharyngeal cavity lies posterior to the larynx (Fig. 880). It is wide above, but at the level of the cricoid cartilage it narrows rapidly and passes down to join the œsophagus.

The *anterior wall* of the laryngeal portion of the pharynx is formed in its whole extent by the posterior surface of the larynx, of which the following parts are seen from the pharyngeal cavity (Fig. 882): The epiglottis above; below this the superior aperture of the larynx, bounded at the sides by the ary-epiglottic folds; lateral to these folds is seen, on each side, a deep recess, the **recessus piriformis** (Fig. 825). Lower down still, the muscles and mucous membrane which cover the posterior surfaces of the arytenoid and cricoid cartilages are distinguishable.

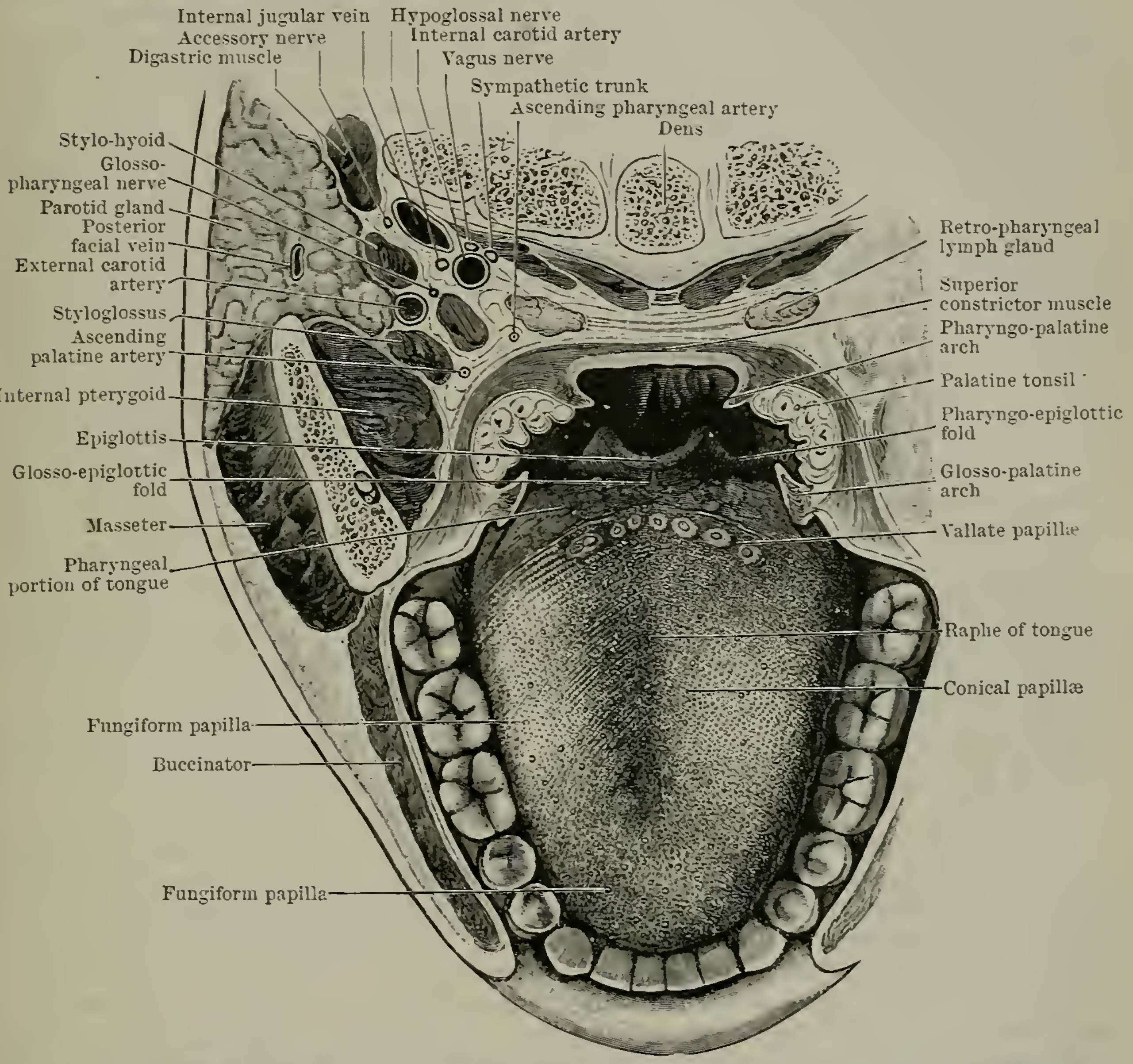


Fig. 883.—Horizontal Section through Mouth and Pharynx at the Level of the Palatine Tonsils.

The stylopharyngeus, which is shown immediately to the medial side of the external carotid artery, and the prevertebral muscles, are not indicated by reference lines.

The **recessus piriformis** is a depression on each side between the ary-epiglottic fold and the lamina of the thyreoid cartilage. When viewed from above, as in laryngoscopic examinations, it appears of a piriform shape, the wider end being directed upwards and forwards. When viewed from behind, the recess is boat-shaped and elongated in the vertical direction. Its side wall is formed by the thyreoid cartilage and thyreo-hyoid membrane, covered with mucous membrane; its medial wall is formed by the ary-epiglottic fold, and slightly, below, by the superior part of the cricoid cartilage.

Relations of the Pharynx.—In considering the relations of the pharynx, it is at once evident that these are very different in the superior and inferior portions.

1. Throughout its whole extent it lies anterior to the cervical region of the vertebral column, and is separated from the bodies of the vertebræ and the intervertebral fibro-cartilages by the loose areolar tissue of the prevertebral or retropharyngeal space, posterior to which lie the anterior longitudinal ligament of the vertebral column, and the longus capitis and longus colli muscles.

2. **In the neck**, on each side, it is in contact with the superior part of the thyreoid gland, the carotid sheath, and especially the common and external carotid arteries and, more posteriorly, the internal carotids.

The branches arising from the inferior part of the external carotid are also in close relation to the pharyngeal wall, viz., the superior thyreoid and lingual arteries in the lower part, while the external maxillary artery, as it passes under the digastric and stylo-hyoid muscles, comes into contact with the superior constrictor; and the ascending pharyngeal artery runs upwards by the side of the pharyngeal wall.

3. The relations of the **cranial portion** are more complex, but are of great importance. Reference to Fig. 883 will help to elucidate them. At the upper part, the wall of the pharynx is related to the internal pterygoid muscles, separated from them by the levator and tensor veli palatini muscles. As each internal pterygoid passes posteriorly and downwards to its insertion, it diverges away from the pharynx, and a triangular space is left between its medial surface and the wall of the pharynx. The styloid process, and the muscles which arise from it, project downwards into this space, and lying beside them are numerous vessels and some nerves. Thus, the stylo-glossus and stylo-pharyngeus come into contact with the side wall, and, with the stylo-pharyngeus, the glossopharyngeal nerve. The ascending palatine and tonsillar branches of the external maxillary artery ascend in close relation to the pharyngeal wall.

The internal carotid artery lies rather further back, with the vagus, accessory and hypoglossal nerves.

The external carotid lies more superficially, and is here separated by a considerable interval from the pharyngeal wall.

Lastly, a process of the parotid gland may insert itself on the medial aspect of the internal pterygoid, and come into contact with the pharynx.

The pharyngeal plexus of nerves lies in contact with the side wall.

Structure of the Pharyngeal Wall.—The wall of the pharynx is firmly fixed above to the base of the skull, but below that level it is not attached firmly to any surrounding structures, except to the hyoid bone and the skeleton of the larynx.

The wall is composed of a strong fibrous membrane, called the **fascia pharyngobasilaris** (O.T. **pharyngeal aponeurosis**), lined internally by mucous membrane, and covered incompletely on its outer surface by a series of three overlapping muscles, the constrictor muscles of the pharynx.

These muscles are themselves covered externally by a thin layer of fibrous tissue or fascia, which passes forwards, at its superior part, on to the surface of the buccinator muscle, and is called the **fascia buccopharyngea.**

External to this fascia the wall of the pharynx is in contact with loose cellular tissue by which it is connected to and separated from adjacent structures.

With the wall of the pharynx are associated several accessory muscles, viz., the muscles of the soft palate and the stylopharyngeus and pharyngo-palatine muscles, which blend with the wall but are also attached to the larynx (see p. 465).

The fibrous aponeurosis which forms the principal constituent of the pharyngeal wall is firmly attached (round the margins of the openings into the pharynx) to other structures as follows:—

Above, it blends with the periosteum covering the basilar portion of the occipital bone in front of the pharyngeal tubercle, and on each side it extends out to the angular spine of the sphenoid and the inferior surface of the pyramid of the temporal bone, in front of the carotid foramen, and lateral to the opening of the auditory tube.

On each side it is attached to the medial pterygoid lamina, the pterygo-mandibular raphe, and the mylo-hyoid ridge, and is eventually lost on the side of the tongue.

The fascia pharyngobasilaris is particularly strong in the superior part, where there is an area on each side which is not covered by the superior constrictor muscle. This area forms the sinus of Morgagni, and here the tensor and levator veli palatini muscles pass through the wall.

Mucous Membrane of the Pharynx.—The mucous membrane of the pharynx consists, in the lower part, of a stratified squamous epithelium, while in the upper or nasal portion it is, in part, composed of ciliated epithelium. In the superior part of the pharynx and in the side wall, there are found large masses of lymph tissue, constituting the pharyngeal tonsil in the roof, and the palatine tonsil on each side. The same tissue is found in considerable amount in the pharyngeal recess and on the pharyngeal portion of the dorsum of the tongue.

There are also numerous racemose glands, of the mucous type, in the walls of the pars nasalis, and in the soft palate, and in the ary-epiglottic folds.

Pharyngeal Muscles.—For the details of the attachment and relations of these muscles, see pp. 464-466.

External to the pharyngeal muscles lies the fascia buccopharyngea.

The fascia pharyngobasilaris, which is thick above and thin below, and the fascia buccopharyngea, which is thin above and stouter below, are practically blended into one layer above, near the base of the skull, where the muscular coat is absent. Lower down they are separated by the constrictors, and become two distinct sheets. They are strengthened in the median plane posteriorly by a fibrous band descending from the pharyngeal tubercle.

Vessels and Nerves of the Pharynx.—The **arteries** of the pharynx are derived from—1, the ascending pharyngeal; 2, the ascending palatine branch of the external maxillary; 3, the descending palatine from the internal maxillary, with a few twigs from the dorsalis linguæ, tonsillar (of external maxillary), the artery of the pterygoid canal, and the pharyngeal branch of the internal maxillary. The **veins** go to the pharyngeal venous plexus, which is found between the constrictors and the bucco-pharyngeal fascia. The plexus communicates with the pterygoid plexus above and with the internal jugular or common facial vein below.

The **lymph vessels** of the pharynx pass chiefly to the superior set of deep cervical glands. Those from the superior part of the posterior wall join a few retro-pharyngeal glands which are found on each side between the pharynx and the rectus capitis anterior muscle. These latter glands, which are large in the child, small in the adult, but apparently always present (Fig. 883), are of considerable clinical interest, as they often form the starting-point of post-pharyngeal abscess. For fuller details see section on Lymph Glands.

The **nerves** of the pharynx, both motor and sensory, are derived chiefly from the pharyngeal plexus, which is formed by branches of the vagus, glosso-pharyngeal, and sympathetic. The soft palate and the neighbourhood of the palatine tonsil are supplied by the palatine branches of the spheno-palatine ganglion. The tonsil receives a branch from the glosso-pharyngeal direct. The vault of the pharynx, and the region around the orifice of the tuba auditiva, as well as the orifice itself, are supplied by branches from the spheno-palatine ganglion. Finally, the internal laryngeal nerve supplies the mucous membrane of the back of the larynx, where it forms the anterior wall of the laryngeal portion of the pharynx.

ŒSOPHAGUS.

The **œsophagus** or **gullet** is, with the exception of the pylorus, the narrowest, and at the same time one of the most muscular parts of the whole alimentary tube.

It extends from the termination of the pharynx, at the inferior border of the cricoid cartilage and opposite the sixth cervical vertebra, to the cardiac orifice of the stomach, opposite the eleventh thoracic vertebra. Between those two points it traverses the inferior part of the neck, the whole length of the thorax, and, having pierced the diaphragm, it enters the abdomen, and immediately afterwards joins the stomach. In its course it does not adhere to the median plane of the body, but twice leaves it, and curves to the left. In the inferior part of the neck and the superior part of the thorax, the œsophagus projects to the left beyond the margin of the trachea to the extent of $\frac{1}{6}$ or $\frac{1}{4}$ inch (4 to 6 mm.). It returns to the median plane at the level of the fourth thoracic vertebra, posterior to the aortic arch. Lower down, posterior to the pericardium, at the level of the seventh cervical vertebra, it again passes to the left, and at the same time forwards, in order to reach the œsophageal opening in the diaphragm, and it maintains this direction until the stomach is reached. It crosses anterior to the aorta at the level of the eighth thoracic vertebra, and traverses the diaphragm at the level of the tenth.

In addition to the curvatures just described, it is also curved in the antero-posterior direction, in correspondence with the form of the vertebral column, upon which it, in great part, lies.

In *length* it usually measures from ten inches (25 cm.) to twelve inches (30 cm.).

Its *breadth*, where the tube is widest, varies between half an inch (13 mm.) in the empty contracted condition and an inch or more (25 to 30 mm.) in the fully distended state.

In cross sections (Fig. 885) the œsophagus appears either as a flattened tube with a transverse slit-like cavity, or as an oval or rounded canal with a stellate lumen. The former condition is more common in the neck, owing to the pressure of the trachea, and the latter in the thorax.

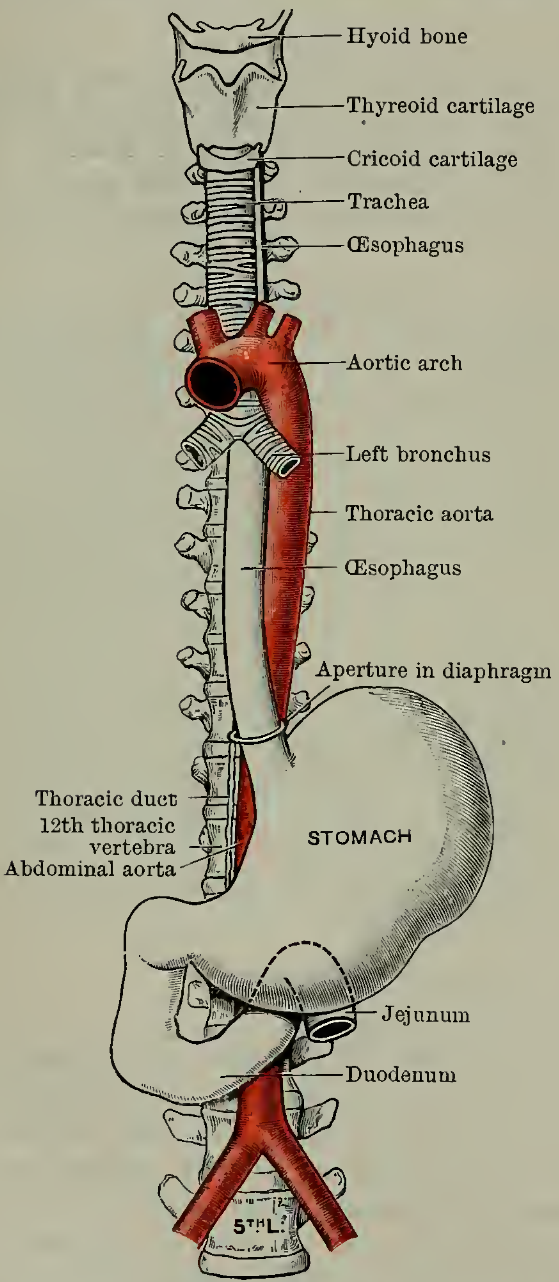


Fig. 884.—Diagram to show the Course of the Œsophagus.

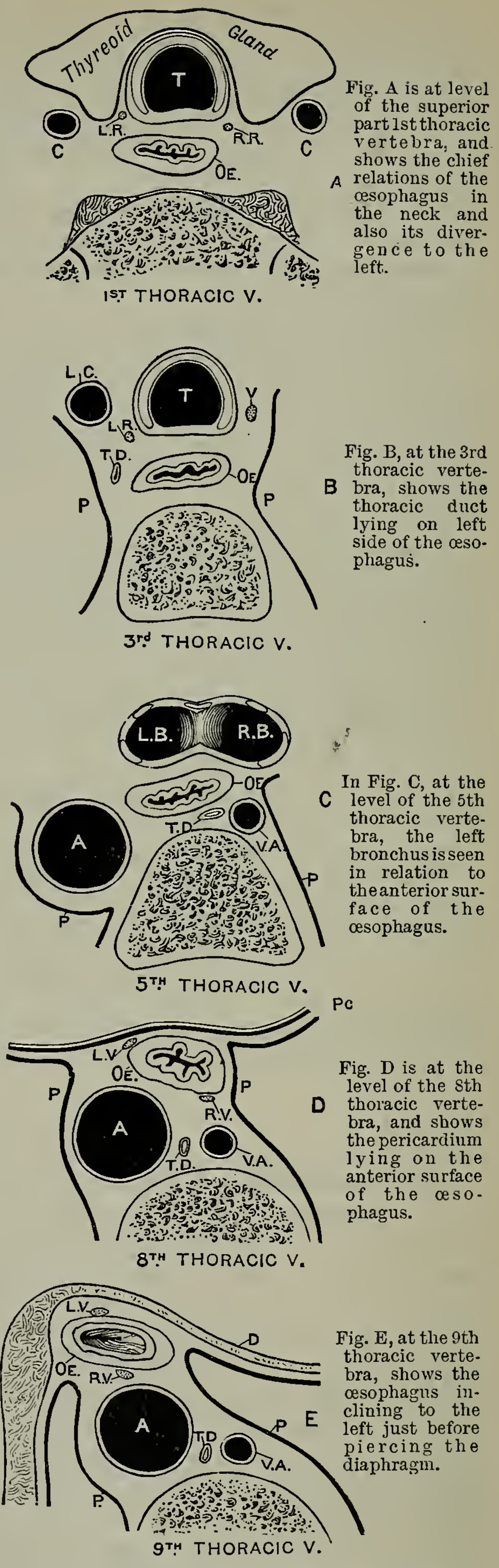


Fig. A is at level of the superior part 1st thoracic vertebra, and shows the chief relations of the œsophagus in the neck and also its divergence to the left.

Fig. B, at the 3rd thoracic vertebra, shows the thoracic duct lying on left side of the œsophagus.

In Fig. C, at the level of the 5th thoracic vertebra, the left bronchus is seen in relation to the anterior surface of the œsophagus.

Fig. D is at the level of the 8th thoracic vertebra, and shows the pericardium lying on the anterior surface of the œsophagus.

Fig. E, at the 9th thoracic vertebra, shows the œsophagus inclining to the left just before piercing the diaphragm.

Fig. 885.—Tracings from Frozen Sections to show the Relations of the Œsophagus at the levels of the 1st, 3rd, 5th, 8th, and 9th thoracic vertebræ, respectively.

A, Aorta; C, Common carotid artery; D, Diaphragm; L.B, Left bronchus; L.C, Left subclavian artery; L.R, Left recurrent nerve; L.V, Left vagus; Oe, Œsophagus; P, Pleura; Pc, Pericardium; R.B, Right bronchus; R.R, Right recurrent nerve; R.V, Right vagus; T, Trachea; T.D, Thoracic duct; V.A, Vena azygos.

When exposed in the ordinary post-mortem examination soon after death, it has rather the appearance of a solid muscular rod or band than of a hollow tube.

The œsophagus presents three distinct *constrictions*, one situated at its beginning, another at the point where it is crossed by the left bronchus, and the third where it passes through the diaphragm. The two upper constrictions are of the same size, and will admit without injury an instrument with a maximum diameter of $\frac{4}{5}$ inch (20 mm.). At each of these points the tube is flattened from before backwards.

The distance from the upper incisors to the beginning of the œsophagus averages about 6 inches (15 cm.).

The size at the two constrictions, when the tube is fully distended, is 23 mm. transversely, and 17 mm. antero-posteriorly. The other parts vary in diameter between 26 and 30 mm. (Jonnesco).

In its first curvature to the left the divergence is greatest opposite the third thoracic vertebra.

Relations of the Œsophagus.—The relations (Fig. 885) differ so widely in the neck and thorax that they must be described separately for each of those regions.

In the Neck.—Anteriorly lies the trachea—to the posterior membranous wall of which the œsophagus is loosely connected by areolar tissue—and in the groove at each side, between the trachea and œsophagus, the recurrent nerve ascends to the larynx (Fig. 885, A). Posteriorly lie the vertebral column and the longus colli muscles, from which the œsophagus is separated by the prevertebral layer of the cervical fascia. On each side are placed the carotid sheath with its contained vessels, and the corresponding lobe of the thyreoid gland and the inferior thyreoid artery. Owing to the deviation of the tube to the left in the inferior part of the neck, its relation to the carotid sheath and thyreoid gland is much more intimate on the left than on the right side.

In the Thorax.—The œsophagus passes successively through the superior and posterior mediastina, in the former lying close to the vertebral column, but in the latter advancing somewhat into the thoracic cavity and coming into contact with the back of the pericardium. The trachea still lies anterior to it as far as the fifth thoracic vertebra, where the trachea bifurcates. Immediately below that the œsophagus is crossed by the left bronchus (Fig. 885, C), and in the rest of its thoracic course it lies in the closest relation to the back of the pericardium. Posteriorly, in the upper part of the thorax, it rests on the longus colli muscles and the vertebral column; but below the bifurcation of the trachea, as already explained, it advances into the cavity of the posterior mediastinum, and is soon separated from the vertebral column by the vena azygos, the thoracic duct, the upper five aortic intercostal arteries of the right side, and in its lower part by the thoracic aorta as well.

On its *left side*, in the upper part of the thorax, lie the left pleura and the left subclavian artery, with the thoracic duct in a plane posterior to the artery; in the middle region, the aorta, and lower down the left pleura again, for a little way, before the œsophagus pierces the diaphragm. On the *right side* the tube comes into relation with the arch of the vena azygos, whilst the right pleura clothes it both below and above that level.

The two vagus nerves, after forming the anterior and posterior pulmonary plexuses, descend to the œsophagus, where they form, by uniting with one another and with the branches of the sympathetic, the anterior and posterior **œsophageal plexuses.** Lower down the left nerve winds round to the anterior, whilst the right turns to the posterior surface of the œsophagus, and in this relation they pass with the tube through the diaphragm to reach the stomach.

The **diaphragmatic portion,** about half an inch in length (1 to 1·5 cm.), corresponds to the œsophageal orifice (or canal) of the diaphragm. The plane of this orifice is very oblique or almost vertical, and its abdominal opening looks forwards and to the left, and but little downwards. Above and in front, it is bounded either by the posterior edge of the central tendon or by a few decussating fibres of the muscular portion of the diaphragm. At the sides and behind, on the other hand, the decussating bands from the two crura, which embrace the orifice, are so arranged that they turn a flat surface (not an edge) towards the opening, and thus, behind and at the sides, the orifice or canal is of some length; and on these aspects the tube is in contact with the diaphragm for a distance of 1 to 1½ cm.

But this contact takes place not around a horizontal line, but in a very oblique plane corresponding to that of the orifice.

The œsophagus is connected to the boundaries of the orifice by a considerable amount of strong connective tissue, but it is extremely difficult, or impossible, to demonstrate any direct naked-eye connexion between the œsophageal muscular fibres and those of the diaphragm.

The **pars abdominalis** of the œsophagus is very short, for immediately after piercing the diaphragm the tube expands into the stomach. It lies against the œsophageal groove of the liver in front.

When the stomach is fully distended the abdominal part of the œsophagus almost disappears, being absorbed into the stomach in its distension.

The portion of the œsophagus which adjoins the stomach is sometimes described as consisting of two parts, namely, the **ampulla phrenica** and the **antrum cardiacum.** The former is a fusiform expansion of the tube, of variable length and girth, which lies within the thorax immediately above the point where the gullet is grasped between the two muscular margins of the œsophageal opening and the diaphragm. It lies in the lowest part of the posterior mediastinum where this is bounded anteriorly by the back of the diaphragm.

The antrum cardiacum is another name for the abdominal portion of the œsophagus. It is funnel-shaped, and expands towards the stomach.

Relation of the Aorta to the Œsophagus.—The arch of the aorta, passing back to reach the vertebral column, crosses to the left side of the œsophagus; consequently the descending thoracic aorta lies at first to its left; lower down, however, as the aorta passes on to the anterior aspect of the vertebral column, and the gullet inclines forwards and to the left, the aorta comes to lie posteriorly, and then, as the diaphragm is approached, it lies not only posteriorly, but also somewhat to the right of the œsophagus (Figs. 884 and 885).

Relation of the Thoracic Duct to the Œsophagus.—The thoracic duct, lying to the right of the aorta below, is not directly related to the œsophagus (Fig. 885, E); but higher up (Fig. 885, D and E) it lies posterior to it. About the level of the aortic arch the duct passes to the left, and above this (Fig. 885, B and A) will be found on the left side of the œsophagus, and on a plane somewhat posterior to it.

Relation of the Pleural Sacs to the Œsophagus.—Above the level of the arches of the aorta and of the vena azygos, between which the œsophagus descends, the pleuræ, though not lying in immediate contact with the œsophagus, are separated from it only by a little connective tissue, and on the left side also, behind the subclavian artery, by the thoracic duct (Fig. 885, B). Here, in thin bodies, the left pleura is very close to the œsophagus, and the thoracic duct, lying on its left side, may occasionally be seen through the pleural membrane. Below the arch of the azygos vein the right pleura clothes the right side of the œsophagus—and very often even a considerable portion of its posterior surface too, thus forming a deep recess behind it—almost as low down as the opening in the diaphragm. On the left side, below the level of the aortic arch, the left pleura comes in contact with the gullet, only for a short distance, just above the diaphragm (Fig. 885, E).

Variations.—The chief anomalies found in the œsophagus are: (1) Annular or tubular constrictions; (2) diverticula, of which the most interesting—known as "pressure pouches"—are usually situated on the posterior wall close to its junction with the pharynx, and these sometimes require surgical interference; (3) doubling in part of its course; and (4) communications between the trachea and œsophagus.

Structure of the Œsophagus (Fig. 888).—The œsophageal wall is composed of three proper coats—(1) *tunica muscularis,* (2) *tela submucosa,* and (3) *tunica mucosa.* In addition, it is surrounded by an outer covering of areolar tissue (4) *tunica adventitia,* by which it is loosely connected to the various structures related to it in its course. This loose covering permits of its free movement and of its increase in size, or of its diminution, during the act of swallowing.

The **tunica muscularis** is composed of two layers — an outer of longitudinal, and an inner of circular fibres. The *longitudinal layer* is highly developed, and, unlike the condition usually found in the digestive tube, it is as stout as, or in places stouter than, the circular layer. Its fibres form along the greater length of the tube an even covering outside the circular layer, and below they are continued into the longitudinal fibres of the stomach. Above, near the superior end of the œsophagus, the longitudinal fibres of each side, separating at the back, pass round towards the anterior aspect and form two longitudinal bands (Fig. 886), which run up on the front of the tube, and are attached by a tendinous band to the superior part of the posterior surface of the cricoid cartilage (Fig. 887).

The *circular muscular fibres,* though not forming such a thick layer as the longitudinal fibres, are nevertheless well developed. Below, they are continued into both the circular and oblique fibres of the stomach. Above, they pass into the inferior fibres of the inferior constrictor of the pharynx.

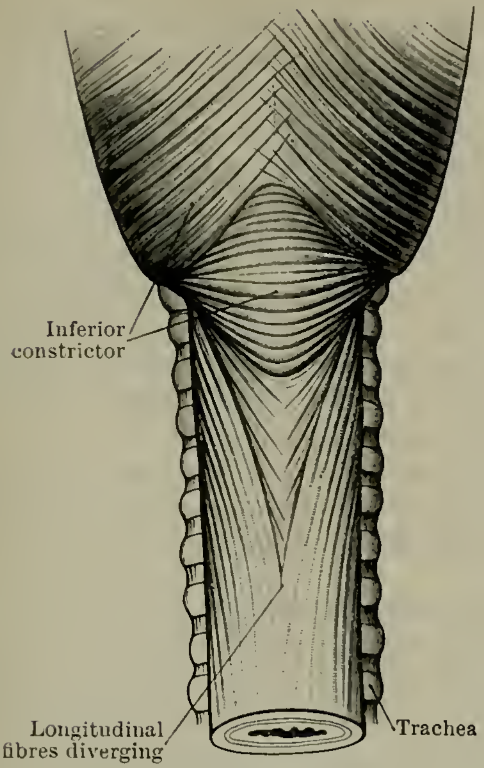


Fig. 886. — Dissection to show the arrangement of the muscular fibres on the posterior aspect of the œsophagus and pharynx. Traced upwards, the longitudinal muscular fibres of the œsophagus are seen to separate posteriorly; passing round to the sides, they form two longitudinal bands which meet anteriorly and are united to the cricoid cartilage, as shown in the next figure.

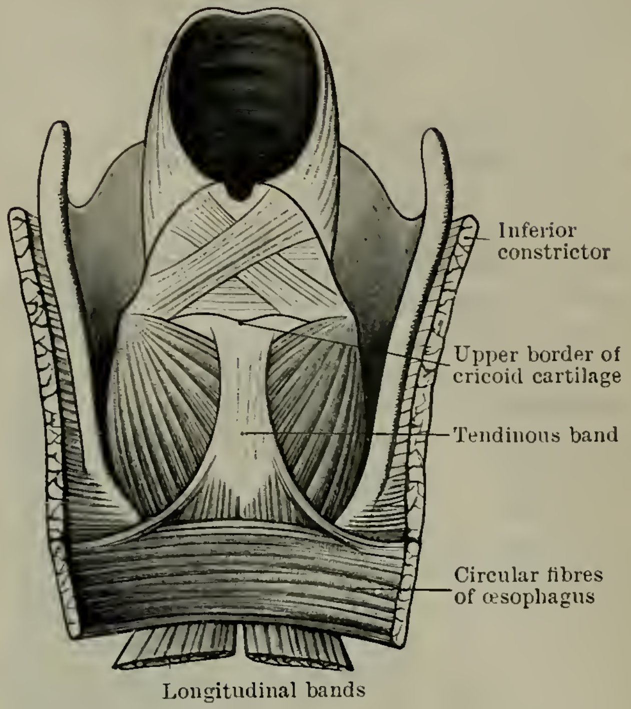

Inferior constrictor
Upper border of cricoid cartilage
Tendinous band
Circular fibres of œsophagus
Longitudinal bands

Fig. 887.—The Inferior Part of the Pharynx and the Superior Part of the Œsophagus have been slit up from behind, and the mucous membrane removed to show the muscular fibres. The two longitudinal bands are seen passing round to the front to be attached by a common tendon to the superior border of the cricoid cartilage. See explanation of last figure.

At the superior end of the œsophagus the muscular fibres are entirely of the striated variety. Soon unstriped fibres begin to appear in increasing numbers, and in the inferior half or two-thirds only unstriped muscle is found.

The longitudinal fibres for about the superior fifth of the tube are entirely striped; in the second fifth striped and unstriped are mixed; whilst in the inferior three-fifths unstriped fibres alone are present. The circular fibres are entirely striated for the first inch; after this unstriped fibres appear; and in the inferior two-thirds, only unstriped muscle fibres are found.

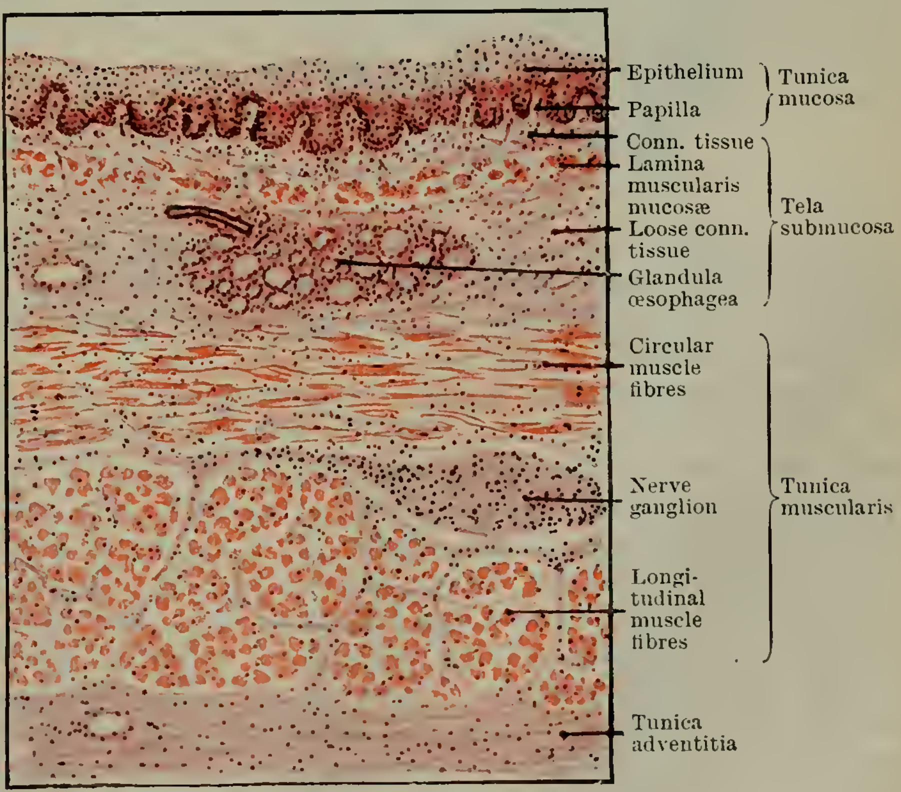


Fig. 888.—Transverse Section of Wall of Human Œsophagus.

The longitudinal fibres are often joined by slips of unstriped muscle, or elastic fibres, which spring from various sources, including the left pleura (*m. pleuro-œsophageus*, constant, Cunningham), the bronchi (*m. broncho-œsophageus*), back of trachea, pericardium, aorta, etc. These slips assist in fixing the œsophagus to the surrounding structures in its passage through the thorax, and have been aptly compared to the tendrils of a climbing plant (Treitz).

The **tela submucosa**, composed of areolar tissue, is of very considerable thickness, in order to allow of the expansion of the tube during swallowing. It connects the mucous membrane loosely to the muscular coat, and admits of the former being thrown into folds when empty. In this coat are contained the numerous racemose mucous glands (glandulæ œsophageæ) which open into the cavity of the œsophagus (Fig. 888).

The **tunica mucosa** is of a grayish-pink colour, much paler than that of the pharynx, and of a firm and resistant texture. It is covered with a thick stratified, squamous epithelium, on the surface of which the openings of numerous glands are found. Inferiorly, its junction with the gastric mucous membrane is indicated by a distinct, irregularly dentated or crenated line, which runs transversely round the tube. In carefully preserved specimens the smooth mucous membrane of the œsophagus above this line contrasts strongly with the mamillated gastric mucous membrane below.

Owing to the inelasticity of this coat, and the fact that it is but loosely connected to the muscular coat by the submucosa, it is thrown into a series of longitudinal folds when the œsophagus is empty and contracted; hence the stellate lumen often seen in sections of the gullet.

Glands.—Numerous racemose mucous glands, the **glandulæ œsophageæ**, large enough to be seen distinctly with the naked eye, are found in the submucosa. They are pretty evenly distributed over the whole tube, and do not appear to be more numerous towards either end. In addition to these, other glands, resembling closely those of the cardiac end of the stomach, are found in the mucous membrane of certain portions of the œsophagus. They are entirely confined to the mucosa, and do not extend beyond the lamina muscularis mucosæ. These glands are specially numerous at both the upper and lower ends of the tube.

Vessels and Nerves.—Its **arteries** consist of numerous small branches derived, in the neck, from the inferior thyreoid, in the thorax, from the bronchial arteries and thoracic aorta, and in the abdomen, from the left gastric artery, and also from the left inferior phrenic.

The **veins** form a plexus on the exterior of the œsophagus, from which branches pass, in the lower part of the tube, to the coronary vein of the stomach, and, higher up, to the azygos, and thyreoid veins. There is thus established on the lower part of the œsophagus a free communication between the portal and systemic veins.

The **lymph vessels** pass to the inferior set of deep cervical glands in the neck, and to the posterior mediastinal glands, many of which, of large size, are seen around the tube, in the thorax.

The **nerves** are derived from the recurrent, and from the cervical sympathetic in the neck, from the vagus and sympathetic nerves in the thorax.

THE ABDOMINAL CAVITY.

As the remaining parts of the digestive system lie within the abdomino-pelvic cavity it will be necessary to describe that cavity, and to refer briefly to its lining membrane—the peritoneum—before passing on to the consideration of the viscera which are contained within it.

The abdomino-pelvic cavity is that portion of the cavity of the trunk which lies below the diaphragm. Its wall is composed in part of bones, muscles, tendons, fascia, etc., and in the cavity lie the greater part of the digestive, urinary, and generative systems of organs, as well as blood-vessels, nerves, and other structures. The internal surface of the greater part of the wall of the cavity, and of the external surfaces of the viscera, are clothed by a continuous smooth membrane, the peritoneum. The contained organs lie in contact with one another or with the wall, and the so-called cavity is merely a potential space between the peritoneal surfaces of adjacent viscera. When air is admitted, the viscera fall away from one another and a space is formed, in place of the capillary interval which exists under normal conditions between them.

In the following description the term **abdomen** or **abdominal cavity** is used to indicate the region enclosed by the muscular and bony walls, and the term **peritoneal cavity** the potential space inside the peritoneal membrane between the viscera.

Shape.—In vertical section the cavity is of a somewhat oval form, with the long axis directed vertically. The superior end is wider than the inferior. In transverse section it is almost reniform, flattened from before backwards, and is encroached upon in the median plane posteriorly by the projection forwards of the vertebral column to such a degree that the front of the vertebral column lies at no great distance from the back of the anterior abdominal wall (usually 2½ to 3 inches), while on each side of the vertebral column there is a deep recess, occupied by the kidneys and portions of the intestine.

The abdominal cavity is divisible into the **abdominal cavity proper** and the **pelvis minor.** Vertical section of the trunk shows that the **pelvis minor** (O.T. **true pelvis**) lies below and behind the abdominal cavity, of which it forms a funnel-shaped termination. The long axis of the funnel is directed downwards and backwards.

The **superior aperture of the pelvis minor** (Figs. 217 and 218, p. 256), which separates the two natural divisions of the cavity, is formed behind by the base of the sacrum, at the sides by the linea terminalis of each hip bone, and in front by the pubic crests and the symphysis pubis. In the erect position it usually makes an angle of about 55 to 60 degrees with the horizontal. The two portions of the abdominal cavity which the superior aperture separates meet at an angle, the abdomen proper extending almost vertically upwards from it, whilst the pelvic cavity slopes backwards and slightly downwards.

As the walls of these two regions are markedly different, the boundaries will be considered separately.

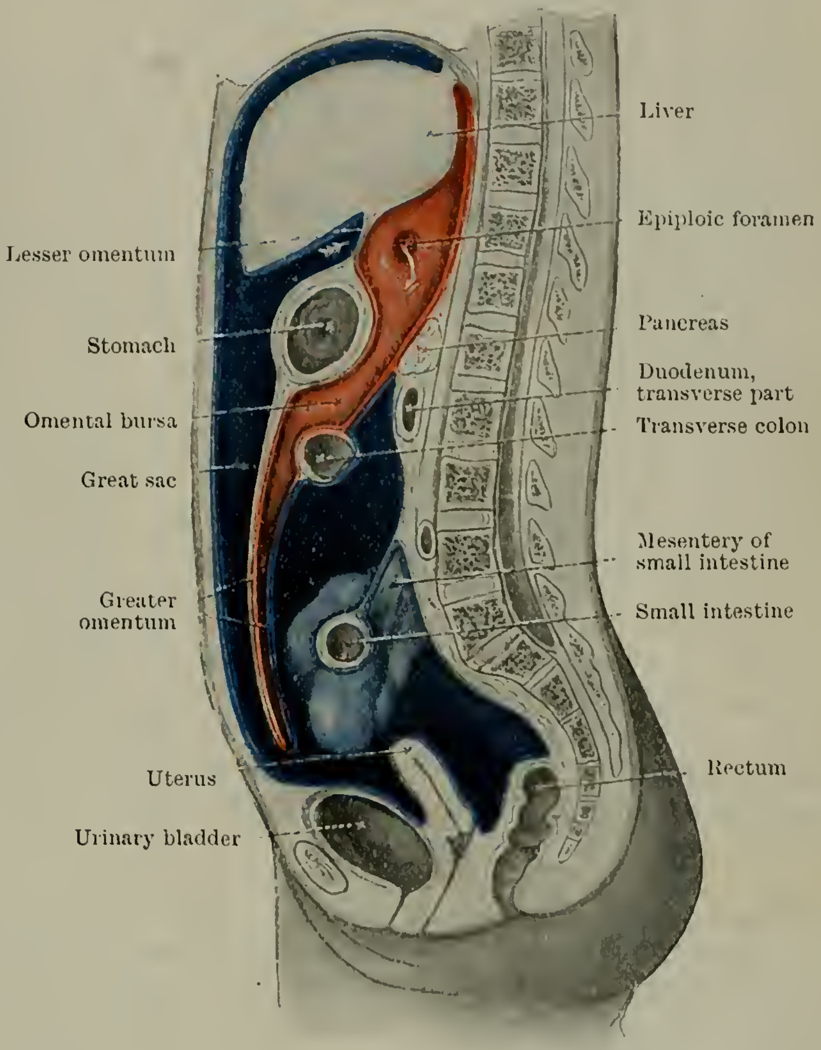


FIG. 889.—DIAGRAMMATIC MEDIAN SECTION OF FEMALE BODY, to show the abdomino-pelvic cavity and the peritoneum on vertical tracing. The great sac of the peritoneum is blue and is represented as being much larger than in nature; the bursa omentalis is coloured red; the peritoneum in section is shown as a white line: and a white arrow is passed through the epiploic foramen from the great sac into the bursa omentalis.

Boundaries of the Abdomen Proper.—The cavity is limited *above* by the concave vault of the diaphragm, which is dome-shaped and presents a right and a left cupola separated by an intervening depression. On the superior surface of each cupola is placed the base of the corresponding lung, whilst between them, on the depression, rests the inferior surface of the heart.

During expiration, the diaphragm ascends almost to the level of the right nipple, and may reach the superior border of the fifth rib, or even the middle of the fourth intercostal space. On the left side it is one-half to one inch (12-25 mm.) lower, and in the median plane it crosses the inferior extremity of the body of the sternum about the level of the seventh rib cartilage.

Below, the cavity is continued into the cavity of the pelvis minor.

The *anterior wall* is formed by the aponeuroses of the three flat abdominal muscles, obliquus externus, obliquus internus, and transversus abdominis, together with the two recti, which latter constitute powerful braces for the wall, on each side of the median plane.

Anteriorly, below the junction of abdomen and pelvis, lies the pubic symphysis. The body of the pubis looks upwards as well as posteriorly, and appears to form a support or floor for the viscera contained within the anterior part of the abdominal cavity.

The *side walls* are formed by the muscular portions of the obliqui and transversi muscles, and below by the iliac bones and the iliacus muscles.

Finally, the cavity is limited *posteriorly* by the lumbar portion of the vertebral column, with the crus of the diaphragm and psoas major muscle on each side, and the quadratus lumborum still more laterally. The iliac bones also enter into the formation of the inferior portion of the posterior wall.

The superior portion of the cavity lies under cover of the ribs, which afford considerable protection to that part of the abdomen, particularly at the sides and posteriorly. Anteriorly, on the other hand, the ribs are wanting below the sternum, and there the abdominal wall is formed only of aponeuroses and muscles. But even at the sides and back there is a considerable zone, usually one to two inches wide, between the lower ribs above and the crest of the ilium below, which has no bony support except that afforded by the vertebral column.

Whilst the circumference of the diaphragm is attached to the inferior part of the thoracic framework anteriorly and laterally, and to the lumbar vertebræ posteriorly, the central portion of the dome, on the other hand, namely, the central tendon, is placed high up, under cover of the ribs, and in a more or less horizontal plane. As a result, the peripheral muscular part slopes upwards and medially from the circumference of the thoracic framework to the central tendon, and lies for a considerable distance in contact with the deep surface of the ribs; thus the diaphragm comes to form, not only the roof of the cavity, but it also enters into the formation of the sides, the posterior wall, and, to a less extent, of the anterior wall; and *almost as much of the cavity of the abdomen as of the thorax lies under shelter of the ribs.*

Owing to the fact that the boundaries of the abdomen are formed chiefly of muscles, it follows that its walls are capable of contraction to a very considerable extent, and the size of the cavity can consequently be altered in all directions. Its chief changes in form are due to the descent or elevation of the diaphragm, the contraction or relaxation of the anterior wall and the side walls, and the raising or lowering of the pelvic floor.

The **pelvic cavity** is bounded in front and at the sides by the portions of the hip bones below the level of the linea terminalis. Those portions of the bony wall are partly clothed by the obturator internus muscles, and, internal to those muscles, by the parietal portion of the pelvic fascia, as low down as the arcus tendineus. The posterior wall is formed by the pelvic surface of the sacrum, covered on each side by the piriformis muscle. That wall (as represented by the piriformes muscles) meets the side wall at the anterior border of the greater sciatic foramen; through that foramen the piriformis passes out, thus closing up what would otherwise be a large aperture in the parietes of the cavity. The floor is composed of the two pairs of muscles which form the pelvic diaphragm, namely, the levatores ani and the coccygei—covered by the visceral layer of the endopelvic fascia. Those muscles pass, on each side, from the side wall of the pelvis, downwards and medially towards the median plane, and present a concave superior surface towards the pelvic cavity.

The internal surface of the muscles forming the walls is lined by an envelope of **fascia**, which separates the muscles from the extraperitoneal connective tissue and peritoneum. This fascial layer is distinguished in different localities as: (1) the *fascia transversalis*, on the anterior and side walls, lining the deep surface of the transversalis muscle and continuous above with the fascia clothing the inferior surface of the diaphragm; (2) the *fascia diaphragmatica*; (3) the *fascia iliaca*, on the posterior wall, covering the psoas and iliacus muscles; and (4) the *fascia endopelvica*, lining the pelvis.

Apertures.—Certain apertures are found in the muscular walls of the abdomen. They are: the three openings in the diaphragm for the passage of the inferior vena cava, the œsophagus, and the aorta, respectively; the apertures in the pelvic floor, through which the rectum, the urethra, and the vagina in the female, reach the surface; the inguinal canal, through which the spermatic funiculus (or the round ligament) passes; and lastly, the femoral canal, a small passage which extends downwards from the abdomen along the medial side of the femoral vessels. The latter two, particularly, constitute on each side weak points in the abdominal wall, through which an inguinal or a femoral hernia may occur. Similar protrusions may also occur at other points in the abdominal and also in the pelvic wall.

Tela Subserosa (O.T. **Extraperitoneal** or **Subperitoneal Connective Tissue**).—Between the fascia which covers the deep surfaces of the abdominal muscles and the peritoneum is found a considerable quantity of connective tissue, more or less loaded with fat, known as the tela subserosa. It is part of an extensive fascial system which lines the whole of the body cavity, outside the various serous sacs, and it is continued on the several vessels, nerves, and other structures which pass from the trunk into the limbs and neck.

In the abdomen it is divisible into a parietal and a visceral portion. The former lines the walls, whilst the latter passes between the layers of the peritoneal folds to the viscera. The two portions of the extraperitoneal tissue are continuous with one another, and contain in their whole extent a vascular plexus, through which a communication is established between the vessels of the abdominal wall on the one hand, and those of the contained viscera on the other. The parietal tela subserosa is also freely supplied by a network of nerve fibres, derived from cerebro-spinal nerves.

The *parietal portion* is thin and comparatively free from fat over the roof and anterior wall of the abdomen, where the peritoneum is firmly attached. In the pelvis minor, on the other hand, the tissue is loose and fatty, and it is continued up for some inches on the anterior abdominal wall above the pubes, and permits of the ascent of the bladder during its distension, in the interval between the peritoneum and the anterior abdominal wall. There also the urachus and the obliterated umbilical arteries will be found passing up in its substance. On the posterior wall the tissue is large in amount and fatty, particularly where it surrounds the great vessels and the kidneys.

From the parietal portion the *visceral expansions* are derived, in the form of prolongations around the various branches of the aorta. Those expansions are connected with the areolar coats of the blood-vessels and pass with them into the mesenteries and other folds of the peritoneum, and thus reach the viscera.

The chief uses of the tela subserosa are: (1) to unite the peritoneum to the fascial and muscular layers of the abdominal wall; (2) to connect the viscera to those walls and to one another in such a loose manner that their distension or relaxation may not be interfered with. That would not be the case if the connecting medium were firm or rigid; (3) in addition, it is a storehouse of fat, forms sheaths for the vessels and nerves, and establishes, through its vascular plexus, communication between the parietal vessels and those distributed to the abdominal viscera.

Subdivision of the Abdomen Proper.—Owing to the large size of the cavity, and in order to localise more correctly the position of the various organs contained within it, the abdomen proper is artificially subdivided by two horizontal and two sagittal planes (Fig. 890).

Of the two *horizontal planes*, one divides the trunk at the level of the lower border of the tenth costal cartilage; this is known as the **subcostal plane**, and the line where it intersects the abdominal wall is the **subcostal line**. The second horizontal plane is at the level of the highest point of each iliac crest which is visible from the front; this point corresponds to the tubercle seen on the external lip of the crest, about two inches posterior to the anterior superior spine, and can be easily located; the line and plane are consequently known as the **intertubercular line** and **plane**, respectively.

The *sagittal planes* are drawn, one on each side, perpendicularly upwards from a point on the **inguinal ligament** of Poupart midway between the anterior superior spine and the symphysis pubis. The planes and the corresponding lines are known as the **lateral planes** and **lines** respectively.

By the two horizontal planes the abdomen is divided into *three zones*, a superior or **costal**, a middle or **umbilical**, and an inferior or **hypogastric zone**. By the two perpendicular planes each zone is subdivided into three regions, a central and two lateral. Thus, in the upper zone, we get a **hypochondriac region** or **hypochondrium** on each side, and an **epigastric region** or **epigastrium** in the centre. Similarly, the umbilical zone is divided into **right** and **left lumbar regions**, with an **umbilical region** between. And the hypogastric zone has a **hypogastric region** or **hypogastrium** in the centre, with **right** and **left iliac regions** at the sides.

In addition, the portion of the abdominal wall above the body of the pubis is known as the *suprapubic region*, and that immediately above the inguinal ligaments as the *inguinal region*.

The three central divisions, namely, the epigastric, umbilical, and hypogastric regions, can conveniently be further subdivided by the median sagittal plane, passing through the middle of the body, into right and left halves.

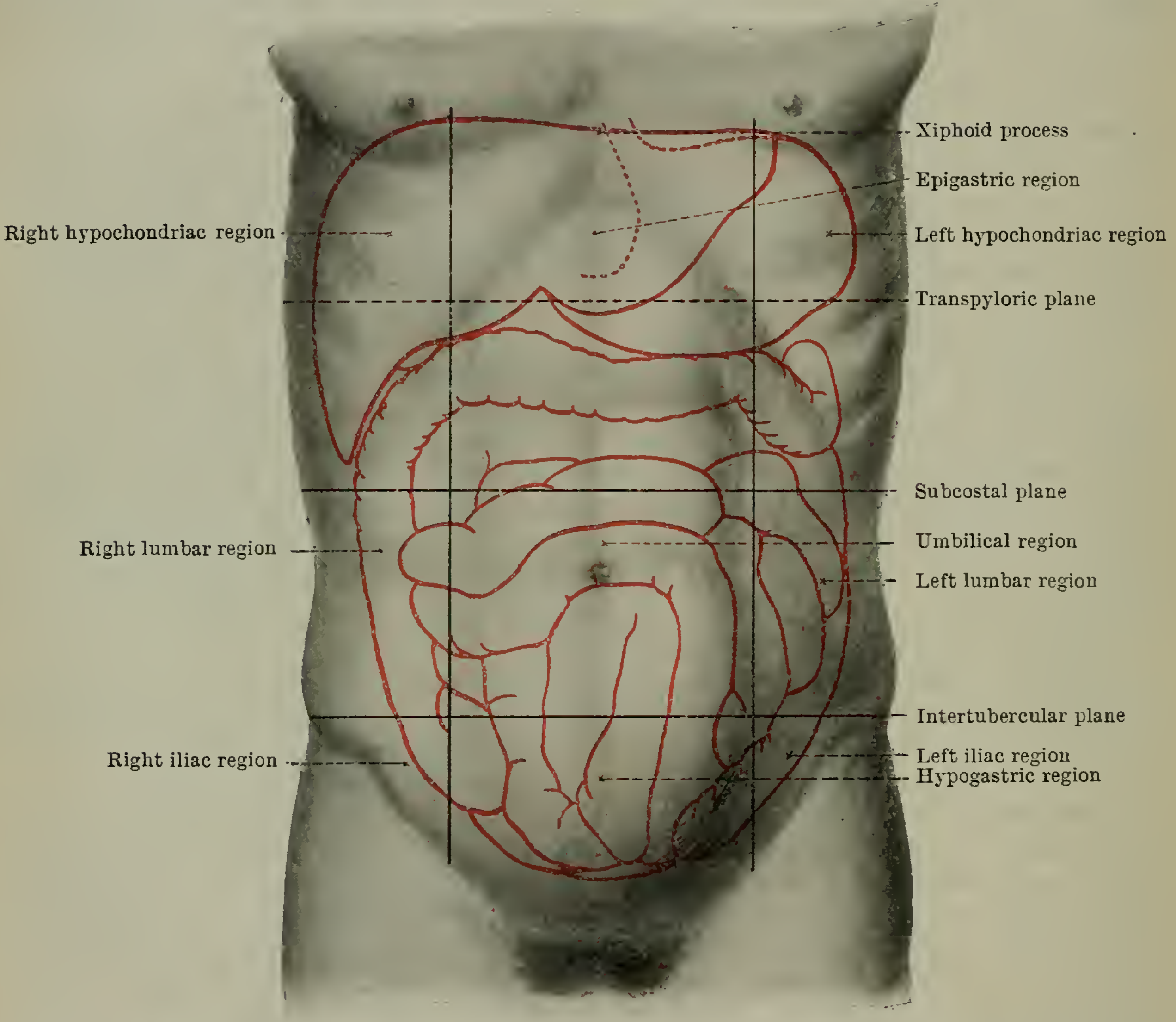


FIG. 890.—PLANES OF SUBDIVISION OF THE ABDOMINAL CAVITY, AND OUTLINE TRACING OF THE LIVER, STOMACH, AND INTESTINE IN RELATION TO THE ANTERIOR ABDOMINAL WALL.

The oblique position of the stomach and the high position of the transverse colon are largely due to the fact that the subject was in the horizontal position.

The superior horizontal, or subcostal, plane passes posteriorly, through the superior part of the third lumbar vertebra, or the fibro-cartilage between the second and third lumbar vertebræ. The intertubercular plane cuts through the middle or superior part of the fifth lumbar vertebra.

The inferior margin of the tenth costal cartilage frequently corresponds to the most dependent part of the thoracic framework. Often, however, the eleventh costal cartilage descends ¼ to ½ inch lower. Nevertheless, the tenth cartilage is selected in drawing the subcostal plane, for two chief reasons, namely, it is visible from the front as a rule, and it is comparatively fixed, whilst the eleventh, being a floating rib, is much more movable, is variable in length, and more difficult to locate.

Another plane which is of some practical value is the *transpyloric plane* (Addison). This is a horizontal plane which is taken to intersect the trunk at the level of the first lumbar vertebra. That level is ascertained during life by taking the mid-point of a line drawn, on the surface of the trunk, from the superior border of the sternum to the upper border of the symphysis pubis. The same level is obtained usually, but not so accurately, by taking the mid-point of a line drawn from the xiphi-sternal articulation to the umbilicus.

PERITONEUM.

The **peritoneum** is the serous membrane which lines the abdominal cavity and invests most of the abdominal viscera, to a greater or less degree. Like the pleuræ, pericardium, and other serous sacs, it is composed of a thin layer of fibrous tissue, containing numerous elastic fibres, covered over on the side turned towards the cavity of the sac by a layer of flattened endothelial cells forming the *tunica serosa.* Like them, too, the peritoneum in the male is a completely closed bag, but in the female this is not the case, for the ostium abdominale of each uterine tube opens into the sac, whilst the ostium uterinum of that tube communicates with the interior of the uterus, and thus, indirectly, with the exterior of the body. Normally the membrane secretes only sufficient moisture to lubricate its surface, otherwise the sac is perfectly empty, and its opposing walls lie in contact, thus practically obliterating its cavity.

The serous lining permits of the movements of the contained viscera during any changes in size or form which they or their containing cavity may undergo, and the stomach and intestines are free to move with the least degree of friction when any change takes place either in the organs themselves or in their surroundings.

The peritoneum is united so intimately to many of the viscera that it appears at first sight to be a superficial layer of the organs themselves rather than a separate membrane.

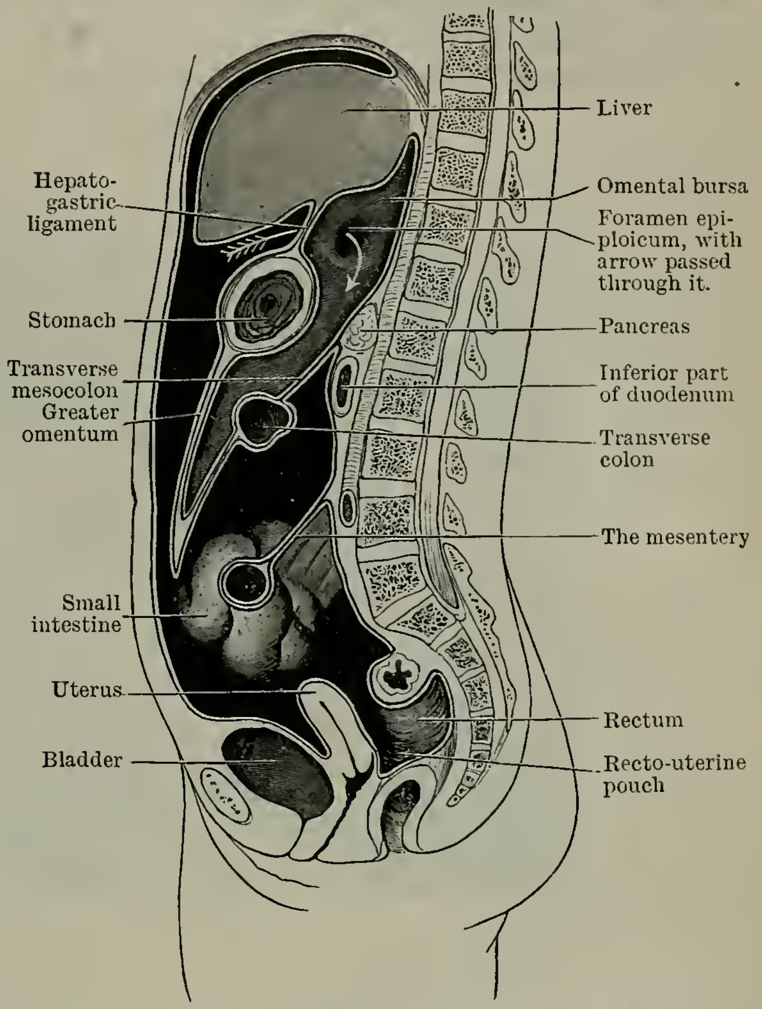


Fig. 891.—Diagrammatic Median Section of Female Body, to show the peritoneum on vertical tracing. The great sac of the peritoneum is black and is represented as being much larger than in nature; the bursa omentalis is very darkly shaded; the peritoneum on section is shown as a white line; and a white arrow is passed through the foramen epiploicum from the great sac into the bursa omentalis.

The peritoneum covering an organ is termed *visceral peritoneum*; where it lines the walls or forms mesenteries and omenta it is termed *parietal peritoneum.*

The term peritoneal cavity has already been explained (p. 1148).

In the adult its arrangement is complicated by the changes which occur during their development in the form and position of many of the viscera, and it is necessary to explain briefly some of the changes which modify the original simple arrangement of the peritoneum.

The peritoneum represents the smooth lining membrane of a large portion of the body cavity, or cœlom.

Many of the abdominal viscera originally lie dorsal to this membrane on the posterior body wall, with their ventral surfaces only in contact with the lining membrane of the cœlom.

The greater part of the intestinal tube, on the other hand, projects forwards from the body wall into the body cavity, and is connected with the dorsal wall by a narrow strand of connective tissue and by blood-vessels. The lining membrane of the abdominal wall covers each surface of this lamina, and the ventral and lateral surfaces of the intestinal tube.

Organs showing the first relationship are said to lie "behind" the peritoneum, or to be "partly invested" by it.

In the condition of the intestine described, the organ is said to be "completely invested" and to have a "mesentery" connecting it to the abdominal wall.

The intestine originally has a continuous dorsal mesentery, and its proximal portion is connected to the ventral wall above the level of the umbilicus by a ventral mesentery.

As the organs develop and alter in their position and form, the peritoneum covering them is involved, and the mesenteries grow or become stretched. Layers of peritoneum may come to lie in contact with one another, and blend, leaving no trace of their original double origin.

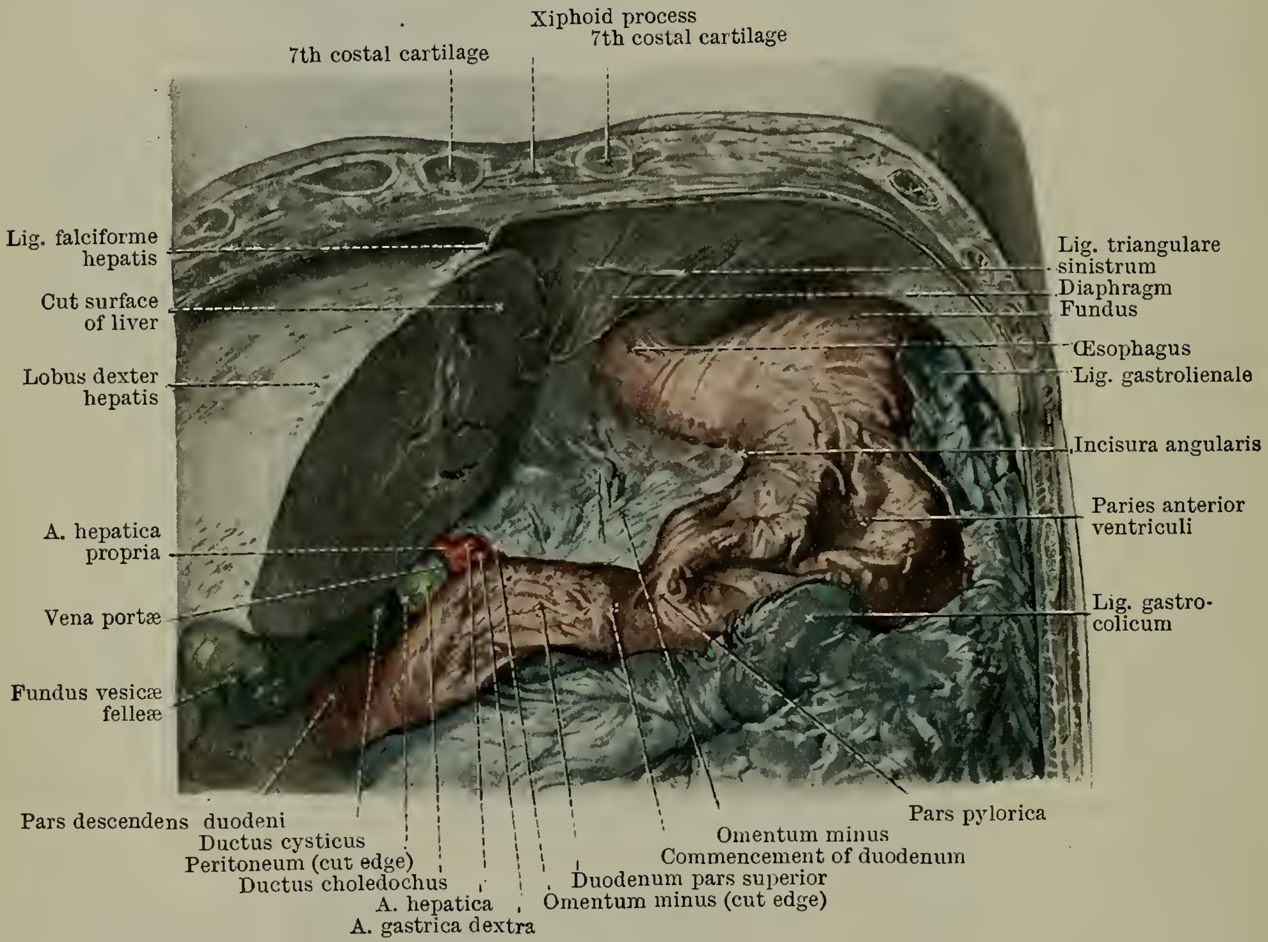


Fig. 892.—The Lesser Omentum.

The left lobe of the liver has been removed, and also the anterior layer of the hepato-duodenal ligament. The view is taken looking upwards as well as backwards.

With the formation of successive organs, especially of the liver and of the spleen, a mesentery which originally was simple may come to contain more organs than one, and so portions of it pass from one organ to another, and not from the wall to an organ. Such folds are usually termed "omenta."

Mesenteries are folds of peritoneum which unite portions of the intestine to the posterior abdominal wall, and convey to them their vessels and nerves. There are several mesenteries, *e.g.* the *mesenterium* (*mesentery proper*), which connects the jejunum and ileum to the posterior abdominal wall, the *mesocolon transversum* (*transverse mesocolon*), the *mesocolon pelvicum* (*pelvic mesocolon*), and occasionally others (see pp. 1206, 1209, 1211).

Of other folds the principal ones are:—

(1) **Omentum Majus.**—The *greater omentum* hangs down like an apron from the transverse colon, in front of the coils of the jejunum and ileum. It consists

embryologically of four layers of peritoneum, two anterior and two posterior. The four layers form a thin, translucent, and often perforated membrane. The anterior two layers were originally connected with the stomach above, and passed down in front of the transverse colon, but as development proceeds they become adherent to the anterior surface of the transverse colon. The fold which extends from the stomach to the colon is termed the gastro-colic ligament. The anterior and the posterior folds are often partly or wholly blended, but if the anterior two layers are separated from the posterior two and from the front of the transverse colon, the anterior layers of the greater omentum are directly continuous with the layers of the gastro-colic ligament. This condition is that usually described in English text-books as the normal adult condition and is represented in Fig. 891, where the gastro-colic ligament is separated from the transverse colon, and passes in front of the transverse colon directly into the anterior layers of the omentum majus, and the great omentum thus descends from the stomach above.

(2) **Omentum Minus.**—The *lesser omentum* is a fold passing from the inferior surface of the liver to adjacent organs. It consists of two, or occasionally three, portions:—

(*a*) The *ligamentum hepatogastricum*, a thin, translucent, and sometimes fenestrated peritoneal fold, extending from the lesser curvature of the stomach to the left end of the porta hepatis, the fossa of the ductus venosus, and partly also to the concave surface of the left lobe of the liver and the caudate process. At the lesser curvature of the stomach it is continued into the peritoneal coats of the anterior and posterior surfaces of that organ. It contains the vessels (blood and lymph) of the lesser curvature, some lymph glands, and a twig from the left vagus nerve which goes to the liver.

(*b*) The *ligamentum hepatoduodenale* passes from the porta hepatis to the pars superior of the duodenum. On the left this fold is continuous with the hepatogastric ligament, on the right it ends in a rounded margin. Traced downwards, the layers of peritoneum which form it clothe the commencement of the duodenum on two sides, and are continued into the transverse mesocolon. In it lie the hepatic artery, portal vein, bile duct, with lymphatic vessels and nerves.

(*c*) The *ligamentum hepatocolicum* is an occasional fold passing from the region of the gall-bladder to the transverse colon and right colic flexure.

(3) **Ligamentum Gastrolienale.**—The *gastro-splenic ligament* (O.T. *gastro-splenic omentum*) is a double layer of peritoneum extending between the greater curvature of the stomach (at the fundus and adjacent portion of the body) and the hilum of the spleen, and continuous below with the gastro-colic ligament. It contains gastric branches of the splenic vessels.

(4) The **ligamentum gastrocolicum** extends from the greater curvature of the stomach to the transverse colon. It consists of two layers of peritoneum, continuous above with the layers on the anterior and posterior surfaces of the stomach, and below with the anterior layers of the great omentum. In it lie the right and left gastro-epiploic vessels, nerves, and some lymph glands.

In English text-books this is not usually recognised as a separate ligament, but is considered to be a portion of the greater omentum, and to pass downwards in front of the transverse colon. It will be found, however, that the arrangement in the adult is usually that described above.

Other folds, specially named, but described elsewhere, are the ligaments of the liver, the so-called "false ligaments" of the bladder, the lieno-renal ligament, and the broad ligaments of the uterus.

Whilst the greater part of the general peritoneal cavity lies anterior to the various abdominal viscera, it should be mentioned that there is a recess of considerable size derived from it, situated mainly behind the stomach; this is known as the *bursa omentalis* (O.T. *small sac*), and it will be described in detail later. The aperture through which one sac communicates with the other is termed the *foramen epiploicum* (*Winslowi*) (O.T. *foramen of Winslow*).

Peritoneal "Adhesions" and Variations.—In addition to the folds mentioned above, many other peritoneal bands and folds are to be made out.

(1) The gall-bladder is often united to the pars superior of the duodenum by a

dense, strong layer of connective tissue, which blends with the hepato-duodenal ligament.

(2) The duodeno-jejunal junction is occasionally firmly joined by similar bands to the transverse meso-colon.

(3) About the cæcum, processus vermiformis, terminal part of the ileum, and proximal part of the ascending colon, it is almost usual to find bands of fairly dense tissue passing (*a*) from the colon to the lateral abdominal wall, (*b*) from the terminal portion of the ileum to the cæcum, (*c*) from the cæcum itself to the parietes.

Such bands are usually ascribed to "peritonitis."

(4) The great omentum may be united to the anterior surface of the ascending colon.

(5) Fibrous bands often pass especially from the left side of the iliac colon to the parietes.

They have been ascribed to faults in development, to peritonitis, and to mechanical traction, and it is not yet possible to state definitely the exact mode and cause of their origin.

Contents of the Abdomen.—The following structures are found within the abdomino-pelvic cavity:—

1. The greater part of the *alimentary canal*, viz., stomach, small intestine, and large intestine.
2. *Digestive glands:* the liver and pancreas.
3. *Ductless glands:* the spleen and the two supra-renal glands.
4. *Urinary apparatus:* the kidneys, ureters, bladder, and part of urethra.
5. The internal *generative organs*, according to the sex.
6. *Blood-vessels* and *lymph vessels*, and *lymph glands.*
7. The abdominal portion of the cerebro-spinal and sympathetic *nervous systems.*
8. Certain *fœtal remains.*
9. The *peritoneum*—the serous membrane which lines the cavity, and is reflected over most of its contained viscera.

VENTRICULUS.

The **stomach** is a dilatation of the digestive tube immediately after it enters the abdomen (Figs. 884 and 893). It constitutes a receptacle in which the food accumulates after its passage through the œsophagus, and in it take place some of the earlier processes of digestion, resulting in the conversion of the food into a viscid fluid, known as chyme. The chyme escapes through the pylorus into the small intestine, where the digestive processes are continued.

The form and the position of the stomach present great variations, not only among different individuals, but also in the same individual at different times. The degree to which it is filled, the size and position of adjacent organs, the condition of the abdominal walls, and even the assumption of the erect or the recumbent attitude can influence its shape and relations.

Of recent years, examination of the stomach by X-rays has afforded information, otherwise unattainable, of the shape and position of the stomach in life, and of the changes which it undergoes. The results obtained by this method have considerably modified conceptions regarding the stomach in the living. A necessary preliminary to the proper comprehension of these appearances is a careful study of the stomach as it presents itself to anatomical examination.

General Shape.—In shape, the stomach is irregularly piriform, with a wide end lying deeply in the hollow of the diaphragm, mainly in the left hypochondriac region, and a narrow tapering extremity which passes downwards and forwards, and is bent over to the right side, in the epigastric region.

The long axis of the organ forms a spiral curve, directed downwards, anteriorly and to the right, and finally backwards.

Size and Capacity of the Stomach.—Probably no organ in the body varies more in size within the limits of health than the stomach. Moreover, as its tissues change so rapidly after death, measurements made on softened and relaxed organs are not only worthless but quite misleading.

The *length* of the stomach in the fully distended condition is about 10 to 11 inches

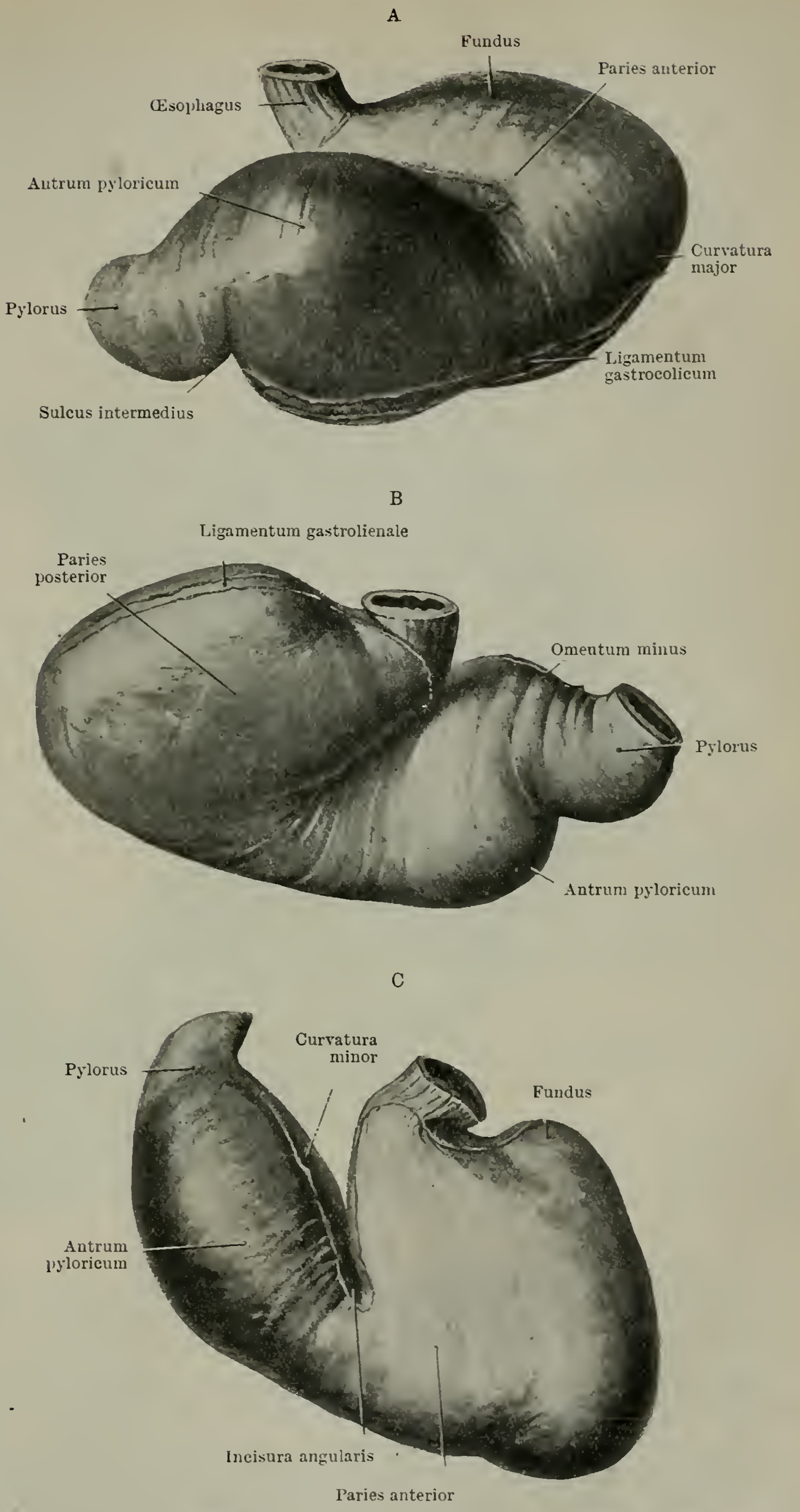


FIG. 893.—THREE VIEWS OF A STOMACH FIXED BY FORMALIN INJECTION *IN SITU*.

A. From the front. B. From the back. C. From above.

The orientation of the stomach was determined by the insertion of long pins into it in the sagittal, frontal, and transverse planes. These views show the comparatively horizontal position of the stomach associated with the horizontal posture of the trunk. They also show the partial division into chambers produced by temporary constrictions of the stomach wall fixed by the action of formalin.

(25 to 27·5 cm.), and its greatest *diameter* not more than 4 to $4\frac{1}{2}$ inches (10 to 11·2 cm.); whilst its *capacity* in the average state rarely exceeds 40 ounces, or 1 quart.

The distance in a direct line from the cardiac to the pyloric orifice varies from 3 to 5 inches (7·5 to 12·5 cm.), and that from the cardia to the summit of the fundus from $2\frac{1}{2}$ to 4 inches (6·2 to 10·0 cm.).

As regards the *weight*, the average of twelve wet specimens freed from their omenta was found to be $4\frac{3}{4}$ oz. (135 grms.), with a maximum of 7 oz. (198·45 grms.) and a minimum of $3\frac{1}{2}$ oz. (99·22 grms.). Glendinning gives the weight as $4\frac{1}{2}$ oz.

In the child at birth the stomach is scarcely as large as a small hen's egg, and its capacity is about 1 oz. (28·3 grms.). In shape it corresponds pretty closely to that of the adult, and the fundus is well developed. It is vertical in position.

The stomach presents the following parts for examination:—

Two surfaces, an anterior (**paries anterior**) directed forwards and to the left, and a posterior (**paries posterior**) which looks posteriorly and also to the right. These surfaces meet above and to the right at the lesser curvature, **curvatura minor**, and below at the greater curvature, **curvatura major**. At the superior end of the lesser curvature the œsophagus enters the stomach, at the œsophageal opening, or cardia, while at the inferior end the stomach passes into the duodenum at the pylorus. The dome-shaped portion to the left of the œsophagus is the **fundus**, while the remainder of the stomach is divisible into the body, **corpus ventriculi**, and the pyloric portion, **pars pylorica**.

Cardia.—The œsophageal opening is situated at the superior end of the lesser curvature, on the right side of the fundus, and more on the anterior than the posterior surface of the stomach.

Around this opening the muscular walls of the œsophagus and the mucous membrane become continuous with corresponding coats of the stomach wall. The longitudinal muscular coat passes onwards into a longitudinal set of fibres, and the circular œsophageal fibres pass into the circular muscular coat. The whitish-coloured stratified squamous epithelium of the œsophagus is continuous with the pinkish-coloured columnar epithelial wall of the stomach, and the junction is marked by a sharp irregular line running round the margin of the opening.

The orifice itself is oval or angular rather than round, being compressed from side to side.

To the right of the orifice, the right margin of the œsophagus merges with a slight curve into the lesser curvature of the stomach, while on the left side there is a deep notch, the **incisura cardiaca**, between the inferior end of the œsophagus and the fundus, in which lies a strong projecting ridge of the right crus of the diaphragm.

This notch on the outer surface produces a fold in the interior of the stomach, which may assist in closing the œsophageal opening, and this, with the decussating fibres of the diaphragm, and the strengthened circular fibres of the inferior end of the œsophagus, forms a kind of sphincter for this orifice which serves to prevent regurgitation from the stomach under ordinary conditions.

The cardia is very deeply placed, and lies about four inches behind the sternal end of the seventh left costal cartilage, at a point one inch from its junction with the sternum. Posteriorly it corresponds to the level of the eleventh thoracic vertebra.

Owing to the fixation of the œsophagus by its passage through the diaphragm, and the close connexion between the stomach and the diaphragm near the cardia where the peritoneum is absent, this is the most fixed part of the whole organ.

Pylorus.—The **pyloric orifice** is placed at the extremity of the pyloric end of the stomach, and its position is indicated upon the surface of the stomach by a slight annular constriction which is most marked at the curvatures, termed the pyloric ring.

Its position is also indicated by an arrangement of blood-vessels at the pyloric ring, which is nearly constant. On the peritoneal surface a thick vein passes upwards from the lower side somewhat more than half-way on the anterior surface, and from the upper border a second vein reaches downwards in the same line, nearly, if not quite, meeting the first (W. J. Mayo).

The **pyloric constriction** marks the junction of stomach and duodenum, and there the various coats of these portions meet with one another.

The peritoneal covering of the stomach is continued onwards on to the first part of the duodenum, and the longitudinal fibres of the stomach (stratum longitudinale) are in part continued onwards into the longitudinal fibres of the duodenal coat, but many of them bend inwards into the thickened ring around the opening, and spread out in diverging bundles, which interlace with the most superficial of the circular fibres, and some of them reach and terminate in the subjacent submucosa.

The circular muscular fibres of the stomach (stratum circulare) are not continuous directly with those of the duodenum. On the contrary, at the orifice they become very much increased in number, and they form a thick ring, or sphincter, which is separated from the circular muscular coat of the duodenum by a fibrous septum.

This sphincteric ring is sharply marked off from the duodenum, but there is no sharp line of demarcation on the gastric side, for there the ring gradually merges into the circular muscular coat of the cylindrical pyloric canal, whose wall when contracted is nearly as thick as the sphincteric ring.

The gastric mucous membrane (**tunica mucosa**) is continued into the mucous membrane of the duodenum at the distal margin of the sphincter. The junction cannot be recognised by superficial inspection. The gastric mucosa is considerably thickened where it covers the sphincter muscle. When examined post mortem in the ordinary way, the aperture, viewed from the duodenal side, is somewhat oval in form. When seen from the opposite side, it presents a stellate appearance, owing to the fact that the rugæ of the gastric mucous membrane are continued up to the orifice.

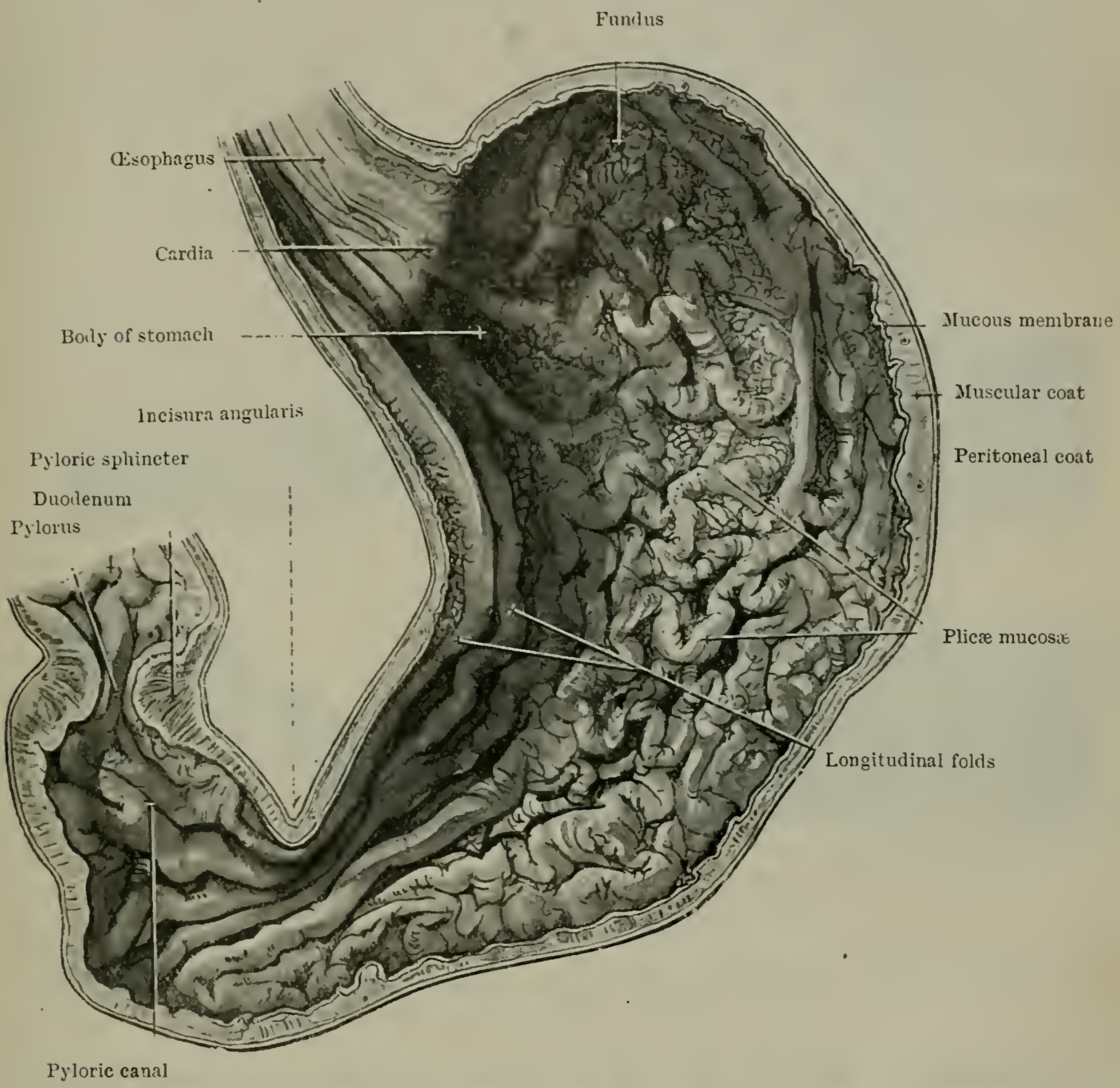


FIG. 894.—INTERIOR OF STOMACH, SHOWING THE MUCOSA AND THE PARTS OF THE STOMACH IN A CONDITION OF MODERATE FILLING.

The orifice is directed horizontally backwards, and to the right. When the stomach is full, however, it looks almost directly backwards, or even slightly to the left side.

The pylorus rests on the neck of the pancreas below and posteriorly, and is overlapped by the liver above and anteriorly. When the stomach is empty the pylorus is usually placed near (*i.e.* within ½ inch, 12 mm., of) the median plane, below the left lobe or sometimes the quadrate lobe of the liver, and at the level of the first lumbar vertebra, or the fibro-cartilage between this and the second lumbar. During distension it is pushed over beneath the quadrate lobe for a variable distance, but very rarely more than 1½ or 2 inches to the right of the median plane. Its average position can be marked on the surface of the body by the intersection of two lines; one drawn horizontally half-way between the top of the sternum and the pubic crest (Addison), the other drawn vertically a little way (½ inch, 12 mm.) to the right of the median plane.

During the earlier stages of gastric digestion the sphincter pylori is strongly contracted and the aperture firmly closed, but it opens intermittently to allow of the passage of properly digested portions of the food. As digestion advances the sphincter probably relaxes somewhat; but in hardened bodies a really patent pylorus is rarely or never found, which would seem to indicate that the pylorus is normally closed, or nearly so, and that its opening is an active rather than a passive condition, as in the case of the anal canal.

As regards its size, the pylorus is stated to be about ½ inch (12·5 mm.) in diameter, but there is no doubt that this represents neither its full size nor its calibre when at rest. Foreign bodies with a diameter of ¾ to 1 inch have been known to pass through the pylorus without giving rise to trouble, even in children. On the other hand, when at rest, with an empty stomach and duodenum, the aperture is practically closed.

Curvatura Ventriculi Minor.—The **lesser curvature** is directed towards the liver. To it is attached the fold of peritoneum called the hepato-gastric ligament which connects the stomach and liver.

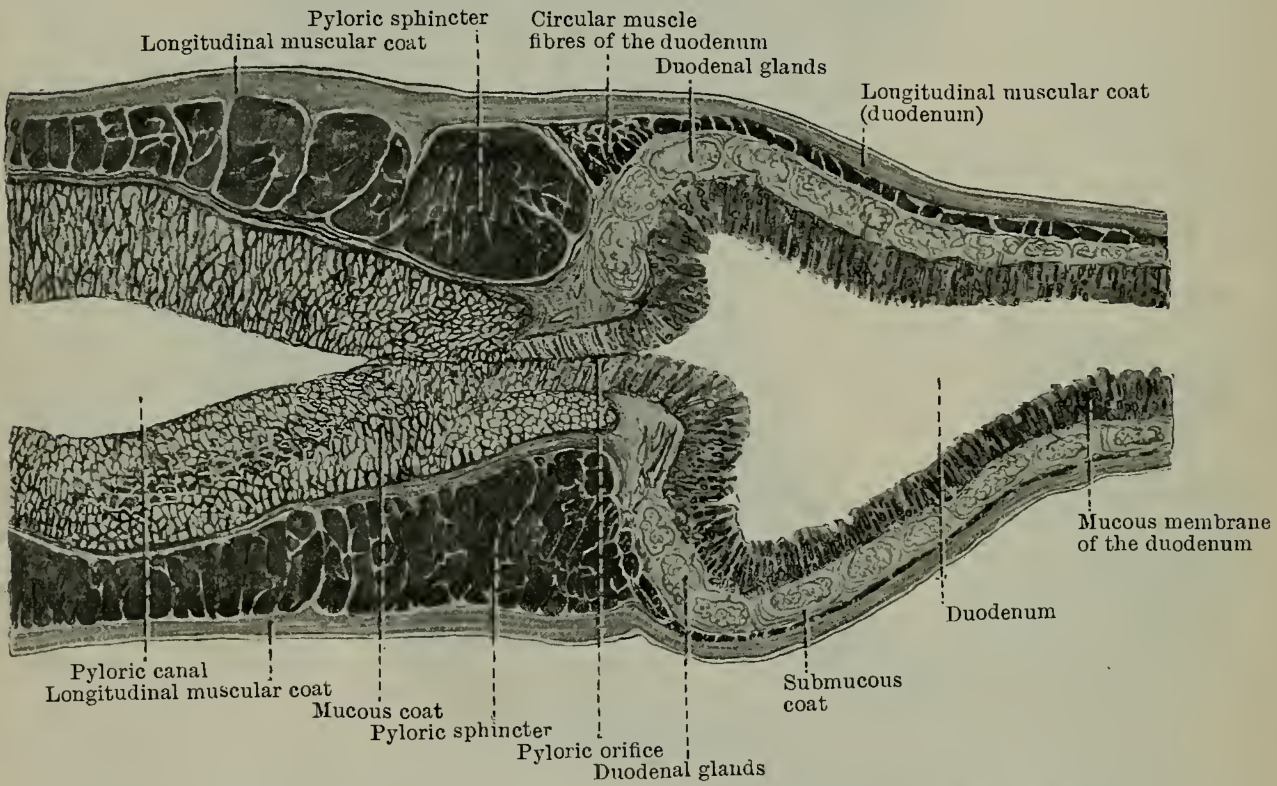

Pyloric sphincter
Longitudinal muscular coat
Circular muscle fibres of the duodenum
Duodenal glands
Longitudinal muscular coat (duodenum)
Mucous membrane of the duodenum
Duodenum
Submucous coat
Pyloric canal
Longitudinal muscular coat
Mucous coat
Pyloric sphincter
Pyloric orifice
Duodenal glands

FIG. 895.—LONGITUDINAL SECTION THROUGH THE PYLORIC CANAL AND COMMENCEMENT OF THE DUODENUM IN A NEW-BORN CHILD. (From Stiles.)

While the lesser curvature is, on the whole, concave, it consists of two portions which meet and form a sharp angle, called the *incisura angularis*. The superior or left portion is the longer of the two, is nearly vertical, and continues the direction of the right margin of the œsophagus, while the inferior or right portion is more nearly horizontal, when viewed from the front. The position, depth, and acuteness of the angle between these two segments varies with the degree of distension of the stomach. When the pyloric portion of the stomach is full, the inferior portion of the lesser curvature becomes distended, and that portion of the border becomes convex in outline. In length the lesser curvature measures some 3 to 4 inches.

Curvatura Ventriculi Major.—The **greater curvature of the stomach** is usually over three times as long as the lesser curvature, and corresponds to a line drawn from the cardia over the summit of the fundus (Fig. 893), and then along the most projecting portion of the stomach as far as the pylorus. In general, it is directed to the left and forwards, but at its beginning, near the cardia, it of course looks in a different direction. The great curvature corresponds in the greater part of its length to the attachment of the gastro-splenic and gastro-colic ligaments, folds of peritoneum passing to the spleen and to the transverse colon respectively; and in close relation to it, between their layers, run the right and left gastro-epiploic vessels.

This border of the stomach, like the lesser curvature, does not present a uniformly curved outline. Towards the pylorus a notch is often found, called the **sulcus intermedius.** The portion to the right of this sulcus is known as the **pyloric canal.**

On the left side of this notch, the greater curvature bulges forwards, forming a chamber called the **antrum pyloricum,** and the projecting rounded prominence which it forms is, in some phases of digestion, marked off from the rest of the body of the stomach by a temporary indentation. Other indentations which are sometimes found on the greater curvature, or the body of the stomach, are probably due to temporary peristaltic waves of contraction.

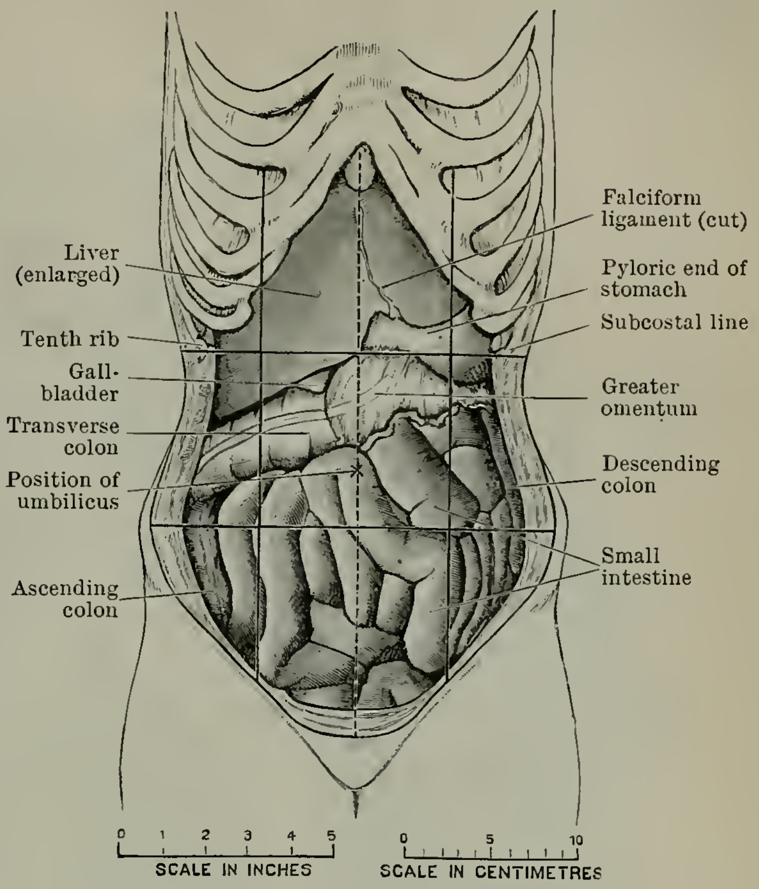


FIG. 896.—ABDOMEN OF FEMALE, SHOWING DISPLACEMENTS RESULTING FROM TIGHT LACING.

The liver is much enlarged, and extends on the left side to the ribs, where it was folded back on itself for over an inch. The pyloric end of the stomach and the beginning of the duodenum are quite superficial below the liver, and all the viscera are displaced downwards. (From a photograph of a body hardened by injections of formalin.)

Paries Anterior.—The **anterior wall of the stomach** is more convex and more extensive than the posterior. When the stomach is distended, it is in contact with the inferior surface of the left lobe of the liver medially, the vault of the diaphragm laterally, and the anterior abdominal wall below (Fig. 893). When the stomach is empty, on the other hand, the transverse colon doubles up in front of it, and separates its anterior surface from the liver and diaphragm and abdominal wall.

Paries Posterior.—The **posterior wall** looks downwards and posteriorly. It is more flattened than the anterior, and is moulded by the structures upon which it rests.

Thus, to the left is a flattened area, passing on to the fundus, which is in contact with the diaphragm and the spleen. To the right of the fundus the superior portion of the posterior wall, nearly vertical, is in contact with the left kidney and supra-renal gland and the diaphragm; and the inferior portion, more horizontal, is in contact with the pancreas, transverse mesocolon, and transverse colon. These structures constitute the posterior wall of the bursa omentalis of the peritoneal cavity.

Between these two areas, the wall comes into contact with the splenic artery as it runs along the superior border of the pancreas.

The different portions into which the stomach may be divided are as follows:—

Fundus Ventriculi.—The **fundus** is that portion of the stomach which lies above a horizontal plane drawn through the œsophageal opening. It is rounded or dome-shaped. This shape seldom alters, whatever the condition of the stomach may be. It is usually filled with gas.

Corpus Ventriculi.—The **body of the stomach** extends from the fundus to the incisura angularis on the lesser curvature, and to the notch on the greater curvature already described. It forms a rounded chamber, capable of great distension, but when the stomach is empty it contracts to a narrow tube-like structure. As the stomach is seldom completely empty, the body usually tapers from the fundus to the proximal end of the pyloric portion (Fig. 894).

Pars Pylorica.—The pyloric portion of the stomach extends from the incisura angularis in the lesser curvature, and a variable and inconstant notch on the greater curvature, as far as to the pyloric orifice (Figs. 893, 902).

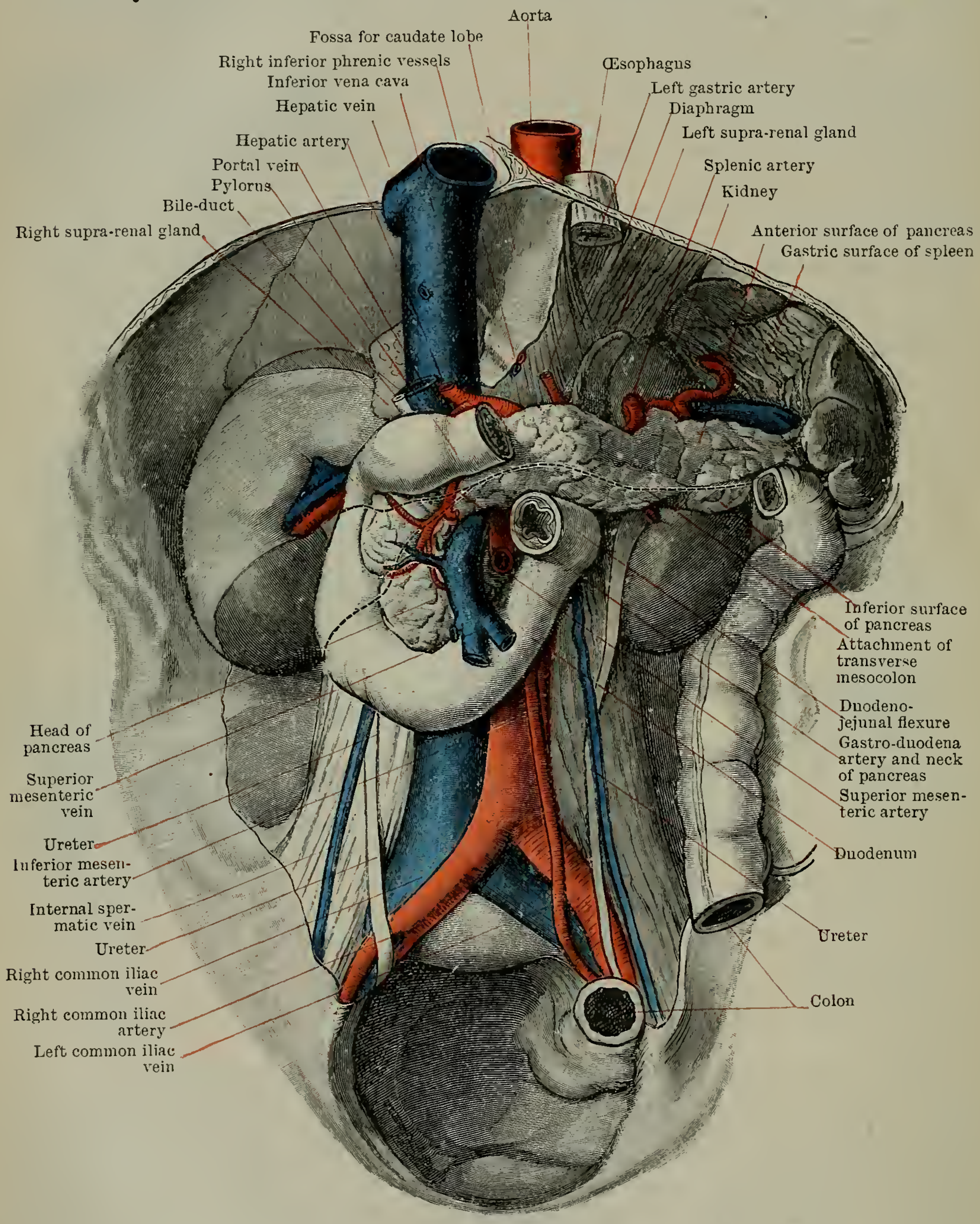


FIG. 897.—THE VISCERA AND VESSELS ON THE POSTERIOR ABDOMINAL WALL.

The stomach, liver, and most of the intestines have been removed. The peritoneum has been preserved on the right kidney, and also the fossa for the caudate lobe. When the liver was taken out, the vena cava was left behind. The stomach bed is well shown. (From a body hardened by chromic acid injections.)

It differs from the body of the stomach in being more tubular in shape, and possessing thicker walls.

It has been divided anatomically into two portions, the **pyloric canal** and the **antrum pyloricum** respectively.

The **pyloric canal** is a short more or less tubular portion rather more than an inch in length, extending from the sulcus intermedius on the greater curvature to the pyloric constriction. The proximal portion, called the **pyloric antrum,** is more expanded. It is not clearly demarcated from the body of the stomach by any constant line of division on the greater curvature. On the lesser curvature it extends from the incisura angularis to the pyloric canal, and it is occasionally pouched outwards on the side of the greater curvature so as to form a chamber or pouch, the "camera princeps" of His.

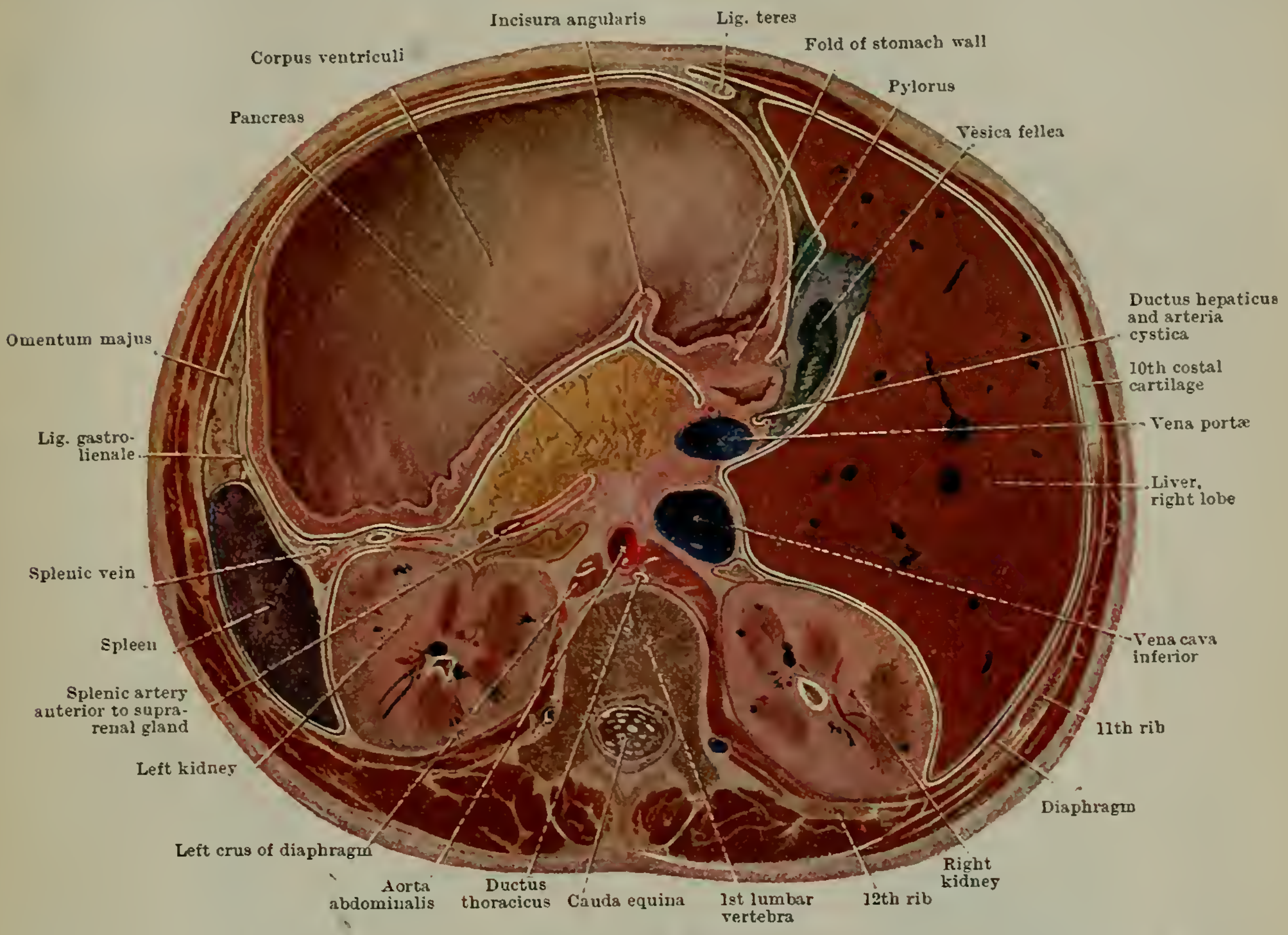


FIG. 898.—TRANSVERSE SECTION OF THE TRUNK AT THE LEVEL OF THE FIRST LUMBAR VERTEBRA. Showing relations of stomach, pancreas, kidneys, etc. From a subject ten years old.

RELATIONS AND CONNEXIONS OF THE STOMACH.

When the stomach has been removed, after the body has been hardened, a chamber or recess is exposed, known as the **stomach chamber.** It is (Figs. 897 and 899) a space in the upper and left portion of the abdominal cavity with an arched roof, an irregularly sloping floor, and an anterior wall. The *roof* is formed partly by the visceral surface of the left lobe of the liver, and in the rest of its extent by the left cupola of the diaphragm, which arches gradually downwards behind and on the left to meet the floor.

The *floor* or "*stomach bed*" (Fig. 897) is a sloping shelf on which the posterior surface of the stomach rests, and by which it is supported. The bed is formed posteriorly by the superior pole of the left kidney (with the supra-renal gland) and the gastric surface of the spleen; anterior to this, by the wide anterior surface of the pancreas; and more anteriorly still, by the transverse mesocolon running forwards above the small intestine, from the anterior edge of the pancreas to the transverse colon (Fig. 899), which completes the floor anteriorly.

Finally, the *anterior wall* of the stomach chamber is formed by the abdominal wall, between the ribs on the left and the liver on the right side.

Peritoneal Relations.—The stomach is almost completely covered by peritoneum—the anterior surface being clothed by that of the general peritoneal sac, and the posterior surface by the anterior layer of the bursa omentalis (see p. 1155). From the lesser curvature the hepato-gastric ligament extends to the liver, whilst to the greater curvature the gastro-lienal and gastro-colic ligaments are attached. Finally, a small peritoneal fold, known as the *gastro-phrenic ligament,* is found running from the stomach up to the diaphragm along the left side of the œsophagus.

A small irregularly triangular area (Fig. 893), about 2 inches wide and 1½ inches from above downwards, during moderate distension of the stomach, on the posterior surface below and to the left of the cardia, is not covered with peritoneum, and over it the organ is in direct contact with the diaphragm, occasionally also with the superior extremity of the left kidney and the suprarenal gland. From the left angle of this "uncovered area" the attachment of the gastro-lienal ligament starts; and at the right angle is the commencement of a fold through which the *left gastric* artery passes to the stomach. This fold is called the *left gastro-pancreatic* fold.

The *right gastro-pancreatic* fold is a fold of peritoneum passing from the right extremity of the superior part of the pancreas to the first part of the duodenum. It encloses the hepatic artery.

Displaced Stomach (Fig. 896).—As a result of disease, or of constriction of the superior part of the abdomen, the stomach is occasionally displaced in position and distorted in shape, so that instead of running obliquely forwards, downwards, and to the right, it is placed nearly vertically along the left side of the vertebral column, in which direction it has a very considerable length. Its inferior part bends rather suddenly, and runs upwards and to the right to join the pylorus, which is often placed quite superficially below the liver. As a result of the displacement, the left extremity of the pancreas is pushed downwards from the horizontal until it assumes almost a vertical position. The narrowing and inversion of the inferior margin of the thoracic framework at the same time constricts the stomach about its middle, and may lead to a bilocular condition.

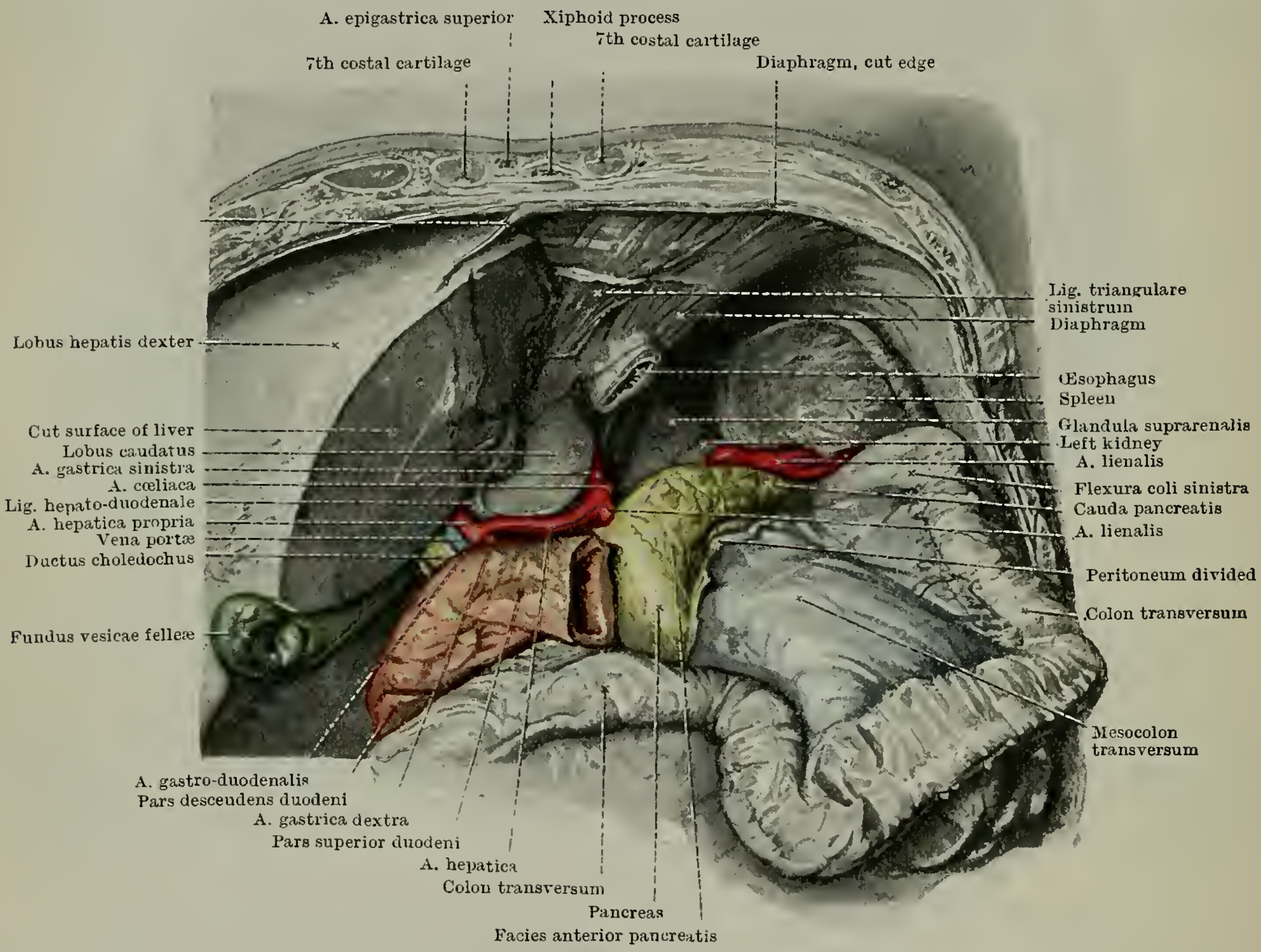


FIG. 899.—STOMACH CHAMBER VIEWED FROM THE FRONT AND FROM BELOW.
From the specimen figured in Fig. 892, after removal of the stomach.

Hour-glass or Bilocular Stomach.—This is a condition of the organ, by no means rare, in which the stomach is more or less completely separated into two divisions—a cardiac and a pyloric—the normal arrangement in certain rodents and other animals. As a rule the former division is the larger, but occasionally the two are nearly equal, or the pyloric portion may exceed the cardiac in size. Sometimes the condition is temporary, and the result of a vigorous contraction of the circular muscular fibres at the seat of constriction. In other cases it is permanent, and may be due to cicatricial contraction after gastric ulcer, or to some other pathological condition. The condition is more frequent in the female than the male, and is rarely found in the fœtus or child.

Position of the Stomach.—*When empty,* or nearly so, the stomach lies in the left hypochondrium and left part of the epigastrium, with its fundus directed posteriorly towards the diaphragm, its long axis lying almost in a horizontal plane and its pyloric part running to the right to join the duodenum. In this state the whole organ is narrow and attenuated, particularly the pyloric part, which is contracted, and resembles a piece of thick-walled small intestine.

When distended, both the cardiac and pyloric parts become full and rounded (Fig. 893). It still lies within the hypochondriac and epigastric regions; but in exceptional cases, or in extreme distension, it may pass down below the subcostal plane and reach into the umbilical and left lumbar regions. As a result of the general increase in length which takes place during distension, the pylorus is moved a variable distance to the right beneath the quadrate lobe of the liver, and at the same time the long axis of the whole organ becomes much more oblique, running forwards, downwards, and to the right. Finally there is developed a special dilatation of the pyloric part, known as the *antrum pyloricum,* which in extreme distension is carried so far to the right that it may even reach to the hypochondrium.

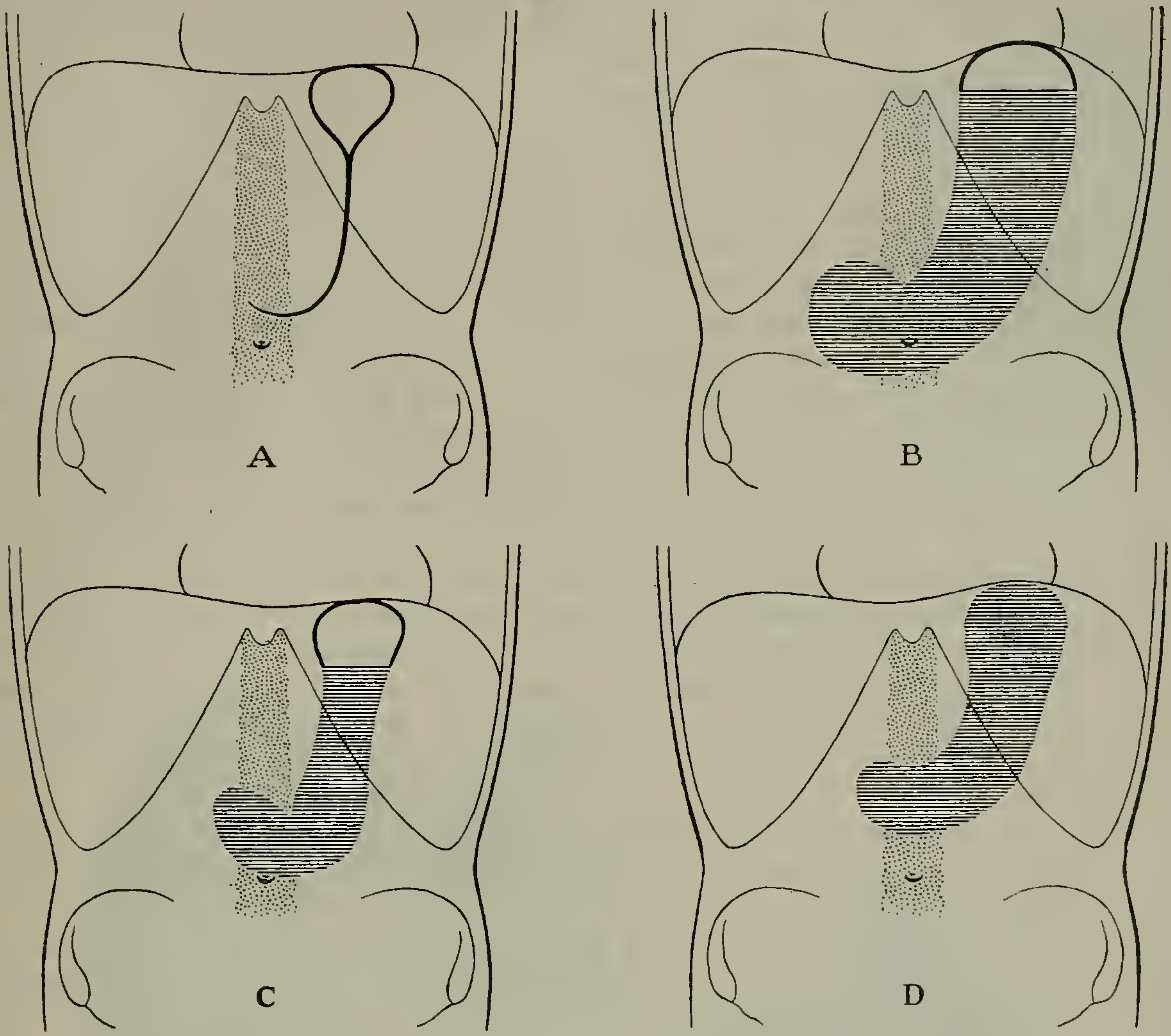


Fig. 900.

A. Empty stomach in vertical position as defined by the X-rays.
B. Filled stomach in vertical position as seen with the X-rays.
C. Half-filled stomach in vertical position as seen with the X-rays.
D. Half-filled stomach in horizontal position as seen with the X-rays.

Shape and Position of the Stomach as seen by X-Ray Examination.—Examination of the stomach by means of X-rays after a "bismuth meal" has given important information about the shape and position of the stomach in the living, and about the changes which occur as the stomach fills and empties.

These examinations corroborate, in great part, the conclusions which have been arrived at by the study of formalin specimens so far as the shape of the stomach, and its division into parts, are concerned. In regard, however, to the position and direction of the stomach, X-rays show that the stomach in the living, and especially in the erect attitude, is more vertical than it is after death, and when the body is examined in the horizontal position. In the upright position, in fact, the long axis of the organ appears to be nearly vertical. The general shape and position of the stomach in the vertical position, moderately distended, is shown in Fig. 900. From this it will be seen that not only is the body of the stomach nearly vertical, but that the greater curvature reaches down to the umbilicus, and may descend beyond it even below the level of a line joining the iliac crests. The pyloric part is directed upwards, as well as backwards, and the pylorus is not usually the lowest point of the stomach.

The other anatomical features of the stomach described above are well brought out. Thus the fundus is a hemispherical dome, lying to the left of the terminal portion of the œsophagus, and continuous in outline with the body of the stomach. It usually contains gas, and appears translucent to X-rays. The body is of uniform outline, and the pyloric part is marked off from it by the incisura angularis, on the lesser curvature. Further, the pyloric part shows division into pyloric antrum and pyloric canal. The incisura angularis and sulcus intermedius are distinct.

The position of the stomach is greatly influenced by attitude and by the condition of the abdominal muscles. Contraction of the abdominal muscles can elevate the stomach from 5 to 13 cm., or 2 to 5 inches, and the change from the horizontal to the erect attitude alters the height of the inferior border from 2 to 10 cm. This sinking which occurs in the alteration from the horizontal to the erect attitude, accounts largely for the differences found between the stomach seen in the post-mortem room or on the operating table and the stomach displayed by means of X-rays. Thus, if the stomach figured on p. 1161 be considered fixed at the cardiac end, and somewhat fixed at the pylorus, and the pyloric antrum and greater curvature should sink downwards, the shape, as seen from the front, would closely resemble the X-ray appearances found often in the living.

The empty stomach is a contracted tubular organ, except at the fundus, where it appears to be always dilated. When food is taken it passes from the œsophageal orifice along the lesser curvature towards the pyloric end of the stomach. It has been shown (p. 1168) that the folds of mucous membrane found near the lesser curvature form channels along which the food is directed in this course. This portion of the stomach is sometimes known as the "gastric canal," and it has been shown that it is derived from the lower part of the œsophagus. The distal portion of the stomach dilates for some distance, or at least as far as the pyloric canal.

As the stomach becomes filled the whole of the body of the organ becomes dilated, but the fundus and cardiac portion more particularly so, and these two latter regions act as a storehouse.

There is no definite division of this portion from the remainder of the stomach by a permanent sphincter, but the peristaltic waves of contraction begin about the middle of the organ, and form a fleeting constriction between the two parts.

As peristalsis goes on, the tubular pyloric part relaxes somewhat. The waves of peristalsis here become so deep as to divide this portion into chambers. The food substances are forced through the pylorus by successive waves of peristalsis, and in the form, usually, of jets which impinge against the posterior aspect of the duodenal wall.

Should there be undigested masses, the pyloric valve relaxes to allow them also to pass into the duodenum.

STRUCTURE OF THE STOMACH.

The stomach wall is composed of four coats—namely, from without inwards: (1) Tunica serosa, (2) tunica muscularis, (3) tela submucosa, and (4) tunica mucosa (Fig. 901).

Tunica Serosa.—The serous coat is formed of the peritoneum, the relations of which to the stomach have already been described. It is closely attached to the subjacent muscular coat, except near the curvatures, where the connexion is more lax.

Tunica Muscularis.—The muscular coat, which is composed of unstriped muscle, is thinnest in the fundus and body, much thicker in the pyloric portion, and very highly developed at the pylorus. It is made up of three incomplete layers—an external, *stratum longitudinale*; a middle, *stratum circulare*; and an internal of oblique muscular fibres, *fibræ obliquæ*.

The *stratum longitudinale* consists of longitudinal fibres, continuous with those of the œsophagus from which they radiate over the stomach wall (Fig. 903, A). They are most distinct on each side of the lesser curvature, where they form two strong bands, termed the tæniæ of the lesser curvature, and to a lesser degree at the greater curvature. Over the two surfaces they are present as an extremely thin and irregular sheet. Towards the pylorus the longitudinal fibres grow much thicker, and also much tougher and more closely united, and they take part in the formation of the **pyloric valve** (see p. 1158).

A specially condensed band of these can be often made out both on the front and back at the antrum pyloricum, the form of which is said to be due to their presence. These bands are known as the **ligamenta pylori** (pyloric ligaments).

The *stratum circulare* is continuous with the more superficial of the circular fibres at the lower end of the œsophagus (Fig. 903). It forms a set of U-shaped bundles which loop over the lesser curvature at the right of the cardia, and pass downwards and to the left on both surfaces. Further to the right these looped fibres are succeeded by circles which surround the organ completely. Traced towards the narrow end of the stomach, the circular bundles grow thicker, and at the pylorus they undergo a further increase, giving rise to the pyloric sphincter which surrounds the orifice as a thick muscular ring.

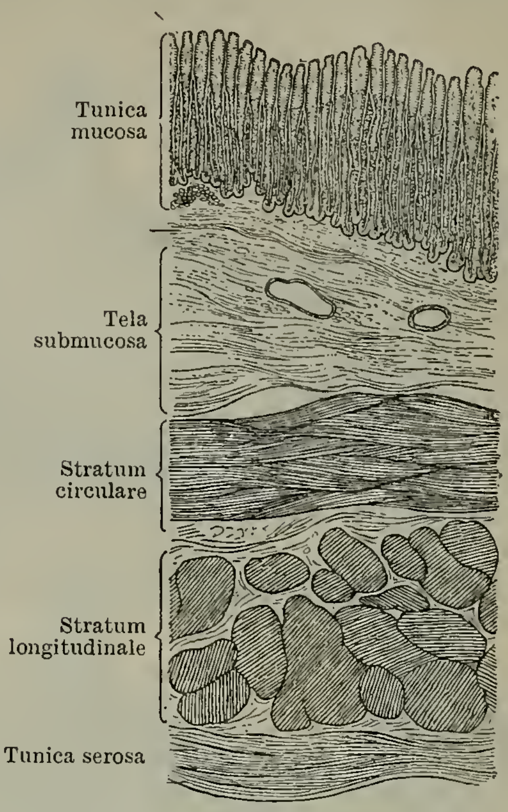


Fig. 901.—Transverse Section through the Wall of a Human Stomach. × 250.

Many authorities believe that the circular coat is arranged in a manner slightly different from that given above, namely, that its fibres form a ring around the fundus, similar to those described above as being formed by the oblique coat.

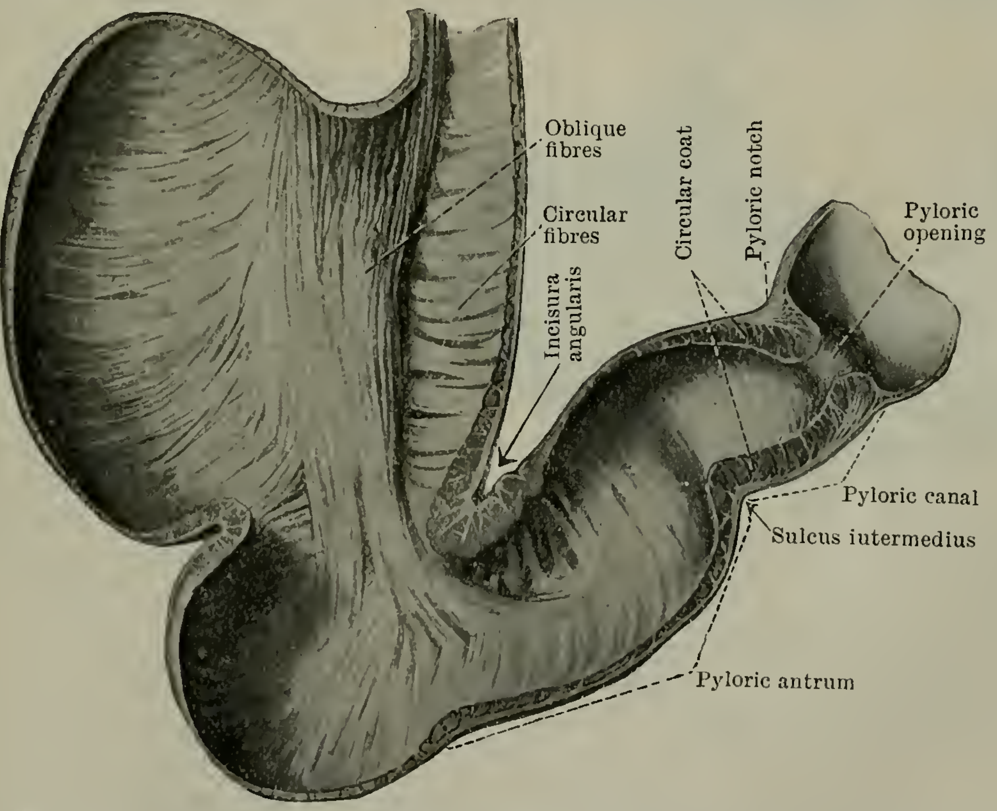


Fig. 902.—Muscular Coat of the Stomach, seen from within after removal of the mucous and submucous layers. The anterior half of the stomach is shown, viewed from behind (Cunningham).

The present description was made out by Professor Birmingham from a series of his own dissections, and is retained as being correct.

The *fibræ obliquæ*, forming the inner layer, consist of fibres which are arranged on the fundus and adjacent parts of the stomach, in much the same manner as those of the middle layer are on the body and pyloric part of the organ (Fig. 903, C). They are continuous above with the deeper circular fibres of the inferior end of the œsophagus, and form U-shaped bundles which loop over the stomach immediately to the left of the cardia, and run very obliquely downwards and to the right for a considerable distance on both surfaces of the organ. These looped fibres, as they pass to the left, gradually become less oblique, and finally form circles which surround the wide end of the stomach completely, even as far as the summit of the fundus. The oblique fibres can be most readily shown by removing the circular fibres on either surface below the cardia. When traced towards the right, they will be found to terminate by turning down and joining the fibres of the circular layer.

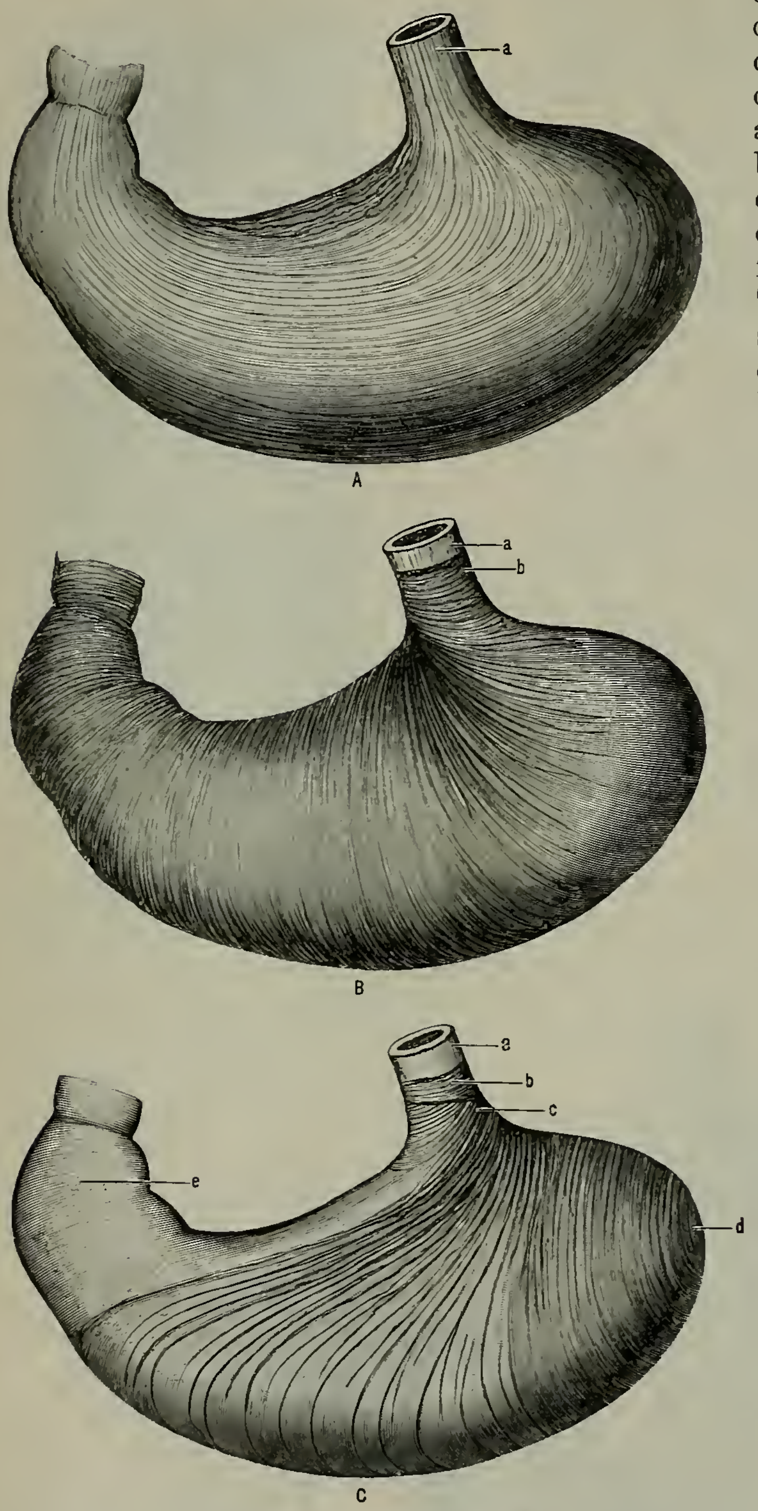


Fig. 903.—The Three Layers of the Muscular Coat of the Stomach. A, External or longitudinal layer; B, Middle or circular layer; C, Internal or oblique layer. *a*, Longitudinal fibres of œsophagus; *b*, Superficial circular fibres of œsophagus passing into circular fibres of stomach in B; *c*, Deep circular fibres of œsophagus passing into oblique fibres of stomach in C; *d*, Oblique fibres forming rings at the fundus; *e*, Submucosa.

Tela Submucosa.—The submucous coat is a layer of strong but loose connective tissue, which lies between and unites the muscular and mucous coats (Fig. 901). It is more loosely attached to the muscular and more closely to the mucous coat, and it forms a bed in which the vessels and nerves break up before entering the mucous membrane.

Tunica Mucosa.—In the fresh state the mucous coat is of a reddish-gray colour and of moderate consistence. After death, the colour turns to a darker gray, and the whole membrane becomes softer and more pulpy. It is thicker (over 2 mm.) and firmer in the pyloric than in the cardiac part, and is thinnest at the fundus. When the stomach is empty all three outer coats, which are extensile, contract; whilst the mucous coat is thrown into numerous prominent folds or *rugæ*, which project into the interior. These are, in general, longitudinal in direction, with numerous cross branches. They disappear when the stomach is distended. Along the lesser curvature are three or four long, narrow, very constant ridges, which pass without a break from the œsophageal orifice towards the pyloric part of the stomach (Fig. 894). These ridges are parallel to one another, and are apparently never obliterated. Between them are deep furrows, which form channels leading from the œsophageal orifice to the pyloric portion. At the junction of the body and pyloric portions, at the level of the sulcus intermedius, is often a transverse fold of mucosa, which is of some size, termed the plica pre-pylorica.

When the surface of the mucous coat is examined in a *fresh* stomach, it is seen to be marked out into a number of small, slightly elevated, polygonal areas, *areæ gastricæ*, by numerous linear depressions; the mucous membrane is consequently said to be mamillated (Fig. 904, A). These little areas, which measure from 1 to 6 mm. in diameter, are beset with numerous small pits, *foveolæ gastricæ*, about ·2 mm. wide, which are the mouths of the gastric glands, and they are so closely placed that the amount of surface separating them is reduced (particularly in the pyloric portion, where the gland mouths are widest) to a series of elevated ridges, *plicæ villosæ*, resembling villi on section. Although the gland mouths cannot be seen with the naked eye, a very slight magnification is sufficient to show them clearly; it is also possible to see the gland tubes leading off from the bottom of each (Fig. 904, B).

Minute Structure of the Mucous Coat.—In structure the mucous coat consists of an epithelial covering composed of long columnar cells, and of numerous tubular glands, *glandulæ gastricæ*, which are prolonged outwards from this surface, and which are enclosed in a delicate connective tissue stroma, with some small lymph nodules, *noduli lymphatici gastrici.* The bases of the glands reach outwards to the lamina muscularis mucosæ, a layer consisting of an external longitudinal and an internal circular layer of plain muscle fibres.

Glandulæ Gastricæ.—These consist of a duct terminating in one or more secreting tubules. The duct is lined with columnar epithelial cells, similar to those which cover the surface of the mucous membrane. Three varieties of glands are found in different regions of the stomach, and are named from their position—

(1) **Cardiac Glands.**—These glands are situated close to the œsophageal opening. The duct terminates in a single long tubule, which is lined with short columnar granular cells.

(2) **Fundus Glands.**—In these glands the duct terminates in one or more tubules, lined with polyhedral cells, termed the *chief* or *central cells.* At intervals, between this layer of cells and the basement membrane, are placed larger spheroidal cells, which stain more deeply as a rule, termed the *parietal* or *oxyntic* cells. These glands are found in the fundus and body of the stomach.

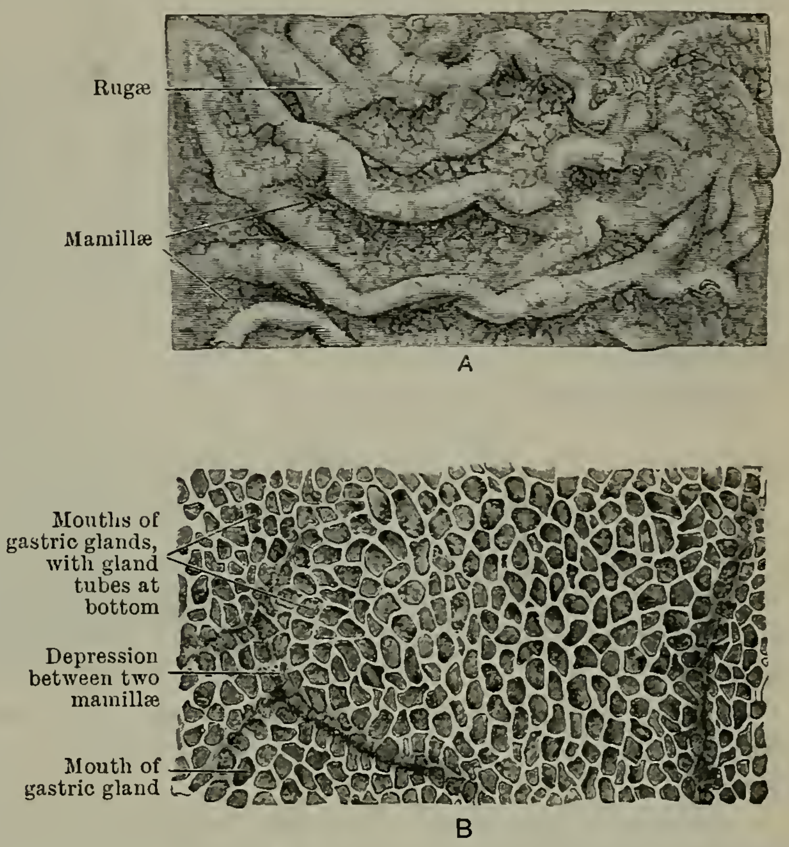

Rugæ
Mamillæ
A
Mouths of gastric glands, with gland tubes at bottom
Depression between two mamillæ
Mouth of gastric gland
B

Fig. 904.—Mucous Membrane of the Stomach. A, Natural size; B, Magnified 25 diameters. In A the rugæ and the mamillated surface are shown. In B the gland mouths (foveolæ gastricæ), with the gland tubes leading off from some of them, and the ridges separating the mouths (plicæ villosæ) are seen.

(3) **Pyloric glands** are found in the pyloric portion of the stomach. These consist of a short duct, terminated in a group of short but tortuous gland tubules. These tubules are lined with short columnar or polyhedral cells, similar to the central cells of the fundus glands.

Blood-vessels.—The arteries of the stomach are all derived ultimately from the *cœliac artery.* The *gastric artery* arises from this trunk direct. Having reached the lesser curvature and given off an œsophageal branch, it divides into two large branches, which run, one on each side of the organ, along this curvature, and join below with two similarly-disposed arteries derived from the *right gastric* branch of the hepatic. From the two arches thus formed, four or five large branches pass to each surface of the stomach, and soon pierce the muscular coat. Along the greater curvature several smaller branches reach the stomach from the *right and left gastro-epiploic arteries,* which are branches respectively of the gastro-duodenal and the splenic, and run in the gastro-colic ligament close to its attachment to the stomach. Finally, four or five *short gastric arteries,* branches of the splenic, are distributed to the fundus of the stomach, which they reach by passing forwards between the layers of the gastro-lienal ligament. At first the arteries lie beneath the peritoneum; very soon, however, they pierce the muscular coat, which they supply, and, reaching the submucosa, break up to form a close network of vessels. From these arise numerous small branches, which enter the mucous membrane and form capillary plexuses around the glands as far as the surface.

The **veins** begin in the capillary plexuses around the glands; uniting, they form a network in the submucosa, from which arise branches that pierce the muscular coat, and finally end in the following veins: the *right gastro-epiploic,* which joins the superior mesenteric; the *left gastro-epiploic,* and four or five veins corresponding to the *short gastric arteries,* which join the splenic; the *coronary vein of the stomach,* which runs along the lesser curvature from left to right, and joins the portal vein. These veins contain numerous valves which, though competent to prevent the return of blood in the child, are rarely so in the adult.

The **lymph vessels** of the stomach arise in an extensive plexus in the mucous membrane around the gastric glands. They then join a plexus of vessels in the tela submucosa, from which some vessels pass at intervals to join another plexus of vessels, subserous in position; piercing the muscular coats obliquely in their course. The efferent vessels pass mainly from the subserous plexus, and are arranged in three main groups, which pass in different directions, and drain three different areas of the stomach wall.

One set of vessels is connected mainly with the whole of the lesser curvature, from fundus to pylorus, and the adjacent half or two-thirds of the anterior and posterior surfaces of the stomach. These vessels pass to the superior gastric glands, along the lesser curvature, and, in company with the left gastric artery, to the cœliac glands.

The second set of vessels drains an area which includes the greater curvature below the fundus, and the adjacent portions of the anterior and posterior surfaces of the stomach. These vessels pass with the right gastro-epiploic artery to some inferior gastric glands which lie below and behind the pylorus, and thence they pass with the hepatic artery to the cœliac glands.

The third set of vessels drains the region of the fundus. The vessels from this area pass in the gastro-lienal ligament to the spleen, where they are connected with some splenic glands, and pass onwards, along the superior border of the pancreas, to the cœliac glands also.

The superior and inferior gastric glands and the splenic glands are the first glands interposed in the course of the lymph vessels. The cœliac glands form the second set.

The **nerves** are derived from the two *vagus nerves* and from the *cœliac ganglia* of the sympathetic. The vagi nerves pass through the diaphragm with the œsophagus, the left lying on its anterior, the right on its posterior aspect; in this way they reach the anterior and posterior surfaces of the stomach respectively. Here they unite with the sympathetic fibres from the cœliac plexus, which pass to the stomach with the branches of the cœliac artery. The nerve fibres, which are chiefly non-medullated, form two gangliated plexuses, those of the myenteric plexus and the submucous plexus, in the muscular and submucous coats respectively.

The development of the stomach is described with that of the intestines on pp. 52 and 1237.

INTESTINUM TENUE.

The **small intestine** is the portion of the digestive tube which is placed between the stomach and the beginning of the large intestine. It commences at the pylorus, and ends at the valvula coli by joining the large intestine. It occupies the greater portion of the abdominal cavity below the liver and stomach (Fig. 849), and is found in the umbilical, hypogastric, and both lumbar regions; also, but to a less extent, in the other regions of the abdomen, and in the pelvic cavity.

In *length*, the small intestine usually measures over 20 feet. According to Treves, it is 22½ ft. in the male, 23 in the female, whilst Jonnesco gives the average length at 24 ft. 7 ins., or 7½ metres. In form it is cylindrical, with a *diameter* varying from nearly two inches (47 mm.) in the duodenum to a little over an inch (27 mm.) at the end of the ileum; there is thus a gradual diminution in its size from the pylorus to the valvula coli.

The small intestine is relatively longer in the child than in the adult; at birth it is to the total height of the child as 7 to 1, whilst in the adult the proportion is as 4 to 1. Notwithstanding Treves' results, it is generally held that the small gut is relatively longer in the male than the female.

While the former figures, 20 to 22 feet, represent the entire length of the intestine in its most extended form after death, when muscular tonus has disappeared, it is probable that during life the length is not so great. The muscular coats, both longitudinal and circular, are more or less contracted, and probably the total length during life may be estimated as 15 to 17 feet.

In formalin-hardened bodies the small bowel rarely measures more than 12 or 13 feet in length. Similarly its diameter is often reduced in places to ½ or ¾ inch (12·5 to 18·7 mm.), although the greater part of the gut may retain its usual width: these narrow parts have apparently been fixed in a state of contraction.

The small intestine is divided into three parts (Fig. 896)—namely, the **duodenum**, constituting the first eleven inches, distinctly marked off from the rest by its fixation and the absence of a mesentery; the **intestinum jejunum** ("empty intestine") which comprises the upper two-fifths, and the **intestinum ileum** ("twisted intestine") the lower three-fifths of the remainder. The jejunum and ileum pass imperceptibly into one another, and the line of division drawn between them is artificial. Typical parts of the two—namely, the beginning of the jejunum and the end of the ileum—differ in size and in the appearance presented by their lining mucous membrane, and they can be distinguished from one another without difficulty (see p. 1200).

As the structure of the large and small intestine is similar in many particulars, it will be convenient to describe here the general structure of the intestines.

Subsequently, the peculiarities of structure of different parts will be described with the corresponding division of the tube.

Structure of the Intestines.

The wall of the intestines, like that of the stomach, is made up of four coats, named from without inwards—tunica serosa, tunica muscularis, tela submucosa, and tunica mucosa (Figs. 905 and 909).

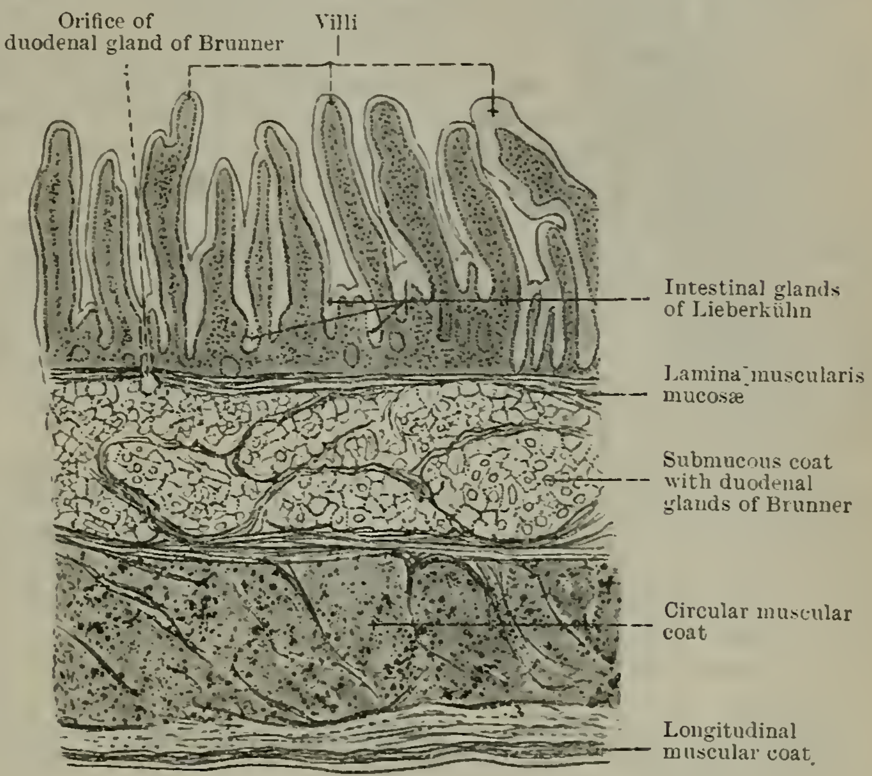

Orifice of duodenal gland of Brunner
Villi
Intestinal glands of Lieberkühn
Lamina muscularis mucosæ
Submucous coat with duodenal glands of Brunner
Circular muscular coat
Longitudinal muscular coat

Fig. 905.—Section of Wall of Duodenum.

1. **Tunica Serosa.**—The serous coat is formed of peritoneum. It varies in the extent to which it clothes the different divisions of the tube. The detailed arrangement of this coat will be given with the description of each division of the intestinal tube.

2. **Tunica Muscularis.**—This consists of unstriped muscle arranged in two layers—an outer *stratum longitudinale*, in which the fibres run longitudinally, and an inner *stratum circulare*, in which they are circularly disposed. The muscular coat is thicker in the duodenum than in any other part of the small intestine, and it gradually diminishes in thickness until the end of the ileum is reached. On the other hand, in the large intestine, it is thickest in the rectum and thinner towards the beginning of the colon.

The **stratum longitudinale** of the muscular coat is much thinner than the underlying stratum circulare. In the small intestine it forms a complete sheet, continuous all round the gut (Fig. 906), whilst in the greater part of the large intestine it does not form a complete coat, but is arranged as three separate longitudinal bands known as the *tæniæ coli*.

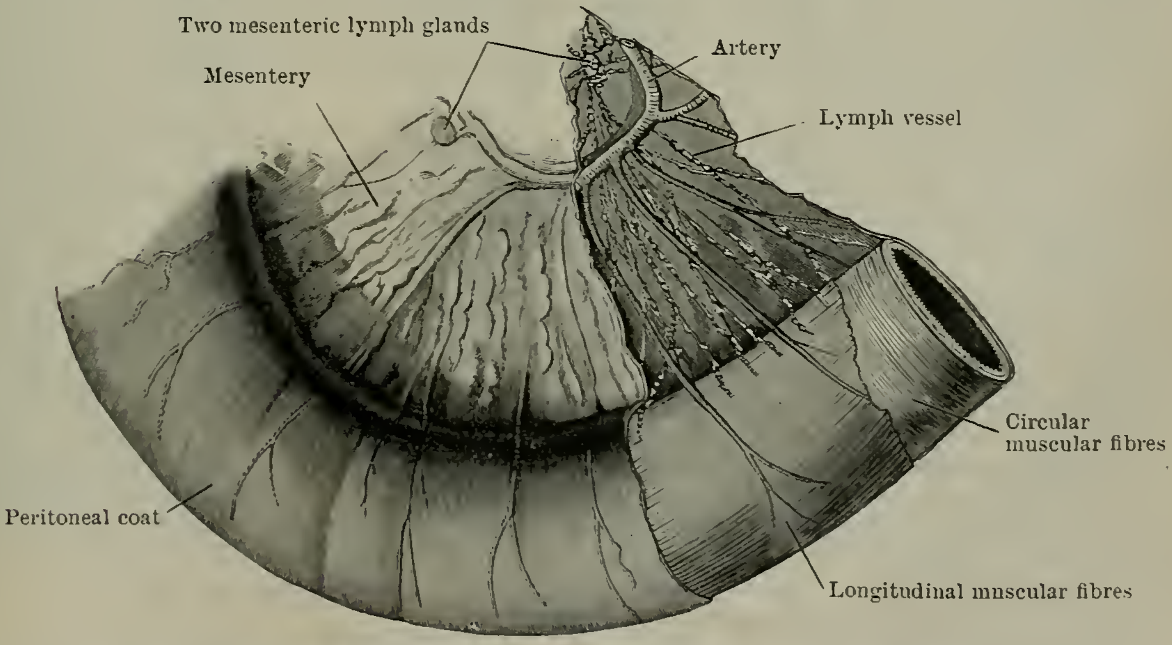


Fig. 906.—A Portion of Small Intestine, with Mesentery and Vessels.
The peritoneal coat has been removed from the right half, and the two layers of the muscular coat exposed.

The **stratum circulare**, thicker than the longitudinal layer, is composed of bundles of muscular fibres arranged circularly round the tube (Fig. 906), and forming in all parts a continuous sheet. Unlike the longitudinal fibres, those of the circular layer take part in the formation of the valves of the pylorus and colon.

It has recently been stated (Eben. J. Carey, *Anat. Record*, vol. xxi.) that in the small intestine these layers are not truly circular or longitudinal, but are both spiral, the inner coat forming a close and the outer a long spiral. In the inner coat one complete turn is made in every 0·5 to 1 mm. or less, while those of the outer coat which are spiral make a complete turn in every 200 to 500 mm. or more.

3. **Tela Submucosa.**—The submucous coat is a loose but strong layer of areolar tissue connecting the muscular and mucous coats, on which chiefly depends the strength of the intestinal wall. In it the vessels break up before entering the mucous coat, and it contains the *glandulæ duodenales* (*Brunneri*) (Fig. 905). In both small and large intestines, the bases of the solitary lymph nodules lie in it (Fig. 910).

4. **Tunica Mucosa.**—The mucous membrane is composed (Fig. 905) of the following parts: (1) A layer of striated, columnar, epithelial cells, resting on a basement membrane. Outside this lies (2) a layer of retiform tissue, containing a considerable number of scattered lymph cells. This layer is limited towards the tela submucosa by (3) an extremely thin sheet of unstriped muscle, the **lamina muscularis mucosæ**, which is not visible to the naked eye. The mucous membrane is very vascular, particularly in the small intestine. It is thicker in the duodenum than in the jejunum, and thicker in the jejunum than in the ileum.

Throughout both the small and large intestines the mucous membrane contains (4) innumerable (small microscopic) tubular glands, the **glandulæ intestinales** [Lieberkühni]. In shape they are minute straight tubes. Their mouths open on the free surface of the mucous membrane: their closed ends lie in the deeper part of the mucous coat, and their cavities are lined with columnar epithelium. In the small intestine they open on the surface between the bases of the villi, and in the large gut their orifices are found all over the surface of the non-villous mucous membrane.

Nerves.—The intestine has a large supply of nerves belonging to the sympathetic system, which accompany the vessels to the wall of the intestine, and are distributed to the vessels and to the walls.

The nerves, derived from the cœliac and mesenteric plexuses, and connected also with the right vagus, anastomose in the subserous tissue, traverse the outer muscular coat, and between the muscle coats form an extensive plexus, composed of interlacing fibres and ganglion cells, termed the myenteric plexus of Auerbach.

From this plexus, branches pierce the inner muscular coat and pass to the tela submucosa, and again form a plexus, known as the plexus of Meissner, from which branches pass to the lamina muscularis mucosæ, to the muscle tissue of the villi, and to the mucosa.

Keith compares the tissue of Auerbach's plexus to the nodal tissue of the heart, and describes special regions in which it is most highly developed, which he considers may act as "nodal points" for peristalsis.

The afferent nerve supply of the intestine is from the sympathetic system, and hence the whole intestine except the anal canal is quite insensitive to stimuli which in other parts would give rise to pain. Strong contraction, however, of the muscle coats causes severe pain, which is referred not to the intestine but to some portion of the abdominal wall.

Vessels.—The vessels, on reaching the intestine, bifurcate, giving a branch to each side of the gut. These latter run transversely round the intestines, at first under the peritoneal coat; soon, however, they pierce the muscular coat and form a plexus in the submucosa, from which numerous branches pass to the mucous membrane, where some form plexuses around the intestinal glands whilst others pass to the villi. The **veins** are similarly disposed, and the blood from the whole of the small intestine beyond the duodenum is returned by the superior mesenteric vein, which joins with the splenic to form the portal vein.

The **lymph vessels** of the small intestine (known as lacteals) begin in the villi, and also as lymph sinuses surrounding the bases of the solitary nodules; a large plexus is formed in the submucosa, a second between the two layers of the muscular coat, and a third beneath the peritoneum. The vessels from all these pass up in the mesentery, being connected on the way with the numerous (from 40 to 150) **mesenteric glands**, and finally unite to form the **truncus intestinalis**, which opens into the cisterna chyli.

Certain special developments of the mucous coat, found in particular regions of the intestinal tube, must next be considered: these are the (1) villi intestinales; (2) plicæ circulares [Kerkringi] (O.T. valvulæ conniventes); (3) noduli lymphatici solitarii (O.T. solitary glands); and (4) noduli lymphatici aggregati [Peyeri] (O.T. Peyer's patches).

Villi Intestinales.—The mucous membrane of all parts of the small intestine presents a soft, velvety, or fleecy internal surface (Fig. 908, B); this is due to the presence of an enormous number of minute processes, known as villi.

They are minute, cylindrical, or finger-like projections of the tunica mucosa (Fig. 907) about $\frac{1}{20}$th to $\frac{1}{50}$th of an inch (0·2 to 1·2 mm.) in height, barely visible to the naked eye. Beginning at the edge of the pyloric valve, they are broad but short in the duodenum, and grow narrower as they are followed down through the intestine to the valvula coli, at the edge of which they cease. They are found, not only on the general surface of the mucous membrane, but also upon the plicæ circulares, and, while they are not present over the solitary lymph nodules, they are found in the intervals between the individual nodules of the aggregated nodules.

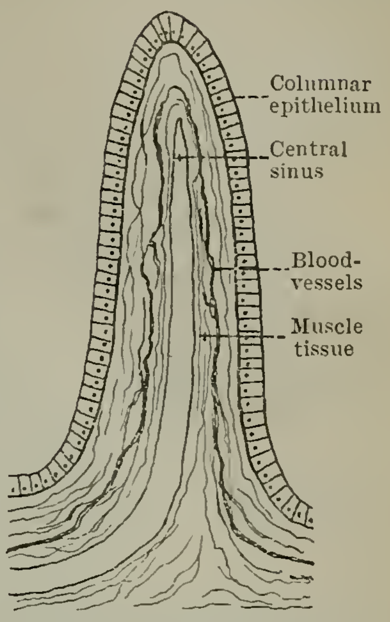


Fig. 907.—Structure of a Villus.

Structure of the Villi.—Each villus is covered by a layer of columnar cells, set upon a basement membrane, and under this is a fine layer of longitudinal non-striated muscle, continuous with the lamina muscularis mucosæ of the intestine.

In the interior of each villus is a *central sinus*, a space lined with endothelium, continuous with the lymphatic vessels (chyle vessels) of the mucosa. There may be several such lymph spaces within the larger villi.

A network of blood-vessels lies between the epithelium and the central sinus.

Dilatation of these vessels causes enlargement of the villus, while contraction of the muscle layer diminishes its height and serves to assist in emptying the central sinus into the lymphatic or chyle channels.

The villi thus play an important part in the absorption of the products of digestion.

Plicæ Circulares [Kerkringi].—When the intestine is empty and contracted, its mucous membrane is thrown into folds which disappear on distension. In addition to these, there are in certain portions of the small intestine a series of large, permanent folds, known as *plicæ circulares* of Kerkring (Fig. 908). These are usually more or less crescentic in shape, and resemble a series of closely placed shelves running transversely around the gut. They rarely form more than two-thirds of a circle; sometimes, however, they present a spiral arrangement, the spiral extending little more than once round the tube, as a rule. Occasionally they bifurcate at one or both ends; sometimes, too, short irregularly directed branches pass off from them. They are usually about 2 to 3 inches (5 to 7·5 cm.) in length, and their height, that is their projection into the cavity, may be as much as $\frac{1}{3}$rd of an inch (8 mm.), whilst in thickness, as seen when cut across, they measure about $\frac{1}{8}$th inch (3 mm.).

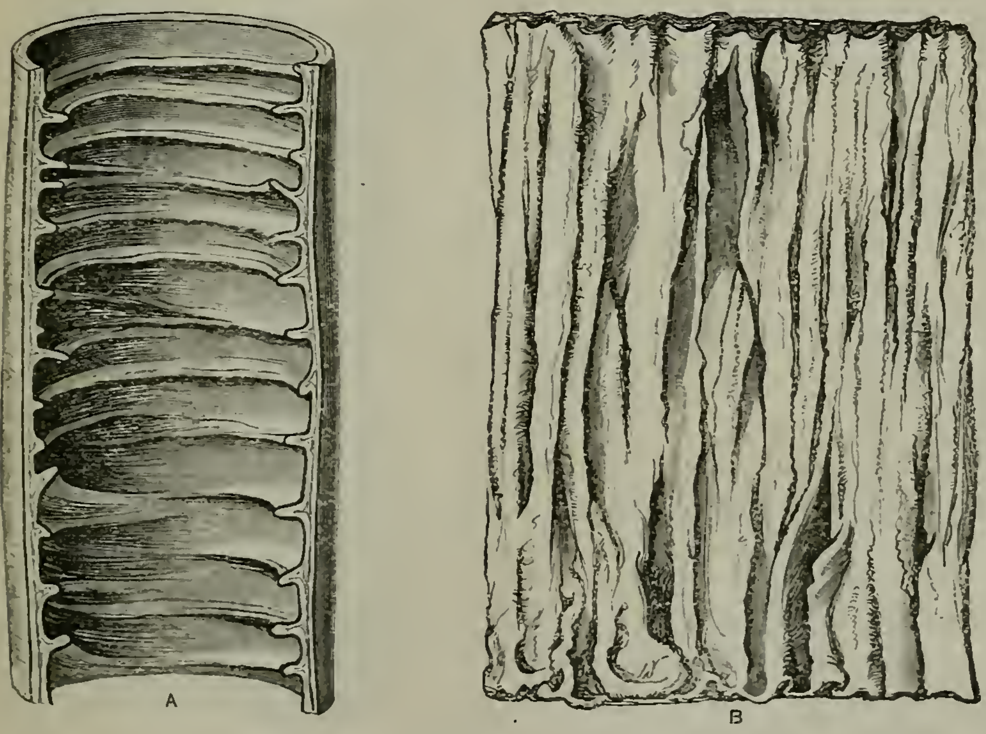


Fig. 908.—Plicæ Circulares (natural size).
A, as seen in a portion of jejunum which has been filled with alcohol and hardened; B, a portion of fresh intestine spread out under water.

They are folds of the tunica mucosa, with a prolongation from the tela submucosa and they increase the amount of surface available for secretion and absorption.

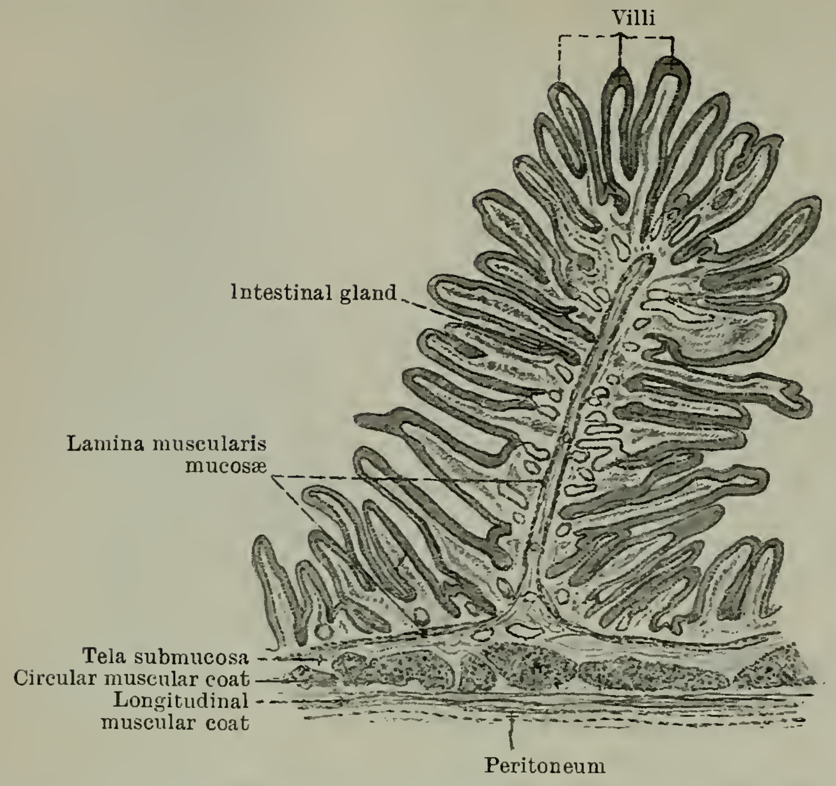


Fig. 909.—Transverse Section of a Plica Circularis and Wall of Small Intestine.

Plicæ circulares are not found in the upper part of the duodenum. They begin at a distance of from 1 to 2 inches (2·5 to 5 cm.) beyond the pylorus. At first they are small, irregular, and scattered; but they are larger lower down, and at the opening of the bile duct (4 inches from the pylorus) they are distinct and prominent. In the rest of the duodenum, and in the superior half of the jejunum, they are highly developed, being large, broad, and closely set. In the inferior half of the jejunum they become gradually smaller and fewer. In the ileum they become still smaller and more irregular, and, as a rule, they practically cease a little below its middle, though patches of plicæ circulares, much reduced in size, can be traced to within a short distance of the valvula coli.

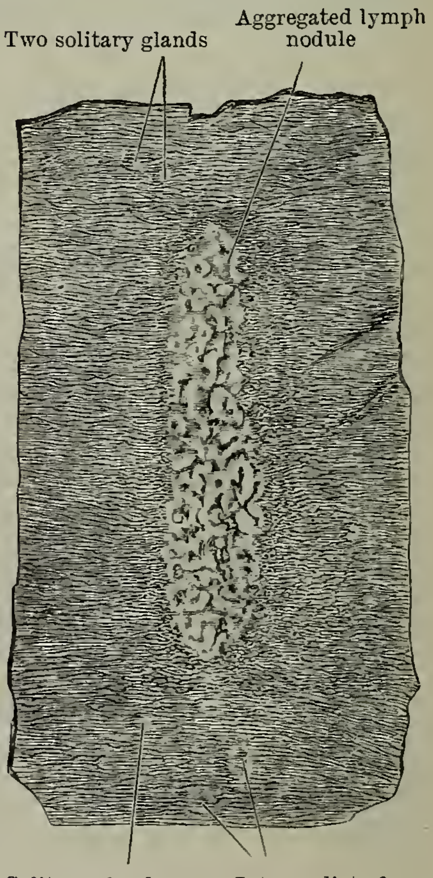


Fig. 910. — Noduli Lymphatici Aggregati and Solitarii, from intestine of child two years old (natural size).

Near the lower border are seen a few small patches made up of two or three lymph nodules; they are marked "intermediate form."

Noduli Lymphatici Solitarii.—The solitary lymph nodules are minute masses of lymph tissue, opaque and of a whitish colour, which project on the surface of the mucous membrane throughout the whole length of both the small and large intestines.

Isolated lymph cells are found in abundance scattered through the connective-tissue layer of the intestinal mucous membrane generally; in places these cells are gathered together to form little nodules, supported by a framework of retiform tissue, and surrounded by a lymph space which communicates below with the lymph vessels of the tela submucosa. Such a collection of lymph cells constitutes a solitary nodule. They are usually of a rounded or oval shape (Fig. 910), the wide end resting in the tela submucosa, the nodule itself piercing the lamina muscularis mucosæ, and the narrow end projecting slightly above the general surface of the mucous membrane. In size they vary from $\frac{1}{40}$th to $\frac{1}{8}$th of an inch (·6 to 3·0 mm.), but their average bulk is about that of a small grain of sago, to which they bear some resemblance.

They are present in the whole digestive tube, but are particularly abundant in the vermiform process and the cæcum.

Noduli Lymphatici Aggregati.—These lymph nodules (Peyer) consist of a large number of minute lymph nodules grouped closely together and forming a slightly elevated area, usually of an oblong form, on the surface of the mucous membrane (Fig. 910). In length they vary from half an inch (12 mm.), or less, to three or four inches (100 mm.), and in width they commonly measure from a third to half an inch (8 to 12 mm.). Their number is variable, but in the average condition about 20 or 30 are found. They are best marked in young subjects, where they form considerable elevations above the general surface, and may be as many as 45 in number. After middle life they atrophy, and in old age, although usually present, they are indistinct, occasionally being marked by little more than a dark discoloration of the mucous membrane. They are invariably situated along the surface of the intestine opposite the line of mesenteric attachment, with their long axis corresponding to that of the bowel. Consequently, in order to display them, the tube must be slit up along its attached or mesenteric border.

These aggregated nodules are entirely confined to the small intestine, being largest and most numerous in the ileum, particularly in its inferior part, where they usually assume an oblong shape; in the inferior half of the jejunum they are small, circular, and few in number; in its superior part they are much less numerous; and in the duodenum only few can be found.

The plicæ circulares stop at the margins of the aggregated nodules, and are not continued across them; but villi are found on the surface of the aggregated nodules, in the intervals between the individual lymph nodules.

The chief bowel lesion in typhoid fever is found in these aggregated and in the solitary nodules.

When the surface of one of these nodules from a child's intestine (in which these structures are particularly well developed) is carefully examined, it is seen to be made up, not of a series of separate, rounded nodules grouped together, but rather of a number of wavy, irregular, and branching ridges connected with one another by cross branches (Fig. 910), the whole recalling in miniature the appearance of a raised map of a very mountainous district in which the chief chains run irregular courses, and are joined to one another by connecting ridges.

Small patches, intermediate in form between solitary and aggregated nodules, and consisting of two or three lymph nodules, are also usually present.

DUODENUM.

The **duodenum** is the first part of the small intestine, and differs from the rest of that tube in having no mesentery, and hence it is fixed to the posterior abdominal wall. The ducts of the liver and pancreas open into it, and some special glands are found in its wall, known as the *duodenal glands of Brunner*.

Shape and Divisions.—The duodenum begins at the pylorus, about the level of the first lumbar vertebra, and ends at the left side of the first or second lumbar vertebra (Fig. 911).

It forms an irregular horseshoe-shaped curve, with the opening directed upwards and to the left, and the ends reaching to within about two inches of one another. Within the concavity of the curve the head of the pancreas is placed. It is divided into three main parts, namely: (1) The **pars superior**, which begins at the pylorus, passes posteriorly and to the right beneath the liver, and ends at the neck of the gall-bladder by turning down, forming the *flexura superior*, and joining (2) the **pars descendens**. This begins at the neck of the gall-bladder, runs down on the posterior abdominal wall, on the right of the vertebral column, behind the transverse colon (Fig. 912), and ends opposite the third or fourth lumbar vertebra. There it turns to the left, and passes into (3) the **pars inferior**. This portion at first runs more or less transversely to the left, across the vena cava, aorta, and vertebral column (*pars horizontalis*), and then ascends as far as the inferior surface of the pancreas (*pars ascendens*). There, at the level of the first or second lumbar vertebra, it bends abruptly forwards, forming the **duodeno-jejunal flexure** (Fig. 912), and passes into the jejunum. The junction of the pars descendens and pars inferior constitutes the *flexura inferior*.

The three parts of the duodenum do not all lie in the same plane; for, whilst its greater part is placed in a frontal plane, the superior part, and the commencement and termination of the inferior part, lie more in a sagittal plane (Fig. 912).

Position and Size.—As a rule, a little more than half of the duodenum lies in the epigastrium; the remainder—namely, about the inferior third of the descending portion and the adjoining two-thirds of the inferior portion—is placed in the umbilical region. With the exception of the terminal ascending portion of the third part, the whole of the duodenum lies to the right of the median plane.

Its length is usually about 11 inches (27·5 cm.), its first portion being the shortest and its third portion the longest. Its diameter varies considerably, and may be stated to average about 1½ inches when empty, but it may be two inches or more in diameter when distended.

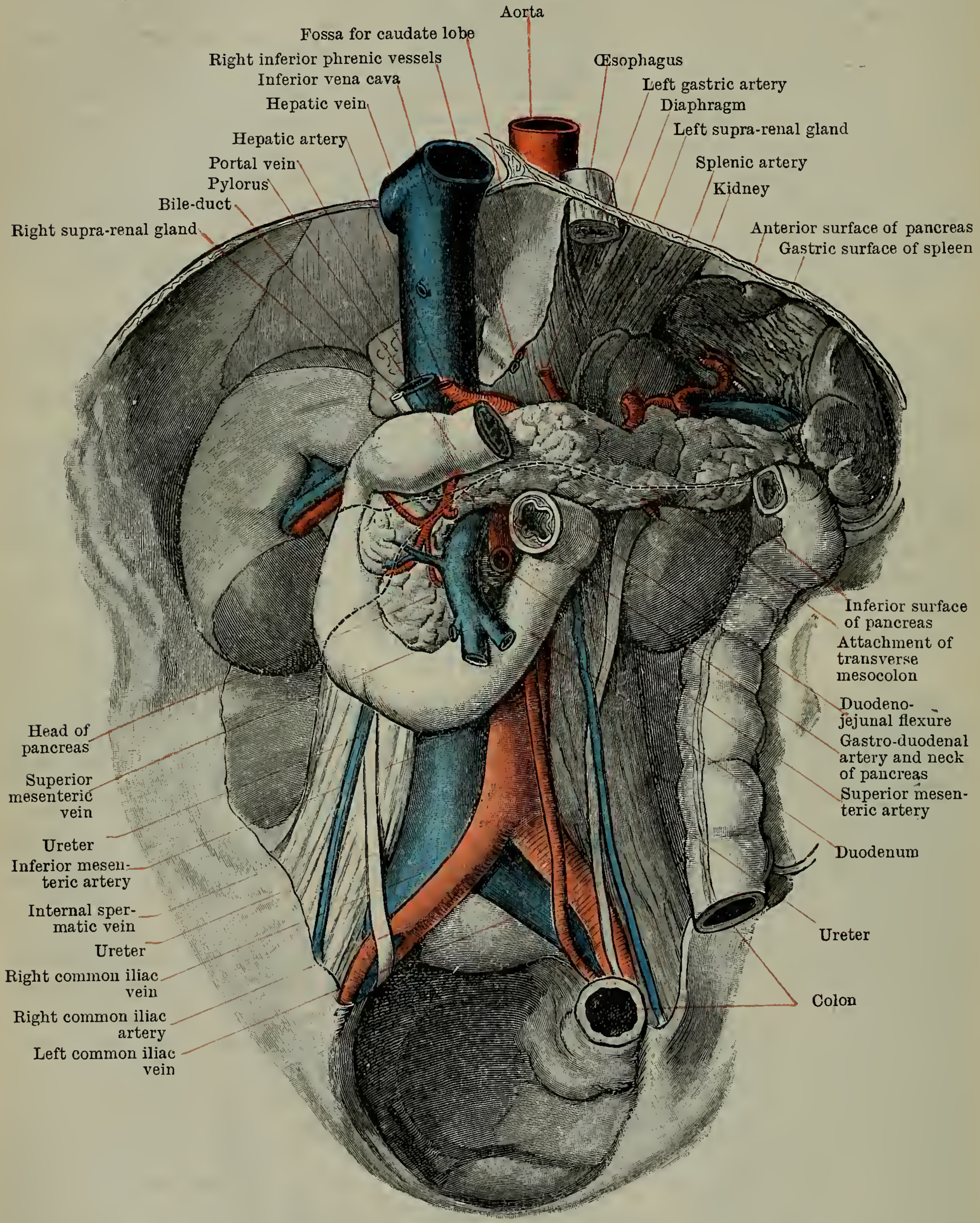


Fig. 911.—The Viscera and Vessels on the Posterior Abdominal Wall.

The stomach, liver, and most of the intestines have been removed. The peritoneum has been preserved on the right kidney, and the fossa for the caudate lobe. When the liver was taken out, the vena cava was left behind. The stomach bed is well shown. (From a body hardened by injection of chromic acid.)

Pars Superior.—The length of the superior part varies from about 1½ to 2 inches (3·7 to 5·0 cm.), and is said to be greater when the stomach is empty than when distended.

Its relations are as follows: It forms the inferior boundary of the foramen epiploicum, and, above that foramen, it is in relation to the caudate process of the liver, while the quadrate lobe of the liver hangs downwards over it and to the right. The hepatic artery is in contact for a short distance with the superior border. Below, it rests on the head and neck of the pancreas. The portal vein, gastro-duodenal artery, and the bile duct lie in contact with it on the left side, and behind them the duodenum comes into contact with the right aspect of the inferior vena cava. The superior pancreatico-duodenal and the right gastro-epiploic vessels pass forwards below its inferior margin.

Its *peritoneal relations* are similar to those of the pyloric end of the stomach for about an inch. It is therefore at first invested by peritoneum on the right and left aspects, and the peritoneum passes upwards from its superior border as the right portion of the lesser omentum, forming the *hepato-duodenal ligament*, while from its inferior border the descending folds of the peritoneum pass downwards. The peritoneum is reflected from off the left surface on to the pancreas and abdominal wall, and forms a fold known as the *right gastro-pancreatic fold*, while the peritoneal covering of the right side is continued onwards along the whole of this part of the duodenum.

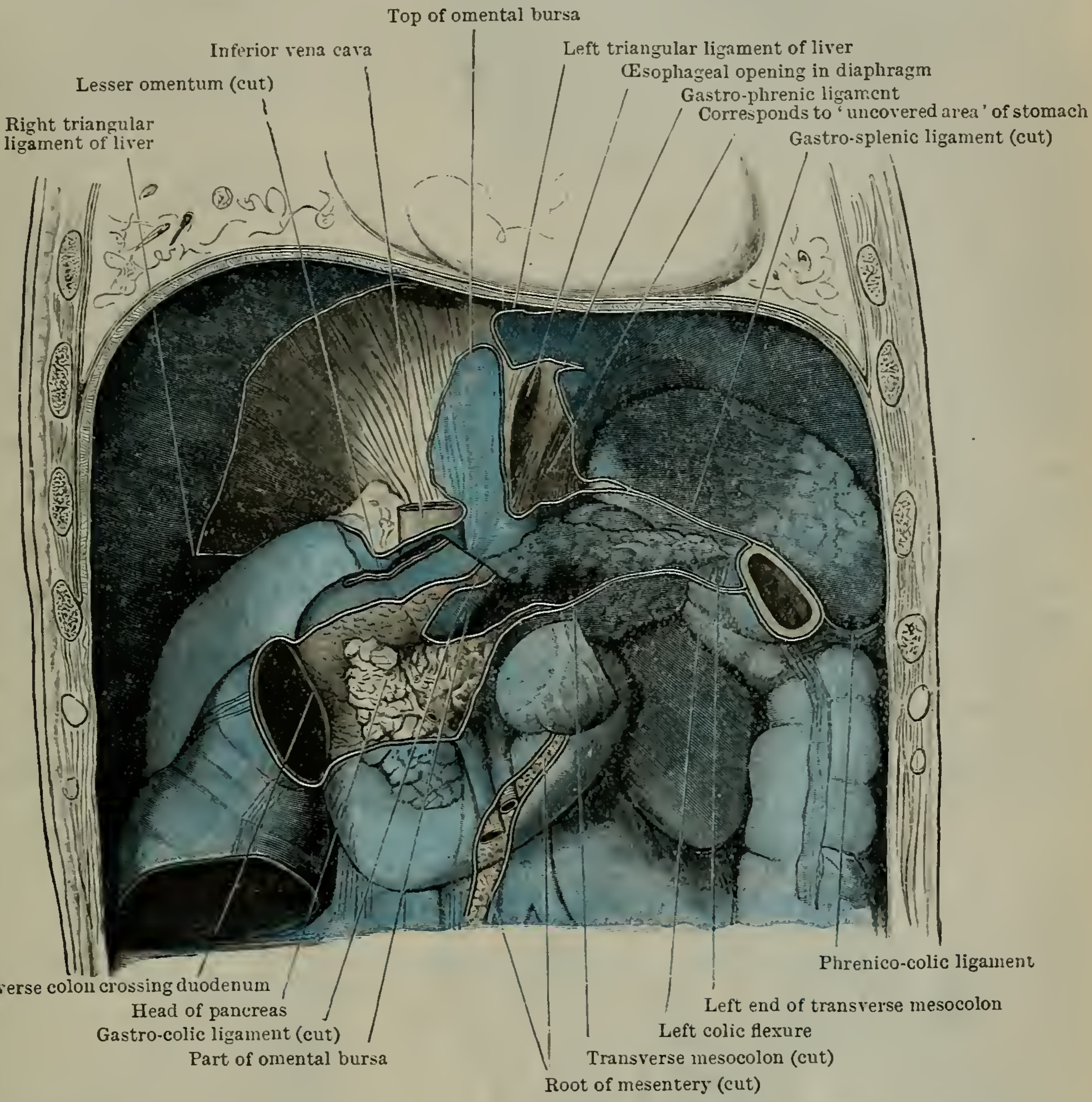

Top of omental bursa
Inferior vena cava
Left triangular ligament of liver
Œsophageal opening in diaphragm
Lesser omentum (cut)
Gastro-phrenic ligament
Corresponds to 'uncovered area' of stomach
Right triangular ligament of liver
Gastro-splenic ligament (cut)
Phrenico-colic ligament
Transverse colon crossing duodenum
Left end of transverse mesocolon
Head of pancreas
Left colic flexure
Gastro-colic ligament (cut)
Transverse mesocolon (cut)
Part of omental bursa
Root of mesentery (cut)

FIG. 912.—THE PERITONEAL RELATIONS OF THE DUODENUM, PANCREAS, SPLEEN, KIDNEYS, ETC.

From a body hardened by injections of formalin. When the liver, stomach, and intestines were removed the lines of the peritoneal reflections were carefully preserved. The peritoneum is coloured blue.

Pars Descendens.—The descending part in length measures 3½ or 4 inches (8·7 to 10 cm.).

Its relations are as follows: It lies on the right of the vertebral column and the inferior vena cava, from the first to the third or fourth lumbar vertebra, and is anterior to the pelvis of the right kidney, the right renal vessels, and ureter, and also, to a varying extent, the front of the right kidney itself; while, below the level of those structures, it rests upon the psoas major muscle.

The lateral aspect is in contact with the sloping inferior surfaces of the liver in its superior part, and with the right flexure of the colon below.

Peritoneal Relations.—The anterior aspect is covered by peritoneum, except about its middle, where the root of the transverse mesocolon crosses the duodenum. Not infrequently, the transverse colon has no mesentery, but is itself in direct contact with the wall of the duodenum. In other cases, the colon is in contact with the peritoneal surface of the duodenum, below the line of reflection of the transverse mesocolon.

The head of the pancreas is in contact with its concave left margin, and occasionally overlaps it anteriorly and posteriorly; and along the margin of the pancreas, both anteriorly and posteriorly, are branches of the superior and inferior pancreatico-duodenal vessels, the veins often forming a dense network on the posterior aspect.

The bile duct, after passing down behind the superior part of the duodenum, descends between the head of the pancreas and the descending part, nearly as far as its middle; there it is joined by the pancreatic duct, and the two, piercing the wall of the duodenum obliquely, open by a common orifice on its inner aspect, about 3 to 4 inches (8·7 to 10 cm.) beyond the pylorus.

Pars Inferior.—The horizontal portion of the **inferior part** runs more or less transversely to the left across the inferior vena cava (Fig. 911) for one or two inches, and the ascending part passes very obliquely, or even vertically, upwards in front of the aorta and left psoas major muscle. Finally, having reached the inferior surface of the pancreas, it bends forwards, and passes into the jejunum.

Anteriorly, the pars inferior is crossed (about the junction of its two divisions) by the superior mesenteric vessels, and also by the root of the mesentery (Fig. 912). On each side of this it is covered by coils of small intestine. *Posteriorly*, the pars horizontalis lies across the vena cava inferior; the pars ascendens lies on the aorta, the left renal vein and occasionally also the artery, and the left psoas major muscle, all of which separate it from the vertebral column. *Above*, it is closely applied in its whole extent to the head of the pancreas. The *left side* of the pars ascendens, which is free, lies in contact with some coils of the small intestine.

Peritoneal Relations.—The inferior part of the duodenum is covered by peritoneum on its anterior surface throughout, except where it is crossed by the superior mesenteric vessels and the root of the mesentery, which contains these vessels (Fig. 912). In addition, its ascending part is also clothed by this membrane on its left side.

The attachment of the root of the mesentery begins, above, quite close to the duodeno-jejunal flexure, on the front of the duodenum; thence it runs down on the anterior aspect of the ascending part, and finally leaves the duodenum about the union of the two divisions of its third portion.

Duodenal Fossæ.—In the neighbourhood of the pars ascendens are found three well-known fossæ of the peritoneum which are of some surgical interest; they are the superior and inferior duodenal and the paraduodenal fossæ (Fig. 913). Other rarer forms are occasionally present.

When the ascending part of the duodenum is drawn over to the right, one or two triangular folds of peritoneum will generally be found passing from the duodenum to the abdominal wall. Each fold at one end is attached to the duodenum, at the other to the parietal peritoneum at the left of the duodenum, whilst the third margin is free, and bounds the opening of a small pouch which lies between the folds, the *recessus duodeno-jejunalis*. Of these folds, the *upper* is situated near the termination of the duodenum, with its free margin directed down. It sometimes contains between its two layers the termination of the inferior mesenteric vein. Behind it lies a prolongation from the recessus duodeno-jejunalis termed the **superior duodenal fossa**. Its opening looks downwards, and will usually admit the tip of a finger (Fig. 913). The second fold is placed lower down. Its free border is directed upwards, as is the mouth of the **inferior duodenal fossa**, which lies behind it. This latter is larger and more constant than the superior duodenal fossa, and is present in 75 per cent of bodies, whilst the superior is present in 50 per cent (Jonnesco).

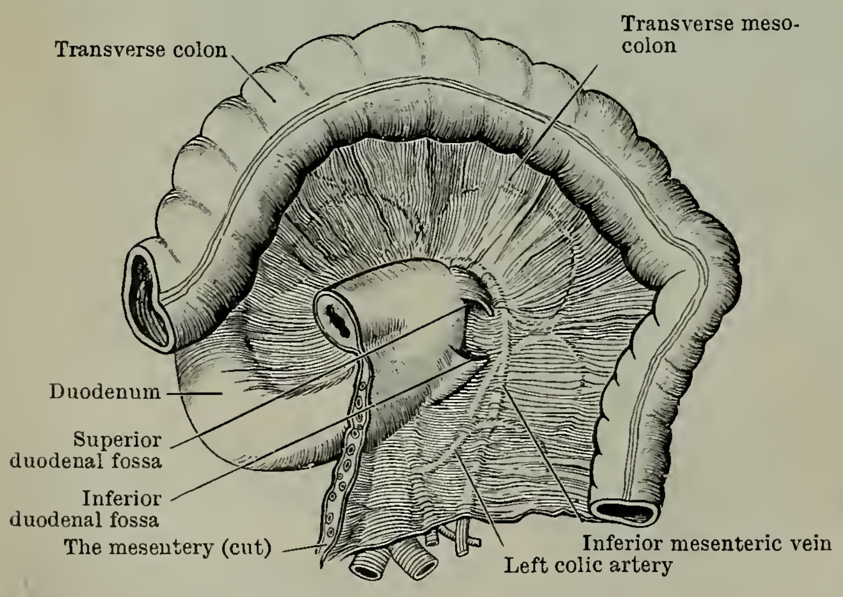


Fig. 913.—The Duodenal Fossæ and Folds.

The transverse colon and mesocolon have been thrown up, and the mesentery has been turned to the right and cut. The paraduodenal fossa (of Landzert) is situated to the medial side of the inferior mesenteric vein, between it and the terminal part of the duodenum. It is not shown in the illustration.

Paraduodenal Fossa (fossa of Landzert).—This fossa, which is seen best in the infant, is placed some distance to the left of the ascending part of the duodenum. It is produced by the inferior mesenteric vein raising up a fold of peritoneum, as it runs medially along the side of the fossa, and then above it (see Fig. 913, where the vein, but not the fossa, is shown). It is limited below by a special fold (the mesenterico-mesocolic fold). According to Moynihan, this is the only fossa to the left of the duodenum capable of developing into the sac of a hernia; and when this occurs, the inferior mesenteric vein always lies in the anterior margin of the orifice of the sac (accompanied for some distance by the ascending branch of the left colic artery).

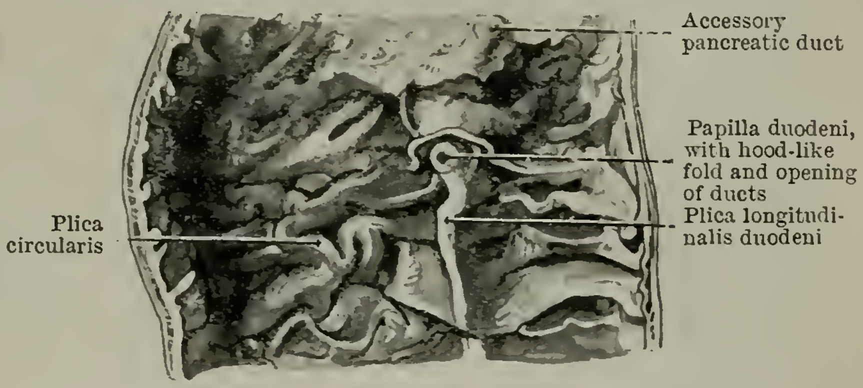

Accessory pancreatic duct
Papilla duodeni, with hood-like fold and opening of ducts
Plica longitudinalis duodeni
Plica circularis

FIG. 914.—INTERIOR OF A PORTION OF THE PARS DESCENDENS DUODENI (viewed from the front).

Peritoneal Relations of the Duodenum.—Whilst the relations of the peritoneum to the second and third portions of the duodenum are usually described as in the foregoing account, it should perhaps be pointed out, that it is not really the front, but the right half of the circumference of the descending portion which has a serous coat. Similarly, it is the inferior and anterior half of the circumference of the horizontal portion of the inferior part which is clothed by peritoneum, whilst considerably more than half of the circumference of its ascending portion is covered; for the peritoneum forms a fold running in behind this portion, in addition to covering its left side and half its anterior aspect.

Interior of Duodenum.—No plicæ circulares are found in the duodenum for an inch or two beyond the pylorus. They begin as low, scattered, and irregular folds; further down, they gradually become larger, more regular, and more numerous; and at the middle of the descending part they have attained a considerable development. In the inferior part of the duodenum the folds are large, prominent, and closely set.

On the postero-medial wall of the descending portion, about its middle—namely, $3\frac{1}{2}$ or 4 inches (8·7 to 10 cm.) beyond the pylorus—is seen a prominent papilla, on which the bile and pancreatic ducts open by a common orifice (Fig. 914) known as the **papilla duodeni** (Santorini).

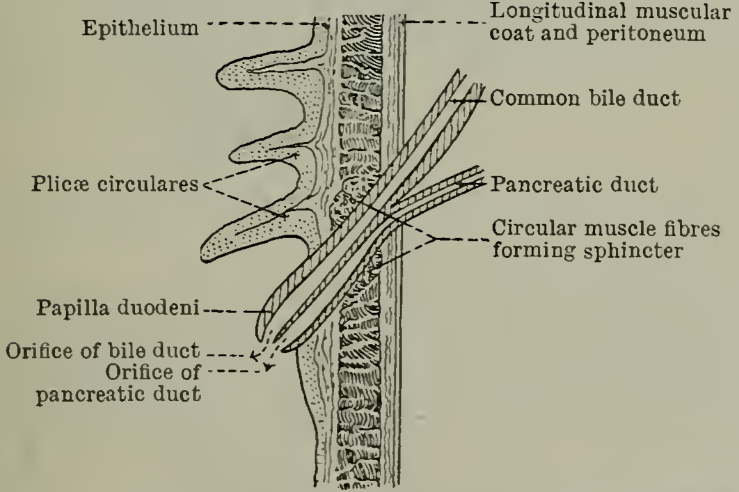

Epithelium
Longitudinal muscular coat and peritoneum
Common bile duct
Plicæ circulares
Pancreatic duct
Circular muscle fibres forming sphincter
Papilla duodeni
Orifice of bile duct
Orifice of pancreatic duct

FIG. 915.—DIAGRAMMATIC SECTION OF WALL OF DUODENUM THROUGH PAPILLA.

The papilla duodeni is placed beneath, and protected by, a prominent, hood-like plica circularis, which is situated immediately above it. From its lower margin a firm ridge of the mucous membrane, the *plica longitudinalis duodeni*, descends for a considerable distance, and acts as a frenum, which fixes the papilla and directs its apex somewhat downwards (Fig. 914). The papilla is prominent, and nipple or dome-shaped, and at its summit is placed the small orifice, which will usually admit the point of a pencil; the whole bears a close resemblance to the nozzle of a perfume-spray.

Nearly an inch higher up, and invariably on the ventral side of the papilla (sometimes as much as $\frac{1}{2}$ to $\frac{3}{4}$ inch distant), is seen a second and smaller papilla, the *caruncula minor* of Santorini, at the point of which is placed the very small orifice of the accessory pancreatic duct. This second papilla seems to be constantly present, although sometimes so small that it may easily escape detection unless carefully sought for. When well developed, it may have a hood-like plica circularis and a little frenulum, like those of the bile papilla.

Structure of the Duodenum.—The tunica serosa, which is incomplete, has already been described in detail, in connexion with each part of the duodenum.

The tunica muscularis is well developed, and is pierced by the bile and pancreatic ducts.

As the united bile and pancreatic ducts traverse the muscular walls, they are surrounded by some fibres from these coats which form a sphincter apparatus, and extend into the papilla.

The **tela submucosa** differs from that of the rest of the small intestine, in that it contains, especially in the superior half of the duodenum, the **glandulæ duodenales** [Brunneri]. These are small acino-tubular glands, closely resembling the pyloric glands of the stomach; they lie in the submucous coat, and send their ducts through the muscularis mucosæ to open on the surface between the glandulæ intestinales, or sometimes into these glands themselves (Fig. 905). To naked-eye examination they are small, round, or flattened masses of a reddish-gray colour, varying in size from $\frac{1}{50}$th to $\frac{1}{12}$th of an inch in diameter (·5 to 2·0 mm.). They form an almost continuous layer as far as the opening of the bile duct; beyond this they diminish progressively, and completely disappear near the duodeno-jejunal flexure.

The **tunica mucosa**, which is thicker in the duodenum than in any other part of the small intestine, is covered throughout with broad, short villi.

Various Forms of Duodenum.—Three different types of duodenum have been described—(1) The **annular**, in which the curves separating the various parts are open, and the two extremities come fairly close to one another. (2) The **U-shaped**, in which the horizontal part of the inferior part is very long, and the ascending part is nearly vertical; and (3) the **V-shaped** duodenum, in which the horizontal portion of the inferior part is very short or absent.

Vessels and Nerves.—The duodenum receives its blood from the superior and inferior pancreatico-duodenal arteries, branches of the gastro-duodenal and superior mesenteric arteries respectively. The blood is returned by the corresponding veins, the superior of which opens into the superior mesenteric, and the inferior into the beginning of the portal vein.

The **lymph** vessels of the duodenum follow for the most part the course of the blood-vessels.

From the anterior surface, lymph vessels pass along the course of the inferior pancreatico-duodenal artery, and communicate with lymph glands found along the course of that vessel. Thence they pass to the inferior cœliac glands, beside the origin of the superior mesenteric artery.

The vessels from the posterior aspect accompany the superior pancreatico-duodenal artery, communicate with the inferior gastric glands, and terminate in the cœliac glands.

The **nerves** come from the cœliac and superior mesenteric plexuses of the sympathetic.

Flexura Duodenojejunalis.—When the ascending part of the duodenum reaches the inferior surface of the pancreas, at a point opposite the left side of the first or second lumbar vertebra, it turns abruptly forwards, downwards, and to the left, and passes into the jejunum. This abrupt bend is known as the **duodeno-jejunal flexure.** Unlike the rest of the duodenum, which is subject to considerable variations in position in different individuals, the duodeno-jejunal flexure is fixed by a thin band of unstriped muscle, which is attached above to the strong connective tissue around the cœliac artery, as well as to the left crus of the diaphragm. This band passes posterior to the pancreas, and inferiorly it joins the muscular coat of the duodenum at the flexure. It is known as the **m. suspensorius duodeni.**

The duodeno-jejunal flexure is occasionally directed to the right, and it lies at a variable distance from the root of the transverse mesocolon. When the attachment of the transverse mesocolon is low, the duodeno-jejunal flexure is in contact with it.

Duodenal Pouches or Diverticula.—Occasional diverticula are found passing from the duodenal wall in different directions. Such diverticula may be hernial protrusions of the mucous and submucous coats through the muscular wall, termed false diverticula, or they may be "true" diverticula, in which all the coats are represented.

They are usually situated on the aspect of the duodenum which is in contact with the pancreas, and frequently in the neighbourhood of the orifice of the bile duct.

Some of these appear to be due to the pressure from the interior of the duodenum, while others, and the majority of the true diverticula, are rather congenital in origin, and are possibly associated with the diverticula which give rise to the liver and pancreas.

HEPAR.

The **liver** is the large glandular organ which secretes the fluid called bile (fel). It occupies the superior and mainly the right portion of the abdominal cavity, and lies immediately below the diaphragm.

Its secretion is conveyed by the hepatic ducts and the bile duct to the duodenum. With the bile duct there is connected a pear-shaped diverticulum, the gall-bladder (vesica fellea), which lies in contact with the liver, and which serves apparently for the temporary storage of bile. Bile is a clear, yellowish-green, or brown fluid, of bitter taste.

In addition to secreting bile, the liver plays an important part in the metabolism of both the carbohydrate and nitrogenous materials absorbed from the intestine which are conveyed to it by the portal vein, and it also has to do with the production and the destruction of some of the blood cells.

Physical Characters.—The liver is a large irregularly shaped mass, of a reddish-brown colour, soft and pliant to the touch, somewhat readily lacerated, and highly vascular.

It is of uniform consistence throughout, and little of its internal structure can be made out by naked-eye examination. If, however, a torn surface is examined, the liver tissue is seen to be somewhat granular. Under the investing peritoneum the surface is somewhat mottled.

This mottled or granular appearance is due to the lobules (**lobuli hepatis**) of which the liver is composed. Each lobule is a small irregular or polygonal area, measuring from $\frac{1}{25}$th to $\frac{1}{12}$th of an inch in diameter, or 1 to 2 mm., with a partial covering of fine connective tissue, forming a delicate stroma.

In the adult, the liver weighs from 3 to $3\frac{1}{4}$ pounds, or about $\frac{1}{50}$th of the body weight, and it is somewhat heavier in the male than in the female, its weight in the former being from 50 to 55 ounces and in the latter 43 to 48 ounces. The ratio to the body weight is the same in both sexes. In the fœtus and child it is relatively very large and heavy. At birth it occupies the greater part of the abdominal cavity, and constitutes from $\frac{1}{20}$th to $\frac{1}{18}$th of the body weight. In the young fœtus the ratio is even larger.

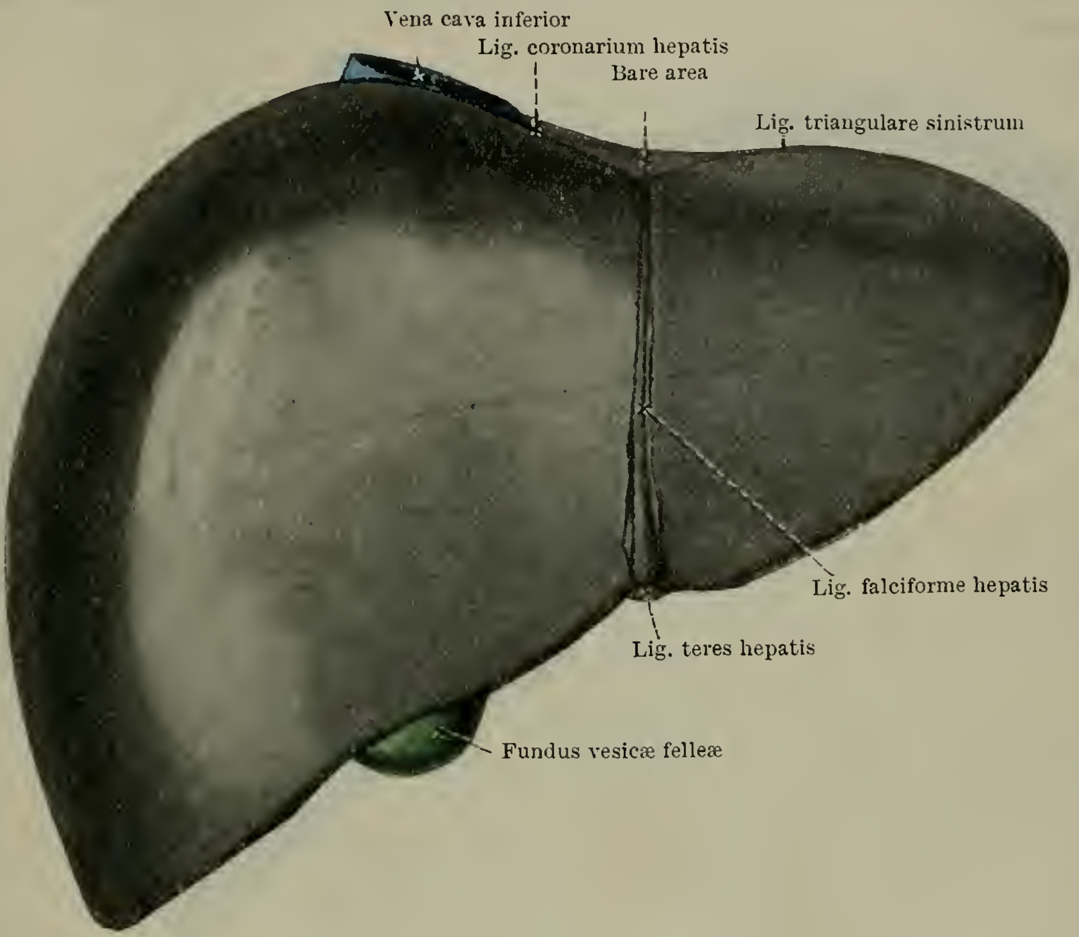


Fig. 916.—Liver viewed from the front.

The average size of the liver may be briefly expressed as follows: It measures in the transverse direction about seven inches (17·5 cm.); in the vertical, six to seven inches (15 to 17·5 cm.); and in the antero-posterior, on the right side where greatest, about six inches (15 cm.). Its greatest width, measured obliquely from side to side along the inferior or visceral surface, is ten inches (25 cm.).

The liver is capable of being greatly distended by fluid forced into its blood-vessels. Its surface then becomes tense, and the consistence of the whole organ becomes much firmer.

Shape.—If the liver is hardened *in situ* and then removed from the body, it will be found to present a form which is fairly constant, but which is modified by the shape and size of the adjacent viscera, and hence shows minor variations in different individuals.

If the liver has not been hardened, it does not retain, after removal, the shape and form which it had when it lay in the abdomen, but tends to collapse into a flattened cake-like mass. The description of the shape, surfaces, and borders given below is drawn from examination of specimens hardened *in situ.*

The liver possesses three principal surfaces, a superior, a posterior, and an inferior or visceral.

The **facies superior** is smooth and rounded, and in contact with the diaphragm and anterior abdominal wall.

The attachment of a sagittal fold of peritoneum, the falciform ligament, divides it into right and left portions, termed right and left lobes.

The superior surface may be further divided into three areas, a superior, an anterior, and a right, following the general direction of these portions of the surface, but they are not clearly marked off from one another by borders.

The **superior area** of the **superior surface** lies in contact with the roof of the abdomen; it is convex on each side, and depressed near the median plane. The two convexities, of which the right is the more prominent, fit into the two cupolæ of the diaphragm; whilst the central depression, *depressio cardiaca*, corresponds to the position of the heart.

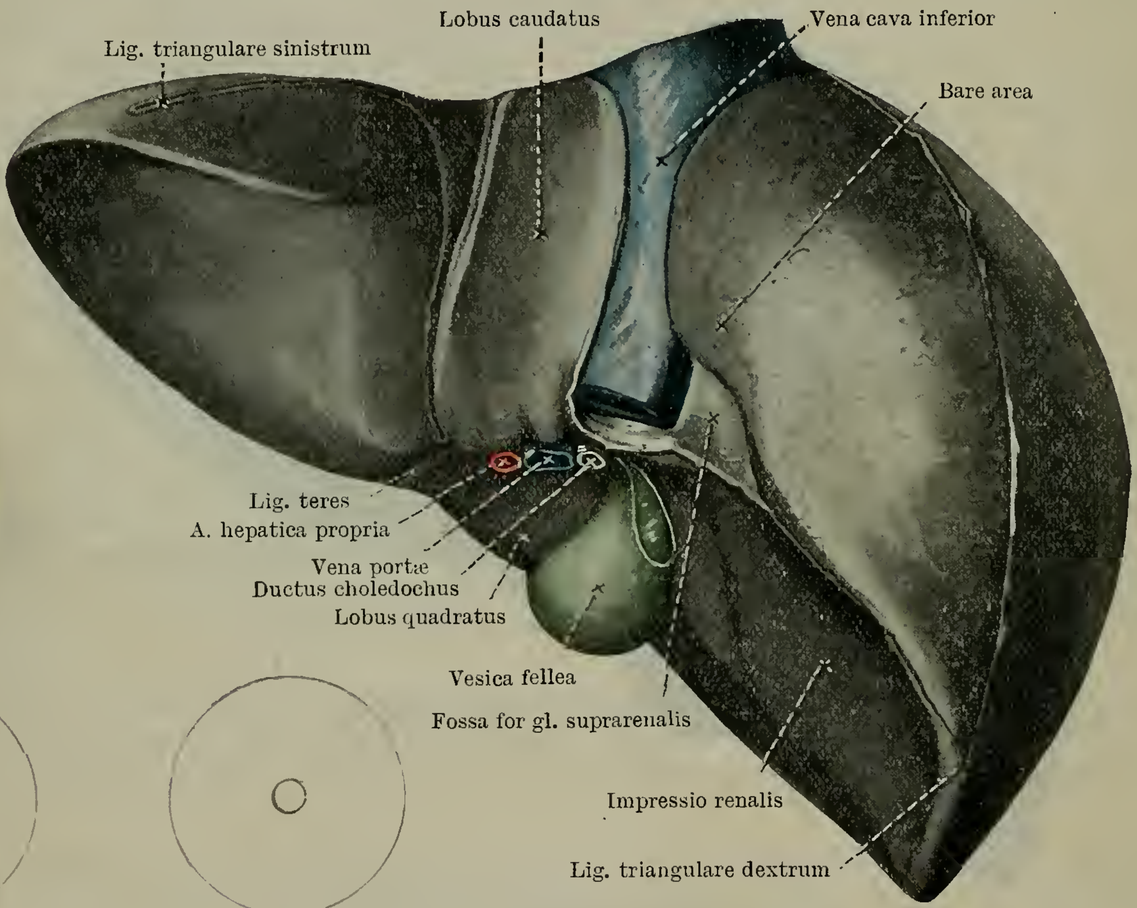


Fig. 917.—The Liver viewed from behind.

The **anterior area** of the **superior surface** is triangular in shape, and after death is usually flattened, owing to the falling in of the anterior abdominal wall. In part it lies in contact with the diaphragm, which separates it from the rib-cartilages on each side, but at the subcostal triangle it comes into direct relation with the anterior wall of the abdomen, for a distance usually of two or three inches below the xiphi-sternal articulation.

The anterior passes gradually into the upper and right areas, but it is distinctly separated from the visceral surface by the sharp anterior margin of the organ. The umbilical notch is often continued upwards for some distance on the surface as a slit-like fissure.

The **right area** of the **superior surface** is convex and extensive, and lies in contact with the diaphragm, which separates it from the inner surface of the lower ribs, and also, above, from the inferior margin of the lung and pleura. Though sharply marked off by an inferior margin from the visceral surface, it passes without distinct limits into the other areas of the parietal surface. It is completely covered by peritoneum.

The **facies inferior** (visceral surface) is directed obliquely downwards and posteriorly, is uneven and concave, and in contact with a number of the abdominal viscera, especially the right kidney, stomach, duodenum, and colon. Its general configuration is influenced to a marked degree by the shape and position of these organs.

The superior and inferior surfaces are marked off from one another in front by a sharp edge, the **margo anterior**, and behind by a wide area, the **posterior surface** (facies posterior). The anterior border is thin and sharp, and usually, but not invariably, presents one or two notches, one the **incisura umbilicalis**, the more constant of the two (Fig. 918), situated at the anterior end of the cleft on the inferior surface, known as the **fossa sagittalis sinistra** lodges at the upper part of the ligamentum teres hepatis. It is usually placed from one to two inches (2·5 to 5·0 cm.) to the right of the median plane. The second notch, less frequently present, contains the fundus of the gall-bladder, and is called the **incisura vesicæ felleæ**.

To the left extremity the margo anterior is continued along the margin of the left lobe, and ends at a groove on the posterior surface, termed the **impressio œsophagea**, in which lies the œsophagus.

The **facies posterior** (Fig. 917), directed backwards, is in contact with the structures of the superior portion of the posterior abdominal wall. It is deeply indented by the projecting vertebral column, and it is nearly flat in the vertical axis.

Fissures and Lobes.—In many animals the liver is divided by deep clefts into several partly or wholly detached masses, known as lobes.

In man such clefts do not as a rule extend deeply into the substance, but on the inferior and posterior surface are found several surface fissures, which partly divide these areas into lobes.

The chief of these are:—

(1) **Porta Hepatis.**—The **gate of the liver** (O.T. **portal** or **transverse fissure**) is the equivalent in the liver of the hilum of other glands. It is a slit-like depression, where the vessels enter the gland, and whence the ducts emerge.

It is placed on the inferior surface, runs transversely from side to side, and measures about 2 to 2½ inches in length. It is bounded anteriorly and posteriorly by prominent margins, and through it the hepatic artery, vena portæ, and hepatic plexus of nerves enter the liver, and the hepatic ducts and many of the lymph vessels leave. To the anterior and posterior margins of the fissure are attached the layers of peritoneum which constitute part of the lesser omentum.

The various structures found in the porta hepatis are arranged in the following way. The vena portæ lies posteriorly, and divides, in the fissure, into right and left branches, which run to right and left. The neck of the gall-bladder, with the cystic duct coming from it, lies at the right extremity of the fissure, and there the cystic duct bends downwards between the layers of the hepato-duodenal ligament.

The right and left bile ducts lie at their respective ends of the porta hepatis, converge towards each other at the right extremity, and lie anterior to the corresponding branches of the hepatic artery, and to the right side of the main vessel at their junction in the hepato-duodenal ligament. The nerves mainly invest the arteries, and the lymph vessels lie in the connective tissue which invests all these structures.

Two or three lymph glands are occasionally found in the porta hepatis, especially at the right end, near the neck of the gall-bladder, and when enlarged, they may press upon the ducts, and interfere with the passage of the bile.

The intervals between the vessels and other structures are filled in by loose connective tissue, which is continued inwards with the vessels as the fibrous capsule of Glisson.

When the porta hepatis is opened up, it is found to extend on the left as far as to the fossa venæ umbilicalis.

(2) **Fossa Venæ Umbilicalis** (O.T. **Umbilical Fissure**).—The fossa of the umbilical vein is a deep crevice-like fissure, of the inferior surface, directed sagittally, parallel to the gall-bladder, but about 1 to 1½ inches to its left side. It intersects the margo anterior, and passes thence backwards to the left extremity of the porta hepatis. Within this fissure lies a rounded cord-like structure, the

ligamentum teres hepatis, the remains of the left umbilical vein of the fœtus. The fissure is often crossed by a bridge of liver tissue, the *pons hepatis,* which may even extend for the whole length of the fissure, and so conceal the round ligament from view.

(3) **Fossa Ductus Venosi.**—At the dorsal end of the fossa venæ umbilicalis the ligamentum teres is attached to the left branch of the portal vein. Beyond that point it is continued backwards as a fine fibrous band, the **ligamentum venosum (Arantii)**, which joins the vena cava inferior. This fibrous cord is the remains of the ductus venosus, and lies in a groove on the posterior aspect of the liver, called the **fossa of the ductus venosus.**

The umbilical vein and the ductus venosus in the fœtus convey the blood back from the placenta to the inferior vena cava.

The umbilical fossa and the fossa of the ductus venosus together form a continuous fossa on the inferior and posterior surfaces which divides them into a right and left lobe. This fossa is known as the **fossa sagittalis sinistra**, in contrast to the porta hepatis, and to the **fossa sagittalis dextra**, lying to the right, which is made up of the following two fossæ:

(4) **Fossa Vesicæ Felleæ.**—The **fossa of the gall-bladder** is a slight depression which begins (often as a notch) at or near the margo anterior of the liver, and passes backwards and to the left, as far as the porta hepatis (Fig. 918). In it lies the gall-bladder, united to it by areolar tissue.

(5) **Fossa Venæ Cavæ.**—The **fossa of the vena cava** is a deep groove, on the posterior surface, on the right side of the caudate lobe, in which the superior part of the vena cava inferior is embedded, immediately before it pierces the diaphragm.

The depressions for the gall-bladder and the vena cava are rightly called fossæ. In hardened specimens it will be seen that the fossa for the umbilical vein, the porta hepatis, and the fossa for the ductus venosus are really fissures.

Taken together, the four fossæ and the porta hepatis are arranged somewhat in the form of the letter A (Fig. 918); the two lower divisions of the diverging limbs being formed by the fossa venæ umbilicalis and the fossa vesicæ felleæ respectively, and the cross-piece by the porta hepatis—all of which are placed on the inferior surface. The two upper divisions of the limbs are represented by the fossae of the ductus venosus and of the vena cava, which meet above and are both placed on the posterior surface. The fossa of the vena cava, represented by the right upper division of the A, does not join the cross-piece (the porta hepatis), but is separated from it below by a narrow ridge of liver substance—the **processus caudatus** (Fig. 918).

To the right of the A is the **lobus hepatis dexter**, to its left the **lobus hepatis sinister.**

The interior of the A is filled by the **lobus quadratus** anteriorly and the **lobus caudatus [Spigeli]** posteriorly, both of which are described as parts of the right lobe, while the processus caudatus cuts across the stem of the A behind the cross-piece, and connects the lobus caudatus (Spigeli) to the lobus hepatis dexter.

Lobi Hepatis (Lobes of the Liver).—As has been pointed out, the attachment of the ligamentum falciforme to the superior surface of the liver divides that aspect of the organ into right and left lobes. Similarly, upon the inferior surface, the fossa sagittalis sinistra is taken as dividing this aspect into right and left lobes.

Lobus Hepatis Sinister.—The **left lobe** is much smaller and flatter than the right, and forms only about one-fifth of the whole mass.

The inferior surface of the *left lobe* is directed downwards and posteriorly, and is in contact with the superior surface of the stomach; and with the lesser curvature with its attached lesser omentum. The part which rests upon the anterior surface of the stomach is rendered concave by the pressure of that organ (Fig. 918), and is known as the **impressio gastrica**; whilst the portion to the right of this, being free from the pressure of the stomach, projects backwards over the lesser curvature against the lesser omentum in the form of a smooth rounded prominence, known as the **tuber omentale.**

Lobus Hepatis Dexter.—The inferior and posterior surfaces of the **right lobe** are intersected by the porta hepatis and the right sagittal fossa, and by them it is subdivided into other parts, which also are called lobes. These are the **lobus caudatus [Spigeli]** with the **processus caudatus**, the **lobus quadratus**, and the right lobe proper.

(1) **The Lobus Quadratus.**—This is a quadrilateral area extending from the margo anterior in front to the porta hepatis behind. On the right, it extends as far as the fossa for the gall-bladder, and on the left to the fossa for the umbilical vein. The surface is flattened or concave, and is mainly in contact with the pyloric part of the stomach and the duodenum.

The **quadrate lobe** is of an oblong shape, the antero-posterior diameter being the greatest. Its surface is generally concave, and is related to the pylorus and the adjacent parts of the stomach and duodenum, when the former is distended. When the stomach is empty, however, the pylorus usually lies beneath the right portion of the left lobe, and the superior part of the duodenum lies beneath the quadrate lobe, the transverse colon also coming in contact with it anteriorly (Fig. 899).

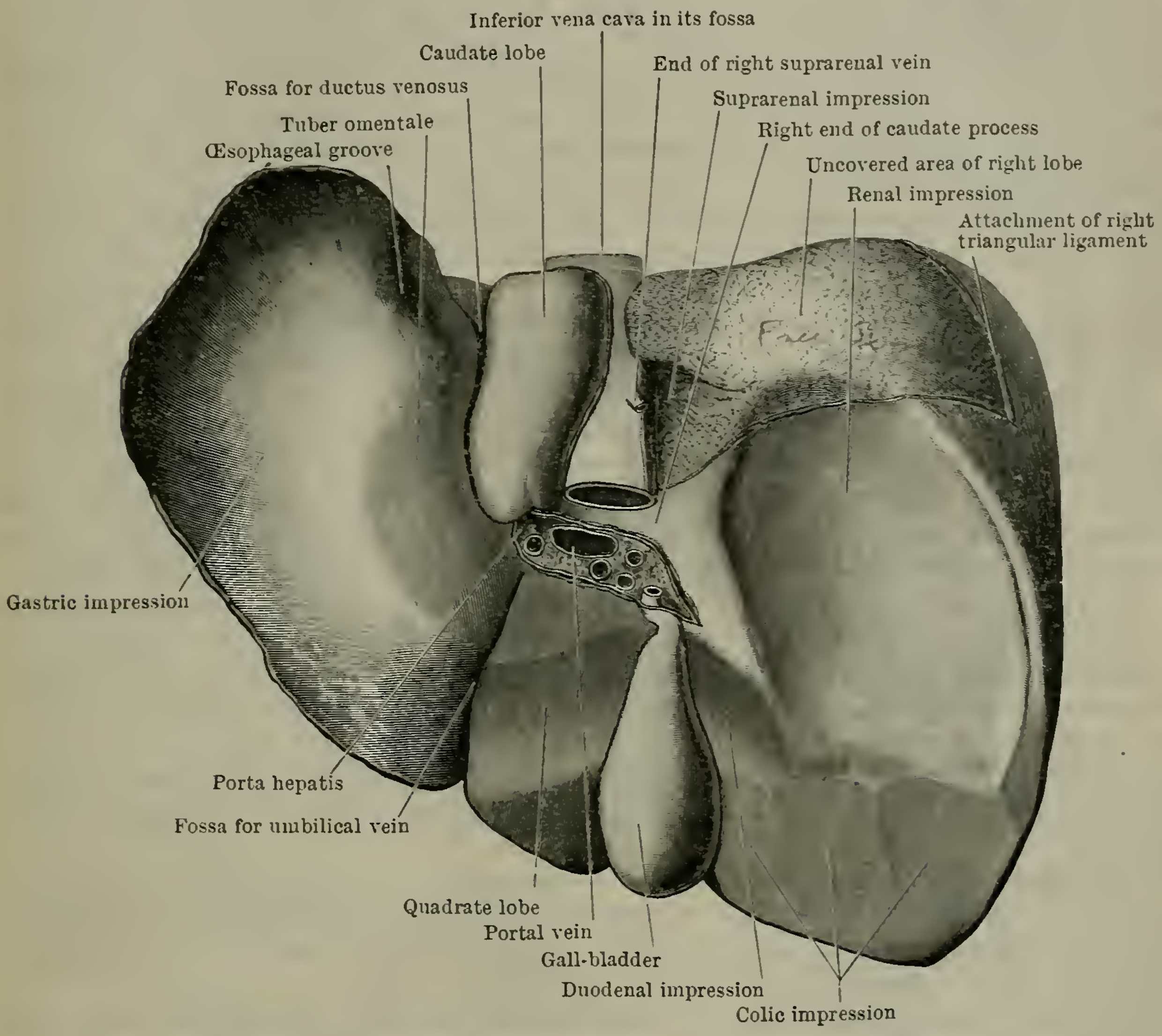


FIG. 918.—INFERIOR AND POSTERIOR SURFACES OF THE LIVER.

(2) **The Lobus Caudatus [Spigeli].**—This is a prominent rather quadrilateral area on the posterior surface, between the fossa for the inferior vena cava on its right, and the fossa for the ductus venosus on its left side.

Its superior limit is formed by the terminal part of the ductus venosus, as it bends to the right to join the vena cava inferior, while, inferiorly, it is free and forms the posterior boundary of the porta hepatis.

This extremity is often grooved by a notch (in which the cœliac artery lies, particularly in the fœtus), which marks off a larger and more prominent left part, the **processus papillaris**, projecting downwards behind the porta hepatis, and a smaller right part, the **processus caudatus**, which connects it (Fig. 918) with the inferior surface of the right lobe.

The posterior surface of the caudate lobe is free; it is placed vertically, and looks backwards and slightly to the left. The lobe has also another surface, which is hidden when in the body and in the hardened liver by the folding of the left lobe across it. By this folding there is formed the deep fossa for the ductus venosus.

(3) The **processus caudatus** (O.T. **caudate lobe**) is merely a narrow bridge of liver tissue which connects the caudate lobe with the right lobe proper. It is limited anteriorly by the porta hepatis, and posteriorly by the fossa for the inferior vena cava. It forms the superior boundary for the epiploic foramen, and so a finger placed in the foramen rests against the caudate process, and has a vein in front and behind, separated by a layer of peritoneum.

(4) **The right lobe proper**, lying to the right of the gall-bladder, is entirely occupied by three impressions, produced by the underlying viscera—namely: (1) The **impressio colica** lies in front. It is formed by the right flexure of the colon and the beginning of the transverse colon. (2) Behind this is the **impressio renalis**, larger than the preceding, which is produced by the superior half or two-thirds of the right kidney. The superior end of the renal impression is frequently devoid of peritoneum (Fig. 918), that is to say, the "uncovered area" of the right lobe extends down over the impression for a little way. This impression is very deep, and accommodates nearly the whole thickness of the kidney. (3) To the medial side of the renal impression, and near the neck of the gall-bladder, is placed the narrow **impressio duodenalis**, which lies in contact with the descending part of the duodenum down to the point at which it is crossed by the colon.

Facies Posterior (Posterior Surface).—This surface is directed backwards, and lies largely in contact with the diaphragm, which here forms the posterior abdominal wall. It is very irregular in shape, and presents the following parts: (1) The "uncovered area" of the right lobe; (2) the supra-renal impression; (3) the fossa for the vena cava; (4) the caudate lobe, separated by the fossa for the ductus venosus from (5) the œsophageal groove, which belongs to the left lobe.

(1) The "**uncovered area**" of the right lobe (Fig. 917) is a considerable portion of the posterior surface of the right lobe—varying from 1½ to 3 inches (3·7 to 7·5 cm.) in width, and from 3 to 5 inches (7·5 to 12·5 cm.) in transverse measurement—which is devoid of peritoneum. Over this uncovered portion, which looks more medially than backwards, the liver and diaphragm are in direct contact, and are united by areolar tissue; here too is established a communication by small veins between the portal circulation of the liver and the systemic circulation of the diaphragm.

(2) **Impressio Suprarenalis.**—On the "uncovered area," immediately to the right of the vena cava, is a triangular impression (Fig. 917), produced by a portion of the right suprarenal gland, which projects upwards from the superior extremity of the right kidney, between the diaphragm and liver.

(3) **Fossa Venæ Cavæ.**—At the left extremity of the "uncovered area" the inferior vena cava lies vertically, embedded in a fossa of the liver substance, between the caudate lobe on the left and the adjacent part of the uncovered area on the right, both of which project over the sides of the vein, almost hiding it from view (Fig. 918); sometimes they actually meet and form a **pons hepatis** across the back of the vein.

(4) **Lobus Caudatus [Spigeli].**—This has already been described—*see above.* The superior recess of the omental bursa separates the posterior surface of the caudate lobe from the diaphragm, which latter, in turn, separates it from the thoracic part of the descending aorta just before that vessel enters the abdomen.

(5) The **Impressio Œsophagea**, or œsophageal groove, is situated on the posterior surface of the left lobe, to the left of the superior end of the caudate lobe, but is separated from it by the fossa for the ductus venosus. The groove leads down into the gastric impression on the inferior surface of the left lobe (Fig. 918).

Surface Markings of the Liver.—The limits even of the normal liver are very variable, but, taking the average condition in the male, they may be marked out on the anterior surface of the body by the following method: Three points are determined—(*a*) half an inch (12·5 mm.) below the right nipple; (*b*) half an inch

(12·5 mm.) below the right margin of the thorax (or below the tip of the tenth rib); and (*c*) one inch (25 mm.) below the left nipple. If these points are joined by three lines, slightly concave towards the liver, they will give the outline of the organ with sufficient accuracy for all ordinary purposes.

To state the matter somewhat more in detail: If the two "nipple points" (*a*) and (*c*) be joined by a line, slightly convex upwards on each side, but a little depressed at the centre corresponding to the position of the heart, and crossing the inferior end of the sternum about the level of the seventh cartilage, it will mark the superior limit. A line, convex upwards, from the right nipple point (*a*) to the subcostal point (*b*) will indicate the right limit, while the inferior limit is marked by a line, convex downwards, drawn from the subcostal point (*b*) to the left nipple point (*c*), and passing through a point half-way between the umbilicus and the inferior end of the body of the sternum, in the median line.

The line indicating the superior limit of the liver is elevated on each side, corresponding to the cupolæ of the diaphragm, and depressed in the centre beneath the heart. On the right side where highest, namely, about one inch (25 mm.), medial to the mammary line, it reaches during expiration to the superior border of the fifth rib; on the left side it is one-half to three-quarters of an inch (12 to 18 mm.) lower; and it crosses behind the sternum at the level of the sixth sterno-costal junction—or sometimes lower. It must be remembered, however, that whilst the liver reaches up to the levels just given, it does so only at the highest part of its convex parietal surface, and is separated from the ribs all round by the thin lower margin of the lung (which extends down between the chest wall and diaphragm to the sixth rib in front, to the eighth in the mid-lateral line, and to the level of the tip of the spine of the tenth thoracic vertebra behind), so that, in percussing over the liver, its dulness is obscured by the resonance of the lungs above these points.

From the back, the superior margin of the liver rises as high as to the *superior* margin of the eighth rib or to the inferior margin of the scapula on the right side. On the left, it rises to the *inferior* margin of the eighth rib, and terminates about an inch medial to the inferior angle of the scapula.

The inferior margin slopes upwards along the eleventh rib of the right side, along a line leading to the superior part of the tenth thoracic vertebra. On the right side the liver extends vertically in the mid-axillary line from the sixth to the eleventh ribs.

Variations in Size, Form, and Position.—Few organs will be found to vary more in size in different bodies than the liver; these variations, however, are very frequently to be looked upon as pathological. But even the normal, healthy liver may vary in weight from 48 to 58 ounces in the adult male, and from 40 to 50 ounces in the female.

Variations in form and position doubtlessly take place physiologically, as a result of the conditions of fulness or emptiness of the adjacent viscera; for, though the liver, like the other solid abdominal organs, has an intrinsic shape of its own, this is capable of modification within certain limits by the varying pressure of the surrounding parts. Thus, distension of the stomach, or of a portion of the transverse colon lying in the stomach chamber, may push the liver over to the right, so that it may hardly reach the median plane, and at the same time it increases its vertical depth. On the other hand, a distended state of the small intestines, with a contracted stomach and colon, may have the opposite effect, flattening it from below upwards and enlarging it in the transverse direction.

Variations in form and position *due to malformations* of the thoracic framework, either congenital or acquired, were very common, particularly in females as a result of tight-lacing, which presses the lower ribs inwards. Sometimes in these cases the constriction of the waist lies chiefly below the liver. The organ is then forced up against the diaphragm, filling its whole vault, and extending across to the left abdominal wall, where its left margin may lie in the interval between the diaphragm and the spleen. But more commonly it would seem that the liver is caught by the constriction: its upper part is then closely pressed into the vault of the diaphragm, which, owing to the narrowing of the thorax, is unable to accommodate the whole organ, so that its inferior part is crushed down for a considerable distance into the umbilical zone of the abdomen (Fig. 896, p. 1161), particularly on the right side. Often, too, a wide, tongue-like process (the so-called "Reidel's lobe") descends from the inferior margin, lateral to the gall-bladder. This process, which when very large may reach to the iliac crest, is sometimes found in men, although more common in women, and is liable to be mistaken for a tumour. A somewhat similar process occasionally descends from the left lobe.

Again, in apparently healthy bodies the liver may extend up on the right side almost to the fourth rib; whilst in other cases it may be as low as the sixth rib, or even lower. Nor is it rare—particularly in females—to find the anterior border projecting two or three inches (5·0 to 7·5 cm.) below the margin of the thorax on the right side (Fig. 896, p. 1161).

Reference should be made here to certain grooves often seen on the liver. Some of these are found running obliquely low down at the right side where the liver is in contact with the ribs; they are particularly common in females, and are due to the pressure of the ribs resulting from tight-lacing. Grooves of a different kind are found at the superior part of the parietal surface; where the liver is in contact with the diaphragm; these usually run radially, that is, in the direction of the muscular fibres of the diaphragm, and are apparently produced by a wrinkling, or irregular contraction, of the diaphragm. At least, ridges of the diaphragm are found lying in the grooves, and these ridges or wrinkles would seem to be responsible for the production of the grooves.

Finally, the liver may present certain **congenital irregularities** in the direction of additional fossæ and lobes, which reproduce the conditions found in the higher apes, and are very commonly present in the fœtus (Thomson). Or the liver may be divided up into a large number of distinct lobes, as in most other animals.

Changes in position have been already referred to in connexion with variations in form; there need only be added here that the liver ascends and descends at every expiration and inspiration respectively, and that it also descends, but very slightly, in changing from the reclining to the erect posture. Occasionally, without any evident cause, the liver and diaphragm are found to occupy a higher or lower position than usual.

Fixation of the Liver.—At first sight it is not easy to understand the means by which the liver maintains its position in the abdomen (and the same remark applies, perhaps, to other solid abdominal organs). The falciform ligament gives it no support, as it is quite lax when in the body. Nor can it be said that its vessels, except perhaps the hepatic veins, assist. However, on considering the conditions under which the viscera are placed in the abdominal cavity the problem becomes less difficult.

The abdomen is a closed cavity, with a firm framework to its superior part, a tightly stretched diaphragm for its roof, and muscular walls all round. Into the concavity of this roof the parietal surface of the liver is fitted with perfect accuracy, so that the two are in absolute contact, and cannot be separated without producing a vacuum, unless some other structure is in a position to fill the space. But there is hardly any other viscus movable enough to pass up over the front of the liver into the vault of the diaphragm, so that atmospheric pressure alone is probably sufficient to retain the organ *in situ*, as in the case of the shoulder joint. In addition, the abdominal muscles are always in a condition of tonic contraction or "tone," which gives rise to an intra-abdominal pressure. This is effective in all directions, and consequently there is a considerable pressure on all the abdominal walls. The liver, being in absolute contact with the roof, may be considered a part of this wall, and it is consequently affected by this pressure which helps to sustain it. Add to this, the support which the organ receives from the intestines, the stomach, and the pancreas; from the coronary and triangular ligaments; from the connexion of the back of the right lobe by areolar tissue to the diaphragm; and, finally, from the inferior vena cava embedded in the liver and sending its hepatic veins forwards to all parts of the organ, just before the vein itself is firmly attached to the margins of the caval orifice in the central tendon of the diaphragm, and we will probably find sufficient cause for the maintenance of the organ in its position in the abdominal cavity.

Relation to Peritoneum.—The relation of the liver to the peritoneum is somewhat complex in its details. The greater part of the liver is covered with peritoneum, forming the tunica serosa, but over an area of some size upon its superior and posterior aspects it is directly in contact with the diaphragm, and round the margins of this area the peritoneum passes from liver to diaphragm. This is known as the bare area, and the peritoneum around this area forms the **ligamentum coronarium (coronary ligament).** Further, the liver is attached to the anterior portion of the diaphragm, and to the abdominal wall as low as to the umbilicus by a fold of peritoneum which is known as the **ligamentum falciforme.** This fold runs forwards from and is continuous with the folds of peritoneum which limit the bare area, and the whole forms a sort of mesentery or meso-hepaticum.

The peritoneum is also reflected off from the margins of the porta hepatis and from the fossa for the ductus venosus, and passes thence to the lesser curvature of the stomach and the first part of the duodenum, forming the omentum minus. The liver may, in fact, be regarded as lying inside a peritoneal fold which stretches from the lesser curvature of the stomach below to the diaphragm and anterior abdominal wall above. This fold is embryologically the ventral mesentery of the stomach, or ventral meso-gastrium, and its original simple character has become complicated by the growth of the liver within it and by the rotation which the stomach undergoes to the right side.

The various ligaments of the liver are as follows:—

(1) **Ligamentum Falciforme Hepatis.**—The **falciform ligament of the liver** is a crescentic fold of peritoneum, which is attached by its convex border to the inferior surface of the diaphragm, and to the anterior abdominal wall (an inch or more to the right of the median plane) to within a short distance (1 to 2 inches, 2·5 to 5 cm.) of the umbilicus. Its opposite border is attached to the superior and anterior aspects of the liver; below this level it presents a free rounded edge, stretching from near the umbilicus to the umbilical notch of the liver, and it contains within its layers a stout fibrous cord called the round ligament.

Near the posterior part of the superior surface of the liver the two layers of which the falciform ligament is composed separate, and enclose a triangular area on the posterior surface, in front of the superior end of the vena cava, uncovered by peritoneum. Traced backwards, the right layer passes into the superior layer of the coronary ligament, the left into that of the left triangular ligament (Fig. 916).

(2) **Ligamentum Coronarium Hepatis.**—The **coronary ligament** consists of the layers of peritoneum which are reflected from the liver to the diaphragm at the margins of the uncovered area of the right lobe. The name of **right triangular ligament** has been given to its pointed right extremity (Fig. 919).

The coronary ligament consists of a superior and an inferior layer. The superior is formed by the prolongation to the right of the right layer of the falciform ligament. The inferior layer is formed by the continuation of the inferior layer of the right triangular ligament to the left side, and by the reflexion from the margin of the caudate lobe by the side of the inferior vena cava (see Fig. 919).

(3) **Ligamentum Triangulare Dextrum.**—The **right triangular ligament** (O.T. **right lateral ligament**) is merely the pointed right extremity of the coronary ligament, where the superior and inferior layers become continuous with one another.

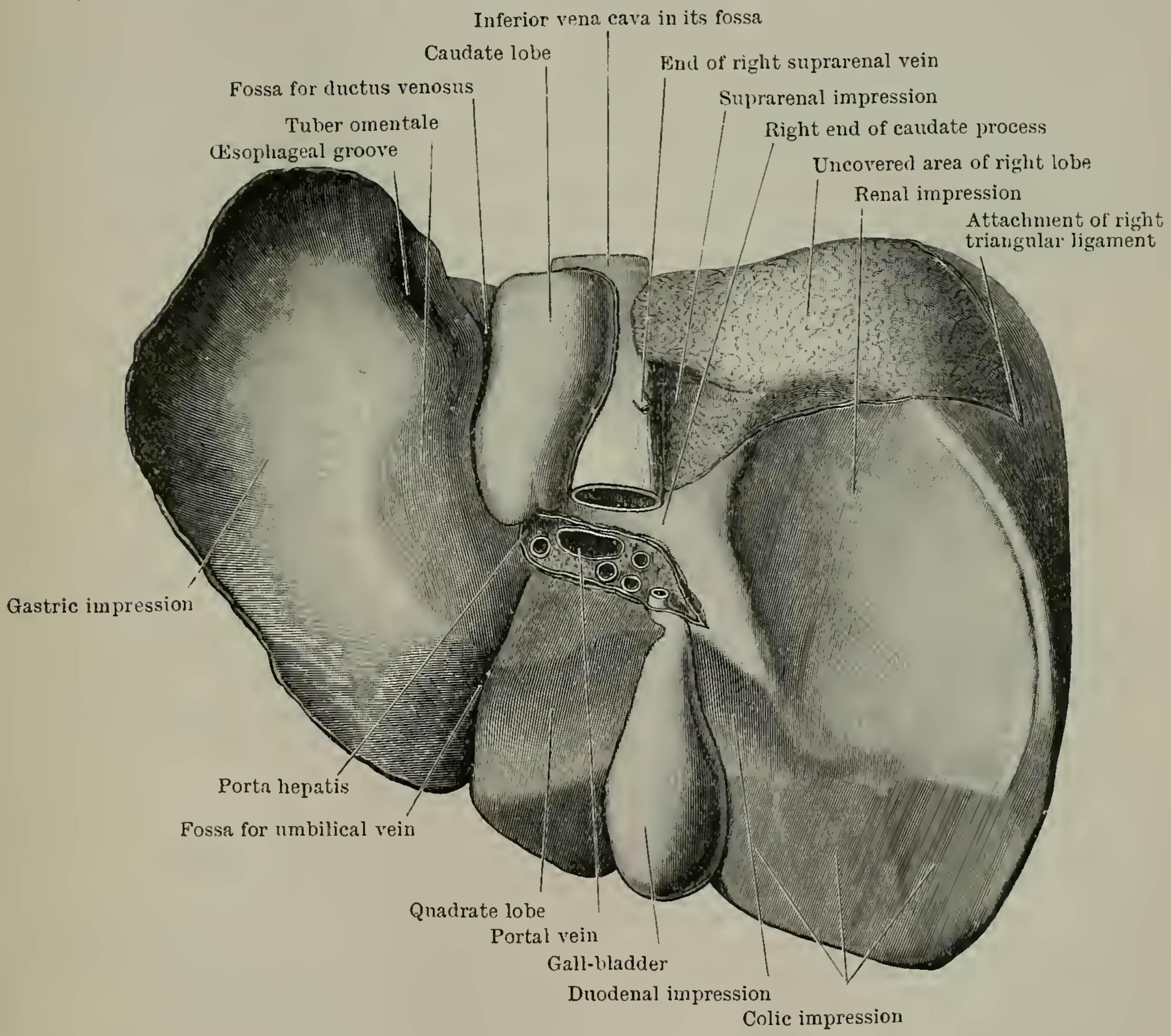


Fig. 919.—Inferior and Posterior Surface of the Liver.

(4) **Ligamentum Triangulare Sinistrum.**—The **left triangular ligament** (O.T. **left lateral ligament**) is a considerable triangular fold, continuous with the left layer of the falciform ligament, which is attached by one border to the superior surface of the left lobe near its posterior border, and by the other to the diaphragm, for a distance of several inches as a rule.

Its attachment to the diaphragm lies nearly altogether to the left of the œsophageal orifice, and about ¾ inch (18 mm.) anterior to the plane of this opening.

Two other structures, termed ligaments, are not peritoneal folds, but obliterated blood-vessels, namely the ligamentum teres hepatis or round ligament and the ligamentum venosum (Arantii).

(5) **Ligamentum Teres Hepatis.**—The **round ligament of the liver** is a stout fibrous band which passes from the umbilicus, backwards and upwards, within the free margin of the falciform ligament, to the umbilical notch of the liver, and thence upwards and

backwards in the umbilical fossa, to join the left branch of the portal vein. It is the remains of the left umbilical vein, which, before birth, carries the arterial blood from the placenta to the body of the fœtus (Fig. 916).

(6) **Ligamentum Venosum [Arantii].**—The **venous ligament** (O.T. **obliterated ductus venosus**) is a slender fibrous cord, which passes from the left branch of the portal vein, nearly opposite the attachment of the round ligament, upwards in the fossa bearing its name, to be connected with the inferior vena cava as it leaves the liver. In the fœtus this structure is a considerable vessel, which conveys some of the blood brought to the porta hepatis by the left umbilical vein directly backwards to the vena cava. At the time of birth the ductus venosus and umbilical vein cease to carry blood, their cavities become obliterated, and they are converted into fibrous cords.

(7) **Omentum Minus.**—The **lesser omentum** is a fold of peritoneum which extends from the liver to the lesser curvature of the stomach and to the duodenum (see p. 1155).

The "bare area" of the liver is triangular in shape, and measures about 3 inches in its greatest vertical extent, and some 5 inches transversely. It is in contact with the diaphragm, a portion of the right suprarenal gland, and the inferior vena cava. It is bounded above and below by the superior and inferior folds of the coronary ligament, and on the left by the attachment of peritoneum to the margin of the caudate lobe. It is prolonged upwards for a short distance on the superior surface of the liver, in front of the inferior vena cava, between the layers of the falciform ligament as they diverge from one another.

STRUCTURE OF THE LIVER.

The liver is invested by an outer **tunica serosa** described in connexion with the peritoneum. Within this is a thin **capsula fibrosa [Glissoni]** of delicate fibrous tissue, which is most evident where the serous coat is absent. In the neighbourhood of the porta hepatis it is particularly abundant, and here it surrounds the vessels entering the porta, and accompanies them through the portal canals in the liver substance. This coat is continuous with the fine areolar tissue which pervades the liver, surrounding its lobules and holding them together.

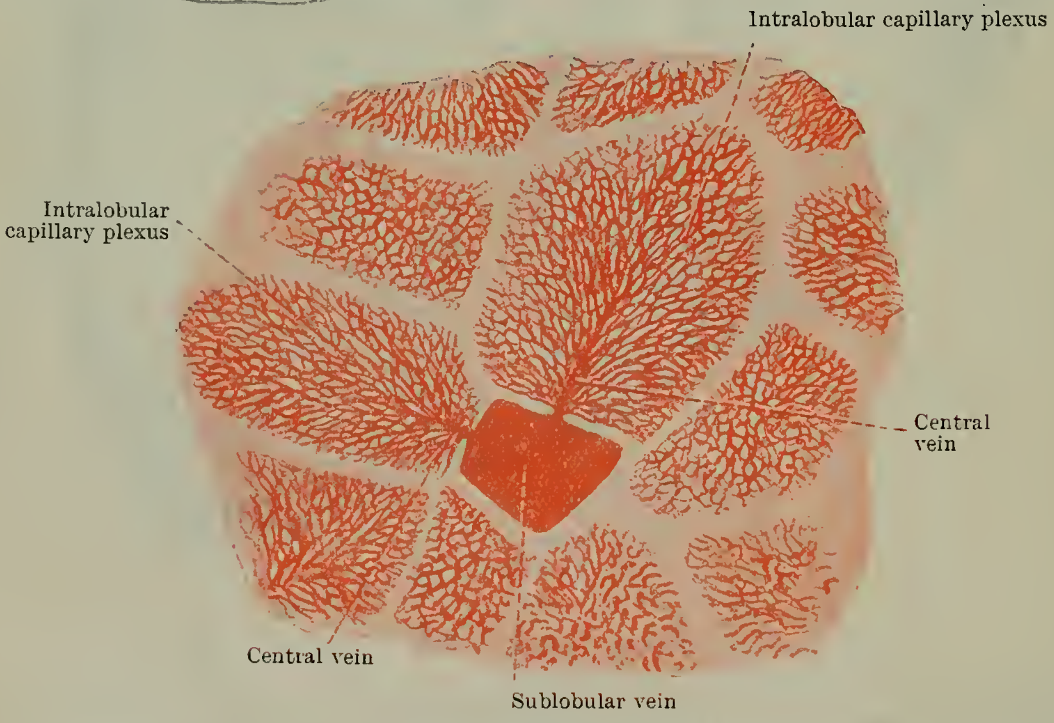


FIG. 920.—LIVER OF A PIG INJECTED FROM THE HEPATIC VEIN BY T. A. CARTER. (From a specimen presented to the Anatomical Department of Edinburgh University by Sir William Turner.)

The liver substance proper is made up of an enormous number of small **lobules** $\frac{1}{25}$th to $\frac{1}{12}$th inch (1 to 2 mm.) in diameter, closely packed, and held together by a small amount of connective tissue. In man the lobules are not completely separated from one another all round their circumference, but coalesce in places; the reverse is the case in certain animals such as the camel and the pig. Each lobule is composed of a large number of columns of liver cells, radiating from the centre to the periphery.

Between the columns—which interlace freely—is a sinusoidal vascular network through which blood passes from marginal veins—interlobular—to a central vein.

The endothelial wall of this network is incomplete, so that the liver cells are in many places in contact with the blood, and in other parts the endothelial cells are modified into stellate cells which are believed to have a special phagocytic property ("star cells" of Kupfer). The columns may be regarded as being composed of two layers of cells, between which is a minute channel, the intralobular duct, passing from the centre to the periphery of the lobule.

Vessels of the Liver.—Blood is conveyed to the liver by the hepatic artery and the portal vein, which enter the liver at the porta hepatis, and break up into branches and finally into capillaries. The blood which has so entered is conveyed from the liver by the hepatic veins to the vena cava inferior.

The circulation within the liver is, therefore arranged differently from that of other glands, and in order to understand properly the structure of the liver, it is necessary to give some account of the relations which it presents to the blood-vessels which pass to and from it.

The **vena portæ** and the **arteria hepatica propria** pass up to the liver between the two layers of the hepato-duodenal ligament, anterior to the foramen epiploicum. Here they are accompanied by the bile-duct, which lies to the right, whilst the artery is placed to the left, and the portal vein posterior to both. In this order they enter the porta hepatis, and there become rearranged, so that the vein lies behind, the artery in the middle, and the duct in front. Each breaks up into two chief branches—a right and a left—and several smaller ones, which enter the liver substance, surrounded by a prolongation of the connective tissue coat of the liver (O.T. Glisson's capsule). Within the organ the three vessels run and divide together, so that every branch of the portal vein is accompanied by a corresponding (but much smaller) branch of the hepatic artery and of the hepatic duct; and the three, surrounded by a prolongation of the fibrous capsule, and accompanied by branches of the hepatic nerves and lymph vessels, run in special tunnels of the liver substance, which are known as **portal canals** (Fig. 921, B).

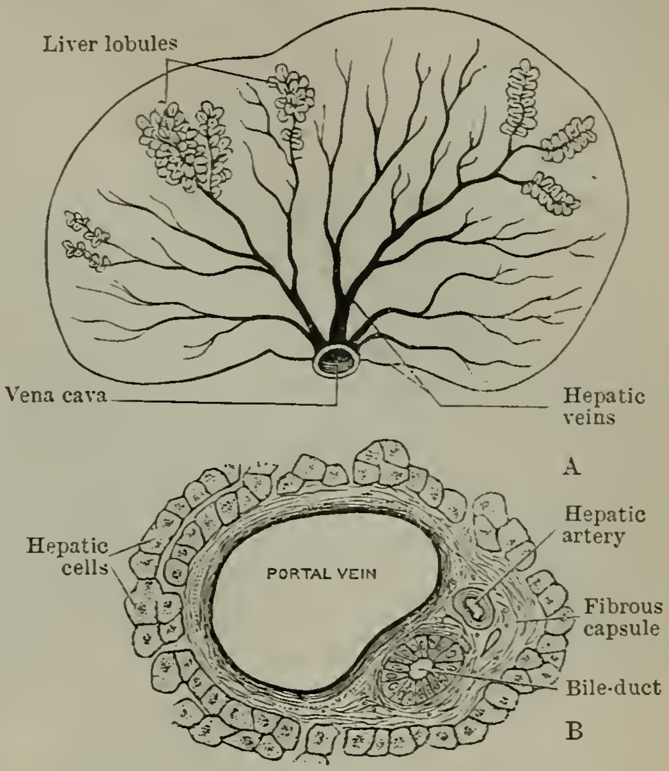


FIG. 921.—DIAGRAMS ILLUSTRATING THE STRUCTURE OF THE LIVER.

A, Arrangement of liver lobules around the sublobular branches of the hepatic vein; B, Section of a portal canal, showing its contained branches of the portal vein, hepatic artery, and bile-duct, surrounded by a prolongation of Glisson's fibrous capsule.

The hepatic artery has but a small part to play in the hepatic circulation within the liver and it supplies minute branches, known as the vaginal and capsular branches, to the fibrous tissue of the portal canals and of the surface of the liver. The terminal branches of the artery end in the capillaries from the portal vein which go to the liver lobules.

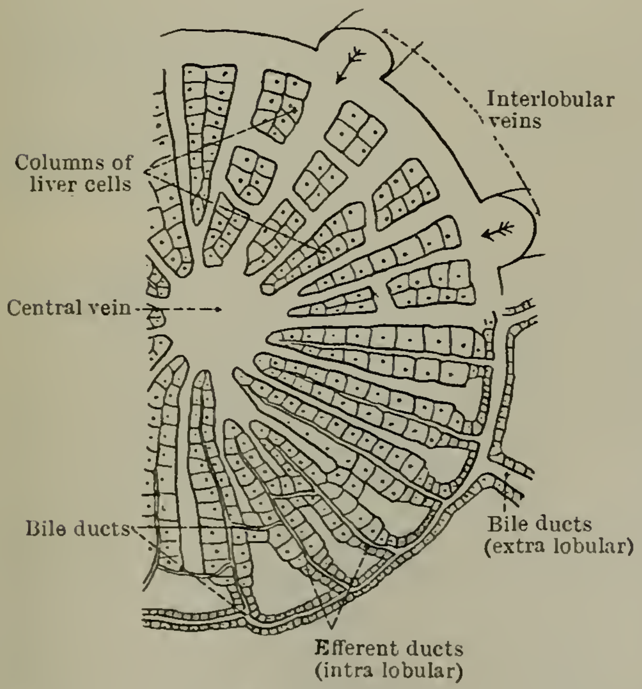


FIG. 922.—DIAGRAM TO ILLUSTRATE THE STRUCTURE OF A LIVER LOBULE.

The portal vein within the liver divides, like an artery, into numerous branches, which eventually form an elaborate meshwork, whose vessels anastomose freely with one another, around the periphery of the liver lobules, and are known as *interlobular vessels.* From this meshwork small capillary-like channels pass into the interior of each lobule between columns of liver cells, towards a channel in the centre of the lobule, called the *central vein.* From the central veins the blood is carried into larger channels or *sublobular veins*, which pass to the hepatic veins.

The hepatic veins gradually unite with one another, and run towards the inferior vena cava. Their mode of termination is variable, but presents the following general arrangement:—The left lobe is drained by a vessel which joins the superior part of the inferior vena cava. The right lobe is drained by one or two vessels which join the superior part of the inferior vena cava, and by a series of small vessels, 4 to 12 in number, which pass from the inferior portion of the right lobe to the inferior vena cava. The caudate lobe and central portion of the liver are drained by vessels which mostly pass to the inferior part of the inferior vena cava. The hepatic veins and their branches are not accompanied by branches of the bile-ducts, and are surrounded by a very small amount of connective tissue.

The **lymph vessels** of the liver are arranged in a superficial and a deep set:—1. The **superficial set** lies beneath the peritoneum on both (*a*) the visceral and (*b*) the parietal surfaces of the organ. (*a*) The vessels from the *visceral surface* pass chiefly to the hepatic glands, which lie between the layers of the lesser omentum; but some of them, from the posterior surface on the right lobe, join the lumbar glands, and others, from the posterior surface on the left lobe, go to the cœliac glands. (*b*) The vessels from the superior surface pass in various directions. Those from the adjacent parts of the right and left lobes pass up in the falciform ligament, and pierce the diaphragm to reach the anterior mediastinal glands, and end finally in the right lymphatic duct. Those from the anterior part of this surface pass down to the inferior aspect, and join the hepatic glands in the lesser omentum. The lymph vessels from the back of the right lobe pierce the diaphragm between the layers of the coronary ligament, and join some glands in the thorax around the upper end of the inferior cava; others run in the right triangular ligament, and either pierce the diaphragm and end in the anterior mediastinal glands, or, turning down, join the cœliac group.

2. The **deep lymph vessels** accompany either (*a*) the portal or (*b*) the hepatic veins. (*a*) The former set pass out through the porta hepatis and join the hepatic glands, the efferent vessels of which join the cœliac glands. (*b*) Those which accompany the hepatic veins pierce the diaphragm with the vena cava, and having formed connexions with the group of glands at its superior end, within the thorax, turn down and join the beginning of the thoracic duct.

The **nerves**, which are chiefly of the non-medullated variety, are derived from the left vagus and the cœliac plexus of the sympathetic. The branches of the former pass from the front of the stomach up between the layers of the lesser omentum to the liver and supply the gall-bladder and bile-ducts. Those of the latter pass from the cœliac plexus along the hepatic artery—forming the hepatic plexus—to the porta hepatis, where they enter the liver with the blood-vessels. They are distributed chiefly to the walls of the vessels.

THE GALL-BLADDER AND BILE-PASSAGES.

The excretory ducts of the liver begin within the hepatic cells as minute channels. Thence they run between the hepatic cells (Fig. 922), and are known as the **ductus biliferi.**

Outside the lobules these join (Fig. 922) the **ductus interlobulares**, which, by uniting, form larger and larger ducts, and finally end in two, or more, chief branches, a larger from the right, and a smaller from the left lobe, which unite immediately after leaving the liver to form the **ductus hepaticus.**

As a rule, five or six ducts leave the liver at the porta hepatis; they generally unite into right and left main ducts; sometimes they all converge towards, and unite at the beginning of the hepatic duct. The ducts from the caudate lobes and process join the left branch of the main duct.

Ductus Hepaticus.—The **hepatic duct** is formed within the porta hepatis by the union of right and left chief ducts (Fig. 923), passes downwards, and, just beyond the porta hepatis, is joined by the **cystic duct** (Fig. 923) to form the **ductus choledochus (bile-duct, O.T. common bile-duct).** In length the hepatic duct usually measures about 1 to 1¼ inch (25 to 31 mm.), and in breadth, when flattened out, nearly ¼ inch (6 mm.), or about as much as a goose quill. It lies, practically altogether, within the porta hepatis.

Vesica Fellea (Gall-bladder).—The **gall-bladder**, with the cystic duct, may be looked upon as a diverticulum of the bile-duct, enlarged at its extremity to form a reservoir for the bile. It is pear-shaped, and lies obliquely on the inferior surface of the liver (Fig. 923). The wide end, or **fundus**, usually reaches the anterior border of the liver and comes in contact with the anterior abdominal wall (Fig. 928). The **corpus (body)** runs backwards, upwards, and to the left, lying in the fossa for the gall-bladder, and near the porta hepatis passes rather abruptly into the narrow neck. The **collum (neck)** is curved medially towards the porta hepatis, in the form of the italic letter *s*, and when distended it presents on its surface a spiral constriction which is continued into the beginning of the cystic duct, and is due to a series of crescentic folds placed somewhat spirally round the interior of its cavity, forming the **valvula spiralis (Heister).** Having arrived near the porta hepatis, much reduced in size, it passes into the cystic duct.

As a rule the gall-bladder is covered by the peritoneum of the inferior surface of the liver, except on its antero-superior aspect, which is united to the fossa for the gall-bladder by areolar tissue. Sometimes, but rarely, the gall-bladder is suspended from the liver by a short peritoneal ligament. *Above*, the gall-bladder lies against the liver; and *below*, it rests on the transverse colon in front, and behind, near its neck, on the duodenum.

In some cases the fundus of the gall-bladder does not reach the anterior border of the liver or the abdominal wall. In others it may be moved considerably to the right of the vertical lateral plane — possibly as a result of distension of the stomach and colon—or as a result of tight-lacing it may lie to the left, near the median plane and far below the ribs (Fig. 896, p. 1161).

Its total absence, as well as the presence of two distinct gall-bladders, and several other irregularities in form, have been recorded.

Its *size* is usually about 3 inches (75 mm.) in length, and 1 to 1¼ inches (25 to 31 mm.) in diameter. Its capacity varies between 1 and 1½ fluid ounces.

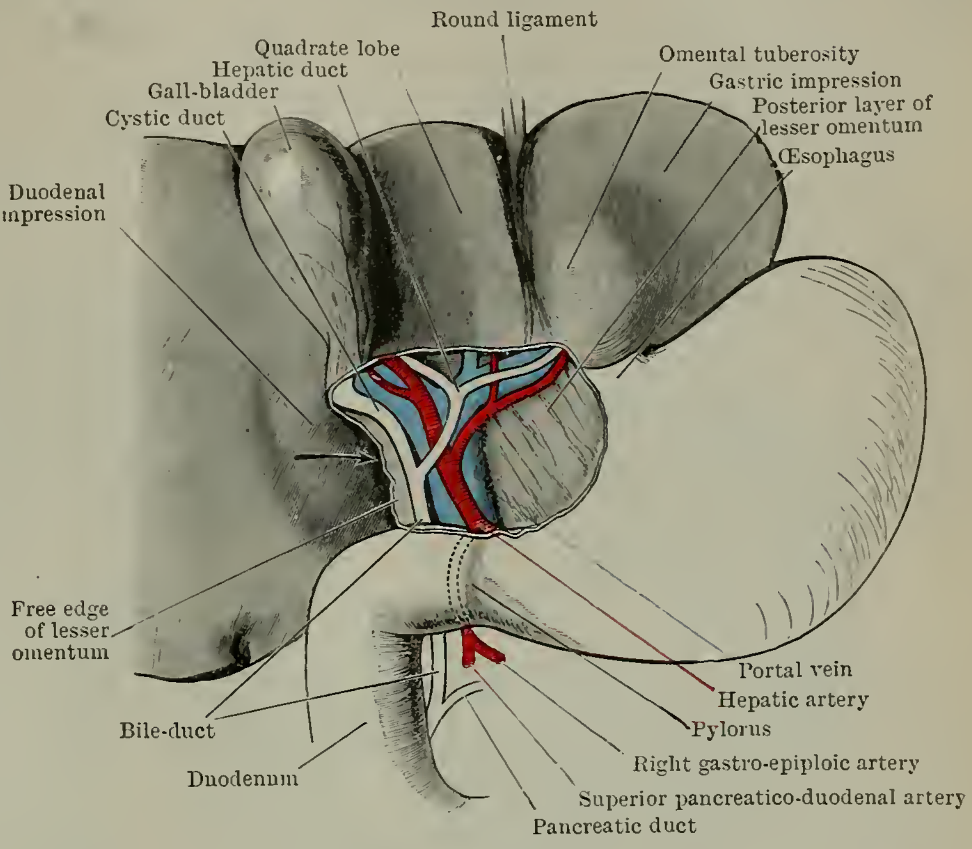


FIG. 923.—STRUCTURES BETWEEN THE LAYERS OF THE LESSER OMENTUM.

Structure of Gall-bladder.—The wall of the gall-bladder is composed of an outer coat of peritoneum, the *tunica serosa*, usually incomplete; a middle coat of unstriped muscle intermixed with fibrous tissue, the *tunica muscularis*; and an inner coat of mucous membrane, the *tunica mucosa*, which is covered with columnar epithelium, and is raised into a number of small ridges, the *plicæ tunicæ mucosæ*, which confer on it a reticulated appearance. The mucous membrane is always deeply stained with bile when the gall-bladder is opened after death.

The **cystic artery** which supplies it with blood arises from the hepatic artery itself, or its right division, and divides into two branches, which run on the sides of the gall-bladder. The **veins** join the vena portæ, and the **nerves** come from the sympathetic plexus on the hepatic artery.

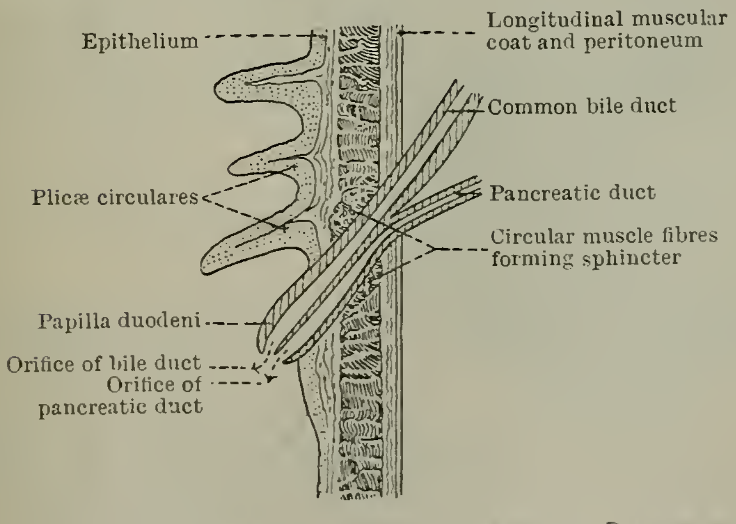

Epithelium
Longitudinal muscular coat and peritoneum
Common bile duct
Plicæ circulares
Pancreatic duct
Circular muscle fibres forming sphincter
Papilla duodeni
Orifice of bile duct
Orifice of pancreatic duct

FIG. 924.—DIAGRAMMATIC SECTION OF WALL OF DUODENUM THROUGH PAPILLA.

Ductus Cysticus.—The **cystic duct**, about half the diameter of the hepatic duct (3 mm.), but usually slightly longer (1¼ to 1½ inches: 31 to 37 mm.), begins at the neck of the gall-bladder, pursues an irregular course backwards and medially, and joins the hepatic duct at the mouth of the porta hepatis, to form the bile-duct. The spiral constriction found in the neck of the gall-bladder is continued into the beginning of this duct. Sometimes the cystic duct joins the right hepatic duct instead of the hepatic duct proper.

Ductus Choledochus.—The **bile-duct** (O.T. **common bile-duct**) begins at the mouth of the porta hepatis, where it is formed by the union of the hepatic and cystic ducts. Thence it passes downwards, anterior to the foramen epiploicum, lying between the two layers of the lig. hepato-duodenale, with the portal vein behind and the hepatic artery to its left. It descends behind and to the left of the superior part of the duodenum (Fig. 923), and then between the pancreas and descending part of the duodenum. Finally, it meets the pancreatic duct, and the two, running together, pierce the medial wall of the descending part of the duodenum very obliquely, and open on the papilla duodenalis about 3½ or 4 inches (8·7 to 10 cm.) beyond the pylorus (see p. 1179).

The length of the bile-duct is about 3 inches (75 mm.), and its diameter, which is very variable, is generally about ¼ inch (6 to 7 mm.).

Structure of the Excretory Ducts.—With the exception of the peritoneal coat, which is absent, the hepatic, cystic, and bile-ducts agree with the gall-bladder in general structure. The tunica mucosa contains a large number of mucus-producing glands, the **glandulæ mucosæ biliosæ.**

The bile and pancreatic ducts, in piercing the wall of the duodenum, run obliquely through its coats for about ½ or ¾ of an inch (12 to 18 mm.), and, as a rule, do not unite until they have almost reached the opening on the duodenal papilla (Fig. 924). This orifice is very much smaller than either duct, and the short and relatively wide common cavity which precedes it is sometimes known as the "ampulla of Vater." In 20 per cent of cases the cystic and hepatic ducts open into the duodenum separately.

PANCREAS.

The **pancreas** is a long, soft, lobulated reddish or yellowish gray gland, which lies transversely on the posterior abdominal wall, its right end resting in the concavity of the duodenum (Fig. 925), and its left end touching the spleen. It secretes a clear, watery, alkaline fluid—the pancreatic juice—which is conveyed to the duodenum by the **pancreatic duct**, and which constitutes one of the chief agents in intestinal digestion, for it contains ferments which can coagulate milk, transform starch into dextrin and sugar, split fats into glycerine and fatty acids, and reduce alkaline albuminous substances to peptone.

In **shape** the pancreas, when hardened *in situ* (Fig. 927), may be compared to the letter J placed thus ⊂.

The gland is divisible into a **head (caput)** with a **processus uncinatus**, a **body (corpus)**, and a **tail (cauda)**. The **head** corresponds to the hook of the ⊂. The stem of the ⊂ represents the **body** of the gland, and the thin left extremity of the body forms the **tail**. The narrow part connecting the head and body is the **neck** (Symington).

When removed from the body without previous hardening, the pancreas loses its true form, and becomes drawn out into a slender, tongue-shaped mass, with a wider end turned towards the duodenum, and a narrow end corresponding to the tail.

Its total *length*, when fixed *in situ*, is about 5 or 6 inches (12·5 to 15 cm.); after removal, if not previously hardened, it is easily extended to a length of 8 inches (20 cm.).

Its *weight* is usually about 3 ounces (87 grammes).

Relations.—The general position and relations of the pancreas may be briefly expressed as follows:—The head (Fig. 927) lies in the concavity of the duodenum, with the vena cava inferior and abdominal aorta behind it; the body crosses to the left of the spine and lies on the left kidney and supra-renal gland; and the tail touches the inferior part of the spleen. The greater part of the organ lies behind the stomach, which must be detached from the gastro-colic ligament, and turned upwards, in order to expose it.

In describing the detailed relations, each part of the organ will require to be considered separately.

Caput Pancreatis.—The **head** of the pancreas, flattened and somewhat disc-shaped, lies in the concavity of the duodenum, extending along its second and third portions almost as far as the duodenal-jejunal flexure. *Above*, in its right half, it is continuous with the neck; whilst to the left of this it is separated from the neck by a deep notch.

incisura pancreatis, in which lie the superior mesenteric vessels (Fig. 925). Its *right* and *inferior borders* are moulded on to the side of the duodenum, which lies in a groove of the gland substance—the bile-duct being interposed as far down as the middle of the descending part of the duodenum. The *posterior surface* of the head is applied to the front of the vena cava inferior, the right renal vessels and the left renal vein, and, at its left end, of the aorta as well. Its *anterior surface* is in contact above and on the right with the beginning of the transverse colon (Fig. 912), without the interposition of the peritoneum as a rule. Below this it is clothed by peritoneum, and is covered by the small intestine.

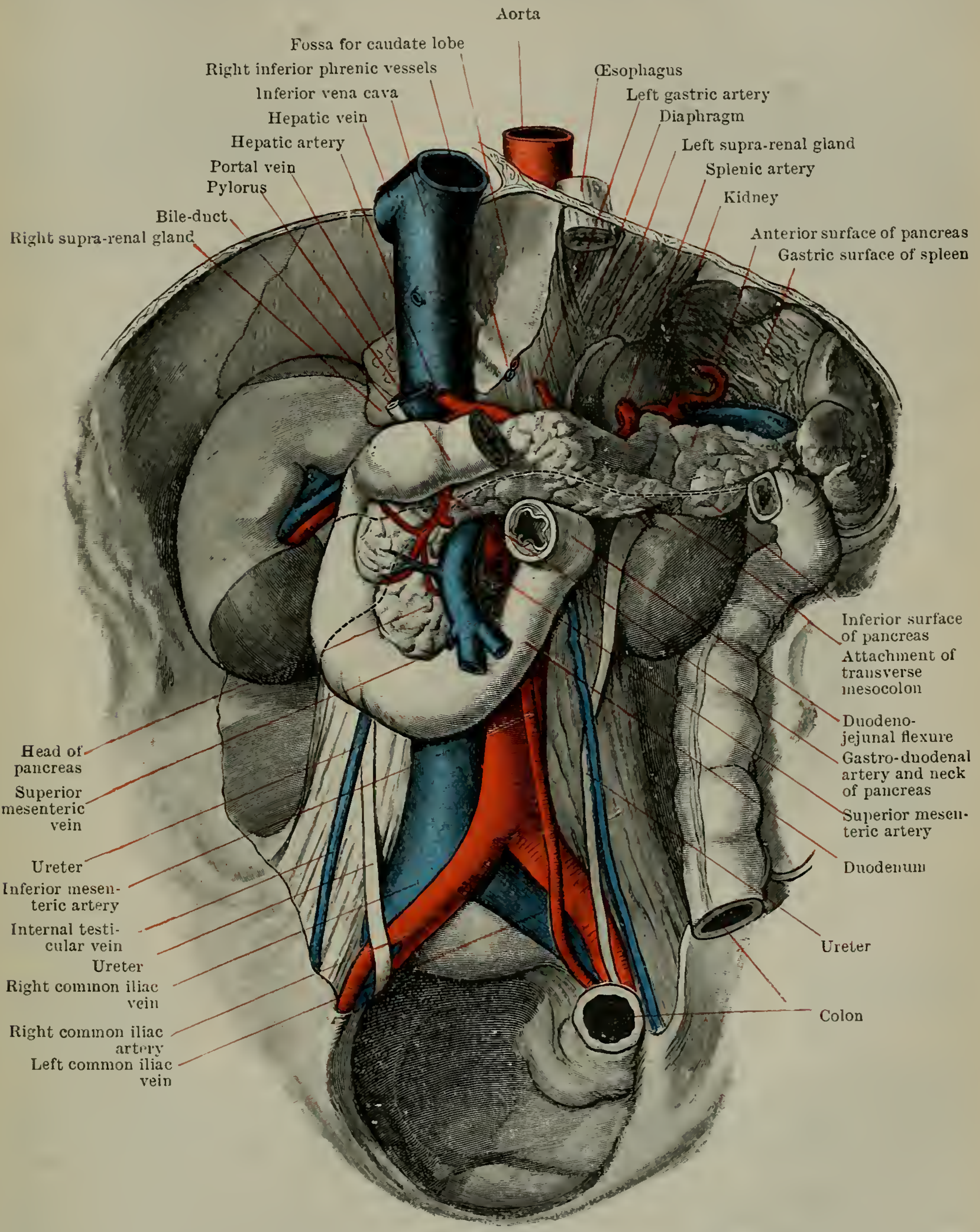


Fig. 925.—The Viscera and Vessels on the Posterior Abdominal Wall.

The stomach, liver, and most of the intestines have been removed. The peritoneum has been preserved on the right kidney and the fossa for the caudate lobe. When the liver was taken out, the inferior vena cava was left behind. The stomach bed is well shown. (From a body hardened by chromic acid injections.)

The **superior mesenteric vessels**, after passing forward through the pancreatic notch, descend in front of that portion of the head (processus uncinatus) which runs to the left along the third part of the duodenum. The **superior pancreatico-duodenal vessels** run downwards, and break up on the front of the head (Fig. 925).

The **neck** (Fig. 925) is a thin portion of the gland which lies in front of the portal vein, and connects the head to the body. It is attached on the right to the upper portion of the head, and runs forwards, upwards, and to the left for about 1 inch (25 mm.), and passes into the body.

The neck is about ¾ inch (18 mm.) in width, and less than ½ inch (12·5 mm.) in thickness. *In front and to its right* lie the first part of the duodenum and the pylorus; *behind and to the left* it rests upon the beginning of the portal vein, which is formed under cover of its lower border by the union of the splenic and superior mesenteric veins. It has a partial covering of peritoneum on its anterior surface; and its beginning is generally marked off from the head by the gastro-duodenal artery, with its continuation the superior pancreatico-duodenal, which lies in a groove of the gland substance between the head and neck.

As the transverse mesocolon is followed to the right it is, as a rule, found to terminate near the neck of the pancreas (Fig. 925). Beyond this, the posterior surface of the colon is connected by areolar tissue to the anterior aspect of the head of the gland. Below the level of the colon the head is covered by the continuation downwards of the peritoneum from the inferior surface of that gut. Often, however, the transverse mesocolon is continued to the right as far as the right colic flexure, and the anterior surface of the head is then completely covered by peritoneum.

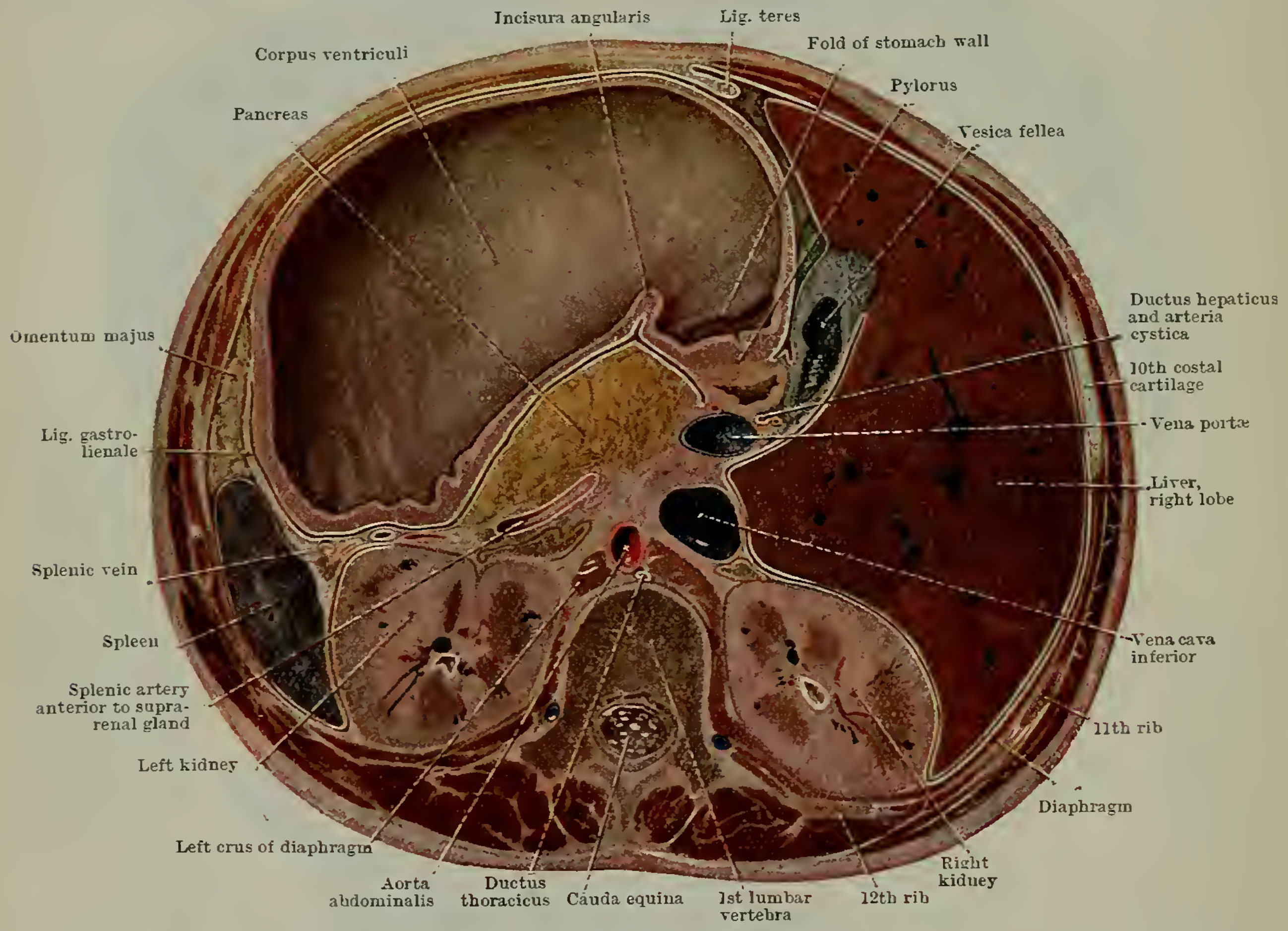


Fig. 926.—Transverse Section of the Trunk at the Level of the first Lumbar Vertebra.
Showing relations of stomach, pancreas, kidneys, etc. From a subject ten years old.

Corpus Pancreatis.—The **body** is of a prismatic form, largest where it lies in front of the left kidney, and usually somewhat tapering towards the tail (Fig. 927). From the neck it runs backwards and to the left across the front of the left kidney, beyond which its extremity or tail comes in contact with the spleen. When hardened *in situ* it presents three surfaces—anterior, inferior, and posterior—all of which are of nearly equal width (namely, about 1¼ inches: 31 mm.).

Facies Anterior.—The **anterior surface** is widest towards the left end; it looks upwards and forwards (Fig. 926), and forms a considerable portion of the stomach-bed. This surface is completely covered by peritoneum, derived from the posterior wall of the bursa omentalis, which latter separates the pancreas from the posterior surface of the stomach. Towards its right extremity it usually presents an elevation or prominence where the body joins the neck. This projects against the back of the lesser omentum when the stomach is distended, and is consequently known as the **tuber omentale**.

Facies Inferior.—The **inferior surface** looks downwards and slightly forwards. It is completely covered by peritoneum, continuous with that forming the posterior layer of the transverse meso-colon (Fig. 912). It lies in contact with the duodeno-jejunal flexure towards its right end, with the left flexure of the colon near its left end, and with a mass of small intestine (jejunum, which is always found packed in beneath it) in the rest of its extent.

Facies Posterior.—The **posterior surface** looks directly backwards, and is entirely destitute of peritoneum. It is connected by areolar tissue to the posterior abdominal wall with the organs lying upon it. From right to left these are: the aorta with the origin of the superior mesenteric artery, the left renal vessels, the left supra-renal gland, and the left kidney. In addition, the splenic artery runs its tortuous course to the left along the superior border of the pancreas, whilst the splenic vein runs, behind the gland, at a lower level than the artery.

The three surfaces of the body of the pancreas are separated by three borders. The **margo anterior** is the most prominent, and gives attachment to the transverse mesocolon (Fig. 912). It is, as it were, squeezed forward, by the pressure of the stomach above and the small intestine below, into the interval between these two sets of viscera, thus following the line of least resistance (Cunningham). Towards the neck this border is no longer prominent, but becomes rounded off, so that here the superior and inferior surfaces are confluent.

The cœliac artery projects over the **margo superior**, and sends its hepatic branch to the right, resting upon it, whilst the splenic artery runs to the left along it (Fig. 925). The **margo inferior** calls for no special description.

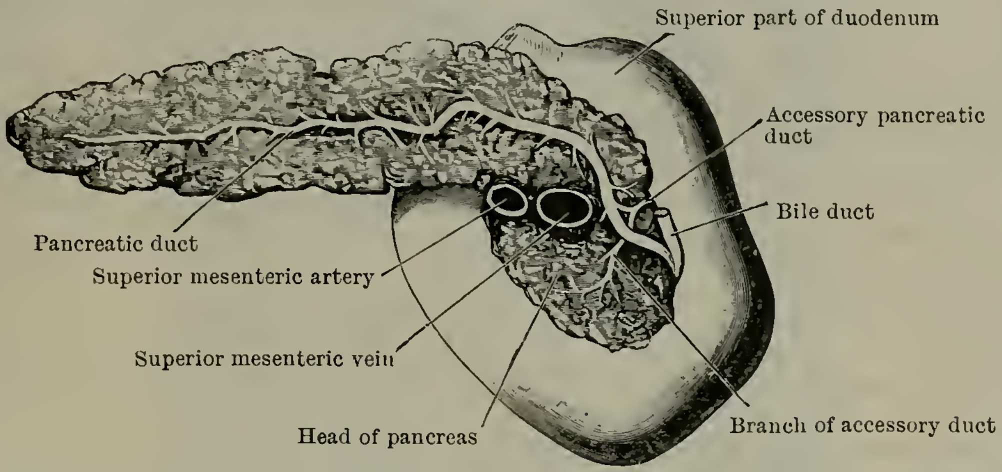


FIG. 927.—POSTERIOR ASPECT OF THE PANCREAS AND DUODENUM, with the pancreatic duct exposed. The superior mesenteric vessels also are shown in section, passing forwards, surrounded by the recurved portion of the head of the pancreas.

Cauda Pancreatis.—The **tail of the pancreas** is the somewhat pointed left end of the body, in contact with the inferior portion of the gastric surface of the spleen. It usually presents an abrupt, blunt ending, or it may be elongated and narrow. It is in near relation below with the left flexure of the colon (Fig. 912).

Ducts of the Pancreas.—Almost invariably two ducts are found in the interior of the pancreas—the **ductus pancreaticus [Wirsungi]** or **pancreatic duct** proper and the **ductus pancreaticus accessorius [Santorini], accessory pancreatic duct.**

The **pancreatic duct** begins near the tip of the tail by the union of small ducts from the lobules forming that part of the organ. From there it pursues a rather sinuous or zigzag course (Fig. 927) through the axis of the gland, at first running transversely to the right, until the neck is reached, then it bends downwards into the head, approaches the descending part of the duodenum, and meets the bile-duct (see p. 1194).

In its course through the gland the pancreatic duct receives numerous tributaries, which join it, as a rule, at a right angle. The tributaries, as well as the main duct itself, are easily recognised by the whiteness of their walls, which contrasts with the darker colour of the gland tissue. The main duct receives tributaries from all portions of the pancreas, and towards its termination attains a considerable size (namely, $\frac{1}{10}$th to $\frac{1}{6}$th of an inch—2·5 to 4 mm.—when flattened out, or somewhat larger than a crow quill).

The **pancreatic accessory duct** (**Santorini**) is a small and variably developed duct (Fig. 927) which opens into the duodenum about ¾ of an inch above and somewhat anterior to the pancreatic duct. From the duodenum it runs to the left and downwards, and soon divides into two or more branches, one of which joins the pancreatic duct, the others pass down and receive tributaries from the lower part of the head. It is generally supposed that the current flows from this into the main duct, and not into the duodenum, as a rule, except in early life.

Physical Characters and Structure of the Pancreas.—The lobules of the pancreas resemble closely in structure the lobules of the salivary glands, and show a similar arrangement of secreting tubules and ducts. The tubules are lined with short cylindrical cells, with a deeply placed nucleus, and often showing granules in the free margin. In the centre of the base of the tubule are found spindle-shaped epithelial cells, termed the centro-acinar cells.

In addition, however, each lobule contains additional structures, known as **Langerhans' islets.** These are masses of cell cords, showing no glandular structure, and not connected with the ducts, lying between the gland acini. They are believed to produce an internal secretion.

Variations.—The chief variations found are:—(1) A separation of the part of the head, known as the uncinate process, which then forms a *lesser pancreas.* (2) A growth of the pancreas around the duodenum, which it may practically encircle for a short part of its course. And (3) an opening of its duct into the duodenum, independently of the bile duct. An *accessory pancreas* (pancreas accessorium) is also sometimes found in the wall of the stomach or of the jejunum. Diverticula of the duodenum, already described (p. 1180), ought perhaps to be mentioned in this connexion.

Vessels.—The **arteries** of the pancreas are: (1) The **superior pancreatico-duodenal**, a branch of the gastro-duodenal artery, which runs down on the front of the head (Fig. 925), sending branches laterally to the duodenum, as well as numerous twigs into the substance of the pancreas. (2) The **inferior pancreatico-duodenal**, a branch of the upper part of the superior mesenteric artery; or from the root of one of the rami jejunales; it runs upwards and to the right across the back of the head, and sends branches to it and to the duodenum, one of which runs between the head and the duodenum. These two pancreatico-duodenal arteries anastomose around the inferior border of the head. (3) **Pancreatic rami** from the **splenic artery**, are several (3 to 5) fair-sized branches which come off from the splenic as it runs behind the superior border of the gland; they enter the pancreas immediately, and traverse its substance from above downwards, some sending branches in both directions along the course of the pancreatic duct.

The **veins** are: (1) The *pancreatico-duodenal veins* (Fig. 925), of which some pass downwards and to the left, on the front of the head, and join the superior mesenteric; while others cross the back of the head, and open into the superior mesenteric; (2) several small pancreatic veins which join the splenic.

The **lymph vessels** pass chiefly with the splenic lymph vessels to the cœliac glands; some also are connected with a few glands which lie near the upper end of the superior mesenteric vessels. All the lymph of the organ passes ultimately to the cœliac glands.

The **nerves**, which are almost entirely non-medullated, come from the plexus cœliacus, through the hepatic and splenic plexuses.

INTESTINUM TENUE MESENTERIALE.

Intestinum Jejunum et Intestinum Ileum.

The succeeding portions of the small intestine do not lie on the posterior abdominal wall, but hang freely from it by a lamina of connective tissue, containing the blood-vessels, lymph vessels, and nerves, and covered on each side by peritoneum, and termed the mesentery. Hence the name of "intestinum tenue mesenteriale" which is given to them.

The part of the tube to which the mesentery is connected is known as the mesenteric or attached border; the opposite side is the free border.

Mesenterium.—The **mesentery** is a broad fan-shaped fold, composed of two layers of peritoneum, which connects the small intestine to the posterior wall of the abdomen. The long free border of the fold contains the intestine within it (Fig. 891). The other, or attached border, known as the **radix mesenterii** (*root of the mesentery*), is comparatively short, being only 6 or 7 inches long; but it is much thicker than the part near the gut, for it contains between its layers a considerable amount of fatty extra-peritoneal tissue, in addition to the large vascular trunks passing to the intestine. The root is attached to the posterior abdominal wall along an oblique line, extending approximately from the left side of the second lumbar vertebra to the right iliac fossa (Fig. 928). In this course its line of attachment passes from the duodeno-jejunal flexure down over the front of the terminal part of the duodenum, then obliquely across the aorta, the inferior vena cava, the right ureter, and psoas major muscle, to reach the right iliac region.

The unattached border of the mesentery is frilled out to an enormous degree, so that, while the root measures but 6 or 7 inches, the free border is extended to some 20 feet, thus resembling a fan, one border of which may be twenty or thirty times as long as the other. The length of the mesentery, measured from its root to the attached edge of the intestine directly opposite, usually measures at its longest part about 6 inches (8 or 9 inches, Treves and Lockwood).

Its longest part goes to the portion of the small intestine situated between two points, one six feet, the other eleven feet from the duodenum (Treves).

Between the two layers of the mesentery (Fig. 928) are contained (*a*) the jejunal and ileal branches of the superior mesenteric vessels, accompanied by the mesenteric nerve plexus and lymph vessels; (*b*) the mesenteric lymph glands, which vary from 40 to 150 in number; (*c*) a considerable amount of fatty connective tissue, continuous with the extra-peritoneal areolar tissue; and (*d*) the intestine itself.

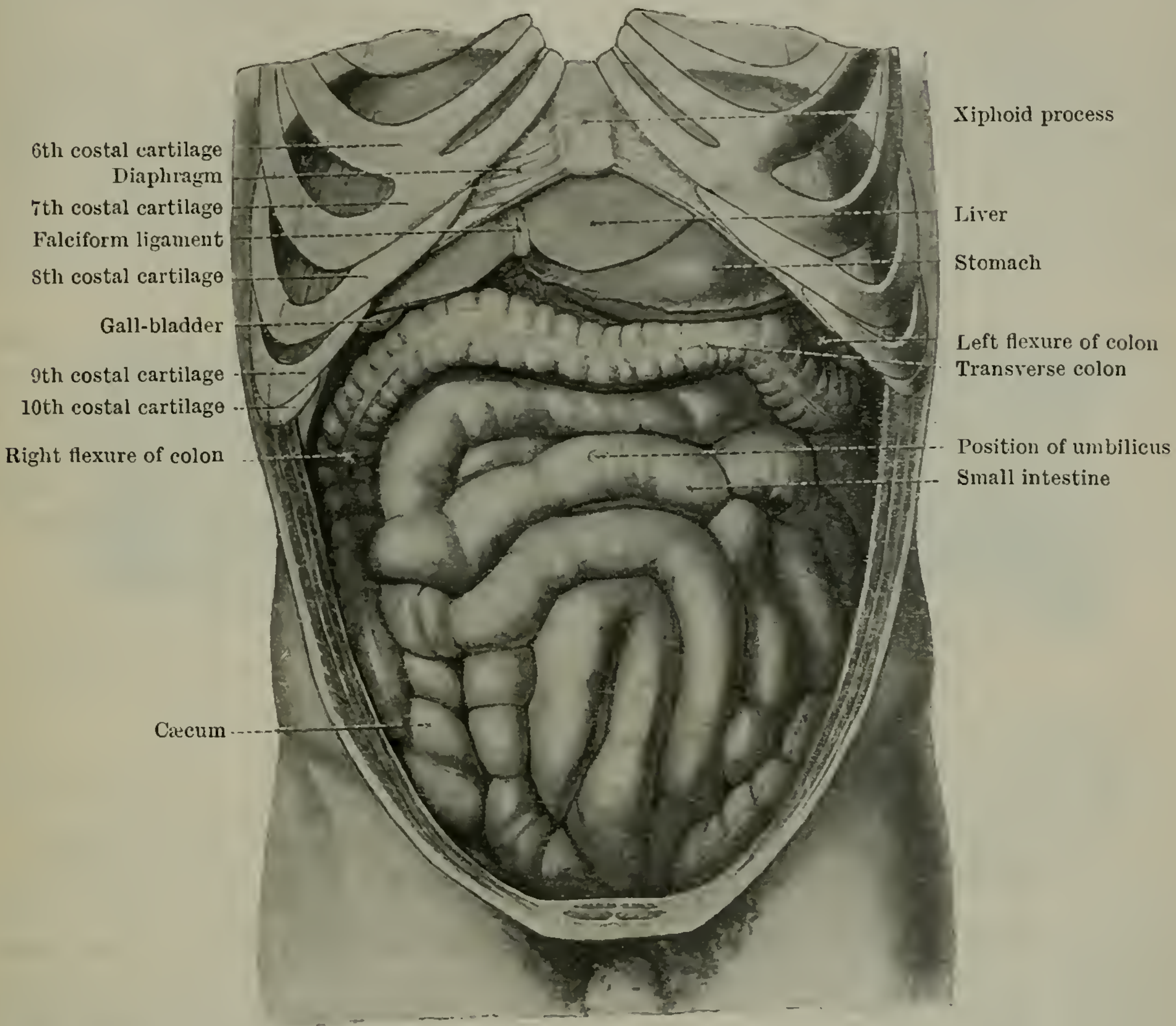


FIG. 928.—THE ABDOMINAL VISCERA, AFTER REMOVAL OF THE OMENTUM MAJUS AND THE LIG. GASTROCOLICUM.

The peritoneum from the right side of the mesentery passes out on the posterior abdominal wall to clothe the ascending colon, and, above, it is connected by a fold with the transverse mesocolon. That of the left side, similarly, passes across the parietes to the descending and iliac portions of the colon.

The mesentery begins above, immediately beyond the ending of the duodenum—that is, in the angle of the duodeno-jejunal flexure—and it ends below in the angle between the ileum and ascending colon. It is very short at each end, but soon attains the average length.

The mesentery is of such a length that the coils are able to move about freely in the abdominal cavity, and consequently the position occupied by any portion of the tube, with the exception of the beginning of the jejunum and the ending of the ileum, can never be stated with certainty. Nevertheless, it may be said that, in general, the jejunum occupies the superior and left portions of the cavity below the stomach, the ileum the inferior and right divisions, its terminal part almost always lying in the pelvis, just before it joins the large gut.

According to Mall, the most usual arrangement is to find the proximal coils of the jejunum on the left side, and high up. Then the tube crosses the vertebral column below the duodenum, and a few coils are placed on the right side. It then crosses to the left side again, and several coils are formed, some of which may descend into the pelvis. Thence it passes again to the right side, where it is coiled up, and then finally descends into the pelvis. The terminal portion almost always lies in the pelvis, just before it ascends to join the large intestine.

Whilst the root of the mesentery pursues at its attachment an almost straight line from one end to the other, if cut across a very short distance from the posterior abdominal wall, it will here be found to form a wavy or undulating line. Further away still this condition becomes more and more marked; and finally, if the bowel is removed by cutting through the mesentery close to its attachment to the intestinal wall, it will be seen that its free edge is not only undulating, but is frilled or plaited to an extreme degree. When shown in this way, it is found that the plaiting or folding is not quite indiscriminate, but that the main folds, of which there are usually six, run alternately to the right and left. As a rule, the first fold runs to the left from the duodeno-jejunal flexure, and goes to a coil of jejunum which lies under the transverse mesocolon, and helps to support the stomach. The second fold passes to the right, the third to the left, and so on up to the fifth and sixth, which are usually small. From the margins of these primary folds secondary folds project in all directions, and from these again even a third series may be formed.

This order is of course by no means constant, but if the intestine is removed from a hardened body in the way suggested, without disturbing the mesentery, it will be found to be arranged with more or less regularity, on some such plan as that indicated.

Differences between Jejunum and Ileum.—If the small intestine is followed down from the duodenum to the cæcum no noticeable change in appearance will be found at any one part of its course, to indicate the transition from jejunum to ileum; for the one passes insensibly into the other. Nevertheless, a gradual change takes place, and if typical parts of the two, namely, the upper portion of the jejunum and the lower portion of the ileum, are examined, they will be found to present characteristic differences, which are set forth in the following table:—

Jejunum.	Ileum.
Wider, 1½ to 1¼ inch in diameter.	Narrower, 1¼ to 1 inch in diameter.
Wall, thicker and heavier.	Wall, thinner and lighter.
Redder and more vascular.	Paler and less vascular.
Plicæ circulares, well developed.	Plicæ circulares, absent or very small.
Noduli lymphatici aggregati [Peyeri], few and small.	Noduli lymphatici aggregati [Peyeri], large and numerous.

The villi are also said to be shorter and broader in the jejunum, more slender and filiform in the ileum (Rauber).

The terminal portion of the ileum, after crossing the margin of the superior aperture of the pelvis minor, runs upwards, and also slightly backwards and to the right, in close contact with the cæcum, until the ileo-cæcal orifice is reached.

Diverticulum Ilei (O.T. **Meckel's Diverticulum**).—This is a short finger-like protrusion which is found springing from the lower part of the ileum in a little over 2 per cent of the bodies examined. It is usually about 2 inches long, and of the same width as the intestine from which it comes off. Most commonly it is found about 2¾ feet from the valvula coli, and opposite the original termination of the superior mesenteric artery. As a rule, its end is free; but occasionally it is adherent either to the abdominal wall, the adjacent viscera, or the mesentery, and in such cases it may be the cause of strangulation of the intestine.

The diverticulum is due to the persistence of the proximal portion of the vitelline (or vitello-intestinal) duct, which connects the primitive intestine of the embryo with the yolk sac. In shape it may be cylindrical, conical, or cord-like, and it may present secondary diverticula near its tip. It arises most frequently from the free border of the intestine, but it sometimes comes off from the side. It runs at right angles to the gut most commonly, but it may assume any direction, and it is often provided with a mesentery. In 3302 bodies specially examined with reference to its existence, it was present in 73, or 2·2 per cent, and it appeared to be more common in the male than in the female. In 59 out of the 73 cases its position with reference to the end of the ileum was examined: its average distance from the ileo-cæcal valve was 32½ inches measured along the gut, the greatest distance being 12 feet, and the smallest 6 inches. In 52 specimens the average length was 2·1 inches, the longest being 5¼ inches, the shortest ½ inch.

The diameter usually equals that of the intestine from which it springs; but occasionally it is cord-like, and pervious only for a short way; on the other hand, it may attain a diameter of 3¾ inches.

Structure (Fig. 906).—The tunica serosa is complete in all parts of the jejunum and ileum. The **tunica muscularis** is thicker in the jejunum, and grows gradually thinner as it is traced down along the ileum. The **tela submucosa** contains the bases of the solitary nodules, but otherwise calls for no special remark. The **tunica mucosa** is thicker and redder above in the jejunum, thinner and paler in the ileum. It is covered throughout by villi intestinales, which are shorter and broader in the jejunum, longer and narrower in the ileum. In its whole extent it is closely set with intestinal glands, and numerous solitary nodules are seen projecting on its surface. Aggregated lymph nodules are particularly large and numerous in the ileum; they are fewer, smaller, and usually circular in the jejunum. Finally, the mucous membrane forms plicæ circulares, which are much more prominent in the jejunum; they are smaller and fewer in the superior part of the ileum, and usually disappear a little below its middle.

INTESTINUM CRASSUM.

The ileum is succeeded by the **intestinum crassum (large intestine)**, which begins on the right side, some 2½ inches below the ileo-cæcal junction, and comprises the following parts: cæcum and processus vermiformis, ascending colon, hepatic flexure, transverse colon, splenic flexure, descending colon, iliac and pelvic colon, rectum and anal canal.

In its course the large bowel is arranged in an arched manner around the small intestine, which lies within the concavity of the curve (Fig. 928).

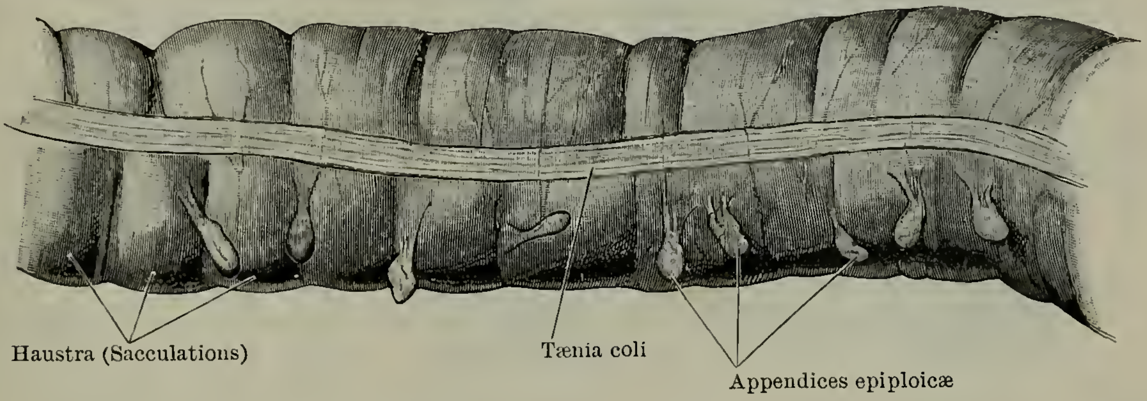


Fig. 929.—Large Intestine.

A piece of transverse colon from a child two years old. The three chief characteristics of the large intestine—sacculations, tæniæ, and appendices epiploicæ—are shown.

In *length*, the great intestine is equal to about one-fifth of the whole intestinal canal, and usually measures between 5 and 5½ feet (1–3 m.). Its *breadth* is greatest at the cæcum, and from this—with the exception of a dilatation at the rectum—it gradually decreases to the anus. At the cæcum it measures, when distended, about 3 inches (75 mm.) in diameter; beyond this it gradually diminishes, and measures only 1½ inches (37 mm.) or less in the descending and iliac divisions of the colon.

The large intestine, with the exception of the rectum and vermiform process, may be easily distinguished from the regularly cylindrical small intestine by (*a*) the presence of three longitudinal bands—the **tæniæ coli**—running along its surface (Fig. 929); (*b*) by the fact that its walls are sacculated; and (*c*) by the presence of numerous little peritoneal processes, known as **appendices epiploicæ**, projecting from its serous coat. In addition, the larger intestine is usually wider than the small, but reliance cannot be placed on this character, for the jejunum is often—indeed, generally—wider than the empty and contracted descending colon. The internal surface of the mucous membrane shows no villi.

Tæniæ Coli.—The longitudinal muscular fibres do not form a complete layer, continuous all round the tube, but, on the contrary, are arranged in three separate bands, known as the **tæniæ coli**. These bands, which are about ¼ inch (6 mm.) wide, begin at the base of the vermiform process, and run along the surface of the gut at nearly equal distances from one another as far as to the rectum. There they spread out and form a layer of longitudinal muscular fibres, which is continuous all round the tube (see p. 1215). The bands are about one-sixth shorter than the intestine to which they belong; consequently, in order to accommodate the bowel to the length of the tæniæ, the gut is tucked up (Fig. 929), and three rows of pouches or saccules are produced, along the length of the tube, between the tæniæ. If the tæniæ are dissected off, the sacculations largely disappear, the intestine becomes cylindrical, and at the same time about one-sixth longer.

The **appendices epiploicæ** (Fig. 929) are little processes or pouches of peritoneum, generally more or less distended with fat, which project from the serous coat along the whole length of the large intestine, with the exception of the rectum proper.

When the interior of a piece of distended and dried large intestine is examined, its saccules appear as rounded pouches, **haustra**, separated by crescentic folds, **plicæ semilunares coli**, corresponding to the creases on the exterior separating the saccules from one another.

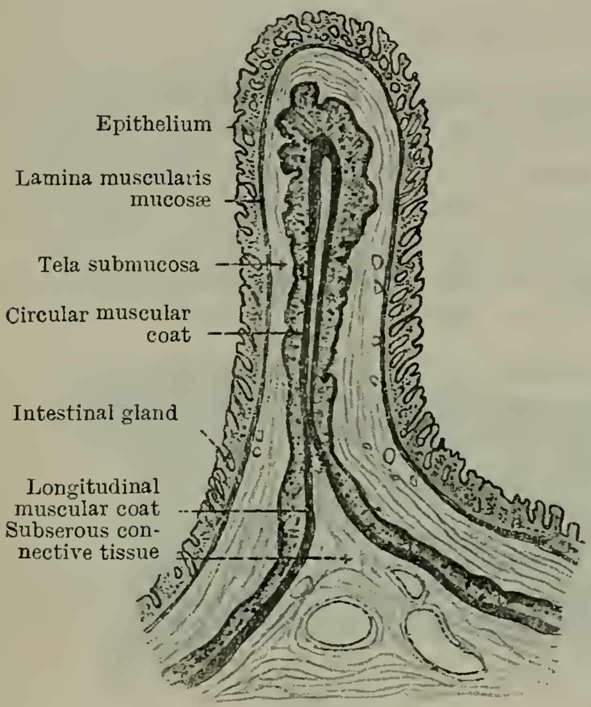


Fig. 930.—Transverse Section of a Plica Semilunaris Coli.

The plicæ semilunares of the colon are made up of a double fold of mucous membrane containing a fold of the muscular coats of the intestine as well as connective tissue, and each extends over only one-third of the circumference of the intestine, between the tæniæ.

The position of the three tæniæ on the intestines is as follows: On the ascending, descending, and iliac colons one tænia lies on the anterior aspect of the gut, and two on the posterior aspect, namely, one to the lateral side (postero-lateral), the other to the medial side (postero-medial). It is chiefly along the first of these (the anterior) that the appendices epiploicæ are found. On the transverse colon their arrangement is different, but is rendered exactly similar by turning the great omentum, with the colon, up over the thorax. On the transverse colon in the natural position, the anterior tænia of the ascending and descending colons becomes the posterior (or postero-inferior) termed *tænia libera*, the postero-lateral becomes anterior or *tænia omentalis*, and the postero-medial becomes superior in position and is termed *tænia mesocolica*. The anterior and postero-lateral tæniæ of the iliac colon pass below on to the front of the pelvic colon and rectum.

In formalin-hardened bodies portions of the large intestine, but particularly of the descending and sigmoid colons, are often found fixed in what appears to be a state of contraction, when they are reduced to a diameter of about $\frac{5}{8}$ or $\frac{3}{4}$ of an inch (16 to 19 mm.). Under similar conditions parts of the small intestine are found correspondingly reduced.

The appendices epiploicæ, although generally said to be absent in the fœtus, can be distinctly seen as early as the seventh month, but at this time they contain no fat.

Structure of the Large Intestine.—The **tunica serosa** is complete on the vermiform process, cæcum, transverse colon, and pelvic colon; incomplete on the ascending, descending, and iliac divisions of the colon and on the rectum. It will be described in detail with each of these portions of the intestine.

The **tunica mucosa** is of a pale, or yellowish, ash colour in the colon, but becomes much redder in the rectum. Unlike that of the small intestine, its surface is smooth, owing to the absence of villi, but it is closely studded with the orifices of numerous large intestinal glands. Solitary lymph nodules are also numerous, particularly in the vermiform process (Fig. 930).

Vessels and Nerves.—The cæcum and vermiform process receive their blood from the **ileo-colic artery**; the ascending colon from the **right colic artery**; and the transverse colon from the **middle colic artery**, which lies in the transverse mesocolon. These are all branches of the **superior mesenteric**. The descending colon is supplied by the **left colic**, and the iliac and pelvic colons by the **sigmoid arteries**, branches of the **inferior mesenteric**. The rectum derives its blood from the three **hæmorrhoidal arteries**, which will be described with that division of the gut.

The **veins** correspond largely to the arteries, and join the inferior and superior mesenteric vessels, which send their blood into the portal vein.

The **lymph vessels** of the large intestine arise from plexuses in the submucous and subperitoneal coats, as in other parts of the alimentary canal.

The deeper vessels escape chiefly along the entering blood-vessels, those from the lateral aspects passing behind the intestine.

The vessels pass medially to a series of glands lying along the medial border of the intestine ("paracolic" glands (Jamieson)); thence they pass along the lines of the main arteries, passing then to glands disposed at intervals about these vessels (intermediate and main glands). The lymph vessels from the lower half of the descending colon, and from the iliac and pelvic colons, join the left lymph trunk of the lumbar glands. Those of the rectum and cæcum will be described later.

Nerves.—The nerves come from the superior mesenteric plexus, an offshoot of the cœliac plexus, and from the inferior mesenteric, a derivative of the aortic plexus. The arrangement is similar to that of the nerves of the small intestine.

INTESTINUM CÆCUM AND PROCESSUS VERMIFORMIS.

Intestinum Cæcum.—After leaving the pelvic cavity, as already described, the terminal portion of the small intestine passes upwards, backwards, and to the right, and opens, by the ileo-cæcal orifice, into the large intestine some 2½ inches from its lower end. The portion of the large gut which lies below the level of this orifice is known as the **intestinum cæcum.** *In shape* (Fig. 931) it is a wide, asymmetrical, or lop-sided cul-de-sac, furnished with the tæniæ and sacculations usually found in the large intestine. Its lower end or *fundus* is directed downwards and medially, and usually rests on the right psoas major muscle, close to the brim of the pelvis; whilst the opposite end is directed upwards and laterally, and is continued into the ascending colon.

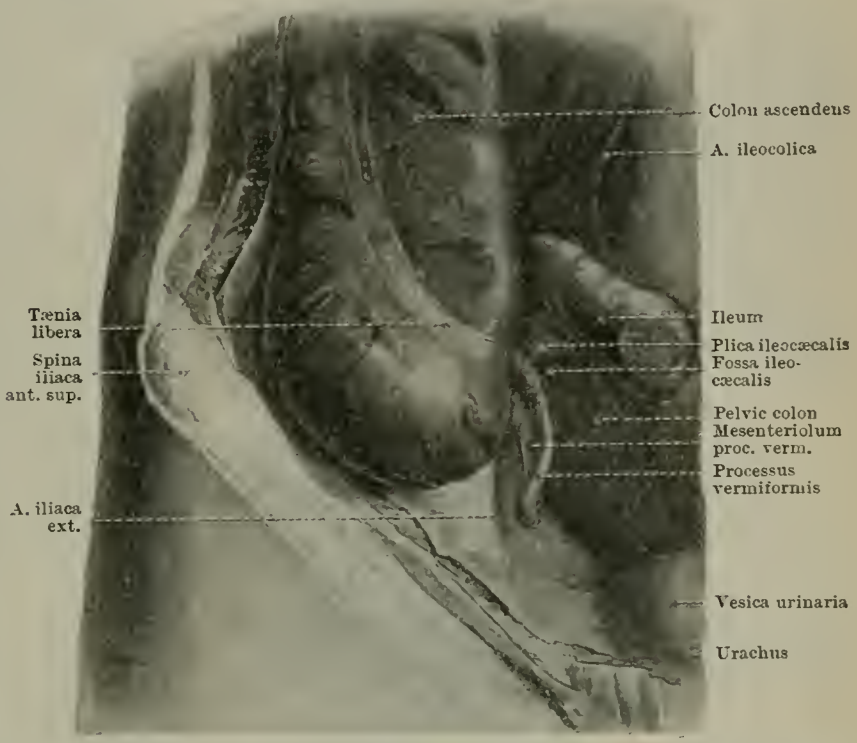


FIG. 931.—THE CÆCUM AND VERMIFORM PROCESS FROM THE FRONT.

Its asymmetrical form is due to the fact that the lateral and medial portions of the organ undergo an unequal development in the child. The medial (or medial and posterior) section lags behind, whilst the lateral (or lateral and anterior) division grows much more rapidly, and, projecting downwards, soon comes to form the inferior end or fundus of the cæcum. As a result the original extremity of the gut, with the vermiform process springing from it, is hidden away behind and to the medial side of the fundus.

In *length* the distended cæcum usually measures about 2½ inches (60 mm.); whilst its *breadth* is usually more, and averages about 3 inches (75 mm.).

Position. — It is usually situated almost entirely within the right iliac region of the abdomen, immediately above the lateral half or third of the inguinal ligament; but its inferior end projects medially in front of the psoas major and reaches the hypogastrium (Fig. 931). On the other hand, it is sometimes found high up in the right lumbar region (owing to the persistence of the fœtal position), or hanging over the pelvic brim and dipping into the pelvic cavity to a varying extent.

In the great majority of cases the cæcum is completely covered with peritoneum on all aspects, and lies quite free in the abdominal cavity. In a small proportion, namely, about 6 or 7 per cent of bodies, the posterior surface (probably as a result of adhesions) is not completely covered, but over a greater or less portion of its extent is bound down to the posterior abdominal wall by connective tissue.

Relations.—*Posteriorly*, the cæcum rests on the ilio-psoas muscle; generally, too, on the vermiform process and the femoral nerve. *Anteriorly*, it usually lies in contact with the omentum and anterior abdominal wall; but when the cæcum is empty, the small intestine intervenes. Its *lateral side* is placed immediately above the lateral half or third of the inguinal ligament (Fig. 931), whilst the *medial side* has the termination of the ileum lying in contact with it. On the medial and posterior aspects, but more on the former than the latter, the small intestine joins the cæcum. On the same aspect, and usually from 1 to $1\frac{1}{2}$ inches (25 to 37 mm.) lower down, the vermiform process comes off.

The *interior* of the cæcum corresponds in general appearance to that of the large intestine; but it presents two special features on the posterior part of its medial wall, namely, the **ileo-cæcal orifice**, guarded by the **valvula coli** (O.T. **ileo-cæcal valve**), and below that the small opening of the **processus vermiformis**, both of which call for further notice.

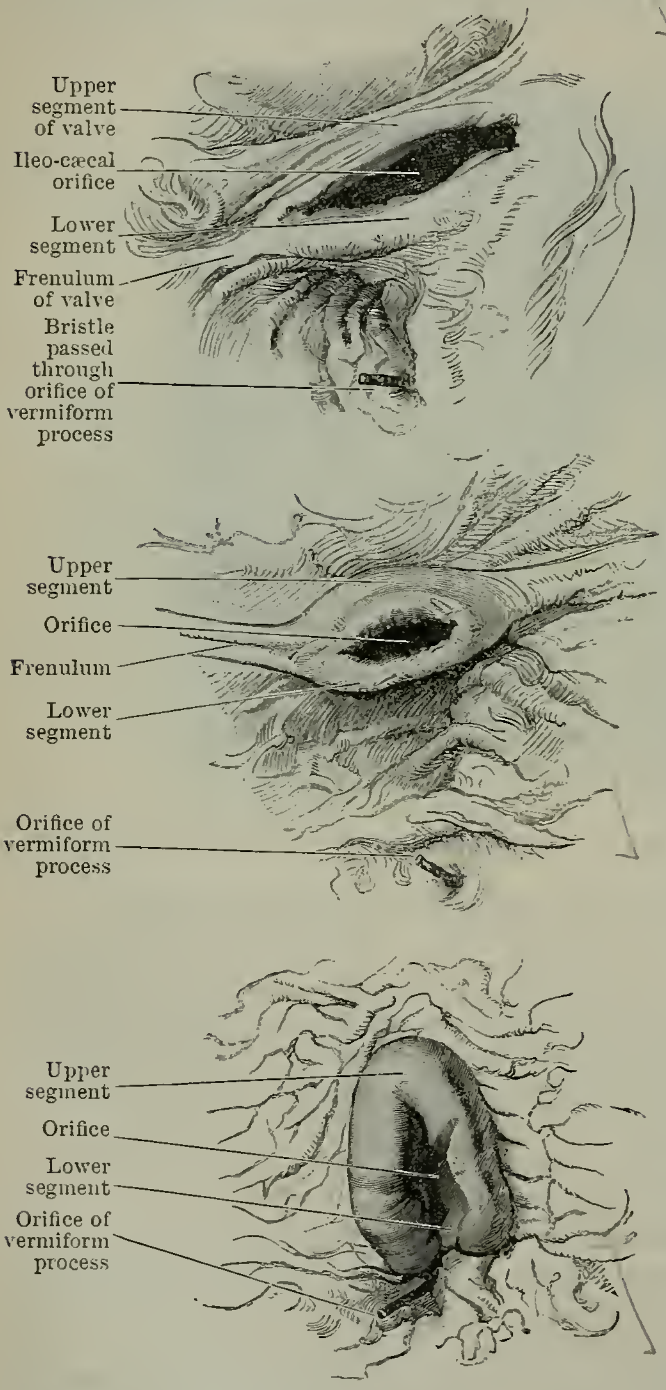


Fig. 932.—Three Forms of Valvula Coli, from bodies hardened by intra-vascular injections of formalin.

The hardening was not so complete in the case of the highest of the three valves represented. In each a bristle is passed through the orifice of the vermiform process.

Valvula Coli (O.T. **Ileo-cæcal Valve**).—Where the ileum enters the large intestine, the end of the small gut is, as it were, thrust through the wall of the large bowel, carrying with it certain layers of that wall, which project into the cæcum in the form of two folds, lying respectively above and below its orifice, and constituting the two segments of the valve (Fig. 933). The peritoneum and longitudinal muscular fibres of the bowel take no part in this infolding; on the contrary, they are stretched tightly across the crease produced on the exterior by the inversion, and thus serve to preserve the fold and the formation of the valve.

As seen from the interior, in specimens which have been distended and dried (Fig. 933), the valve is made up of two crescentic segments—a superior, **labium superius**, in a more or less horizontal plane; and an inferior, **labium inferius**, which is larger, placed in an oblique plane, and sloping upwards and inwards (*i.e.*, towards the cavity of the cæcum). Between the two segments is situated the slit-shaped opening, which runs in an almost antero-posterior direction, with a rounded anterior and a pointed posterior extremity (Fig. 932). At each end of the orifice the two segments of the valve meet, unite, and are then prolonged around the wall of the cavity as two prominent folds—the **frenula valvulæ coli**. It is thought that when the cæcum is distended, and its circumference thereby increased, these frenula are put on the stretch, and, pulling upon the two segments of the valve, they bring them into apposition, and effect the closure of the orifice.

The **position of the valvula coli**, in the average condition, may be indicated on the surface of the body by the point of intersection of the intertubercular and vertical lateral lines. A point 1 to $1\frac{1}{2}$ inches (2·5 to 3·7 cm.) lower down would correspond to the **orifice of the vermiform process**.

In bodies hardened *in situ* with formalin, the valve and orifice present a different appearance (see Fig. 932, in which three different forms of hardened valves are shown), suggesting, much more closely than in the dried state, the appearance of telescoping or inversion mentioned above. In them also the two segments of the valve are much thicker and shorter, but they can always be distinguished, and are found to bear the same relation to one another as in the dried condition, although this may be obscured by foldings or rugæ. The aperture may be slit-like or rounded, with sloping or funnel-shaped edges; the frenula are not so prominent at times; but the whole valve projects much more abruptly into the cavity of the cæcum than in the distended and dried specimen.

Structure of the Valvula Coli.—Each labium of the valve consists of two layers of mucous membrane, with the submucosa and the circular muscular fibres between, all of which are continuous with those of the ileum on the one hand and of the large intestine on the other. The surface of each labium turned towards the small intestine is covered with villi, and conforms in the structure of its mucous membrane to that of the ileum; whilst the mucous membrane of the opposite surface resembles the mucous coat of the large bowel.

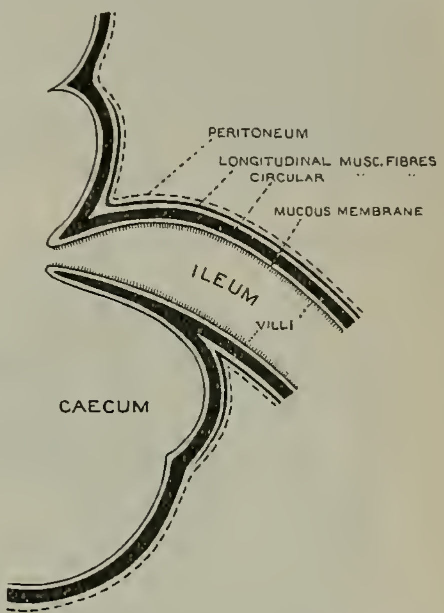


Fig. 933.—Diagrammatic Section through the Junction of the Ileum with the Cæcum, to show the Formation of the Valvula Coli.

In the dried specimen the superior labium usually projects further into the cavity of the cæcum than the inferior, so that the aperture appears to be placed between the edge of the inferior segment and the inferior surface of the superior.

There is little doubt that the efficiency of the valvula coli is largely due to the oblique manner in which the ileum enters or invaginates the large intestine; this oblique passage alone, as in the case of the ureter piercing the wall of the bladder, would probably be sufficient to prevent a return of the cæcal contents. In the great majority of cases, when in position within the body, the ileum is perfectly protected from such a return, although when the parts are removed, and then distended with fluid, this fluid often passes through the valve, and reaches the small intestine. Still, the efficiency of such a test, applied when the parts are deprived of their natural supports, cannot be relied upon.

The size of the segments of the valve, as seen in the dried condition, varies considerably; they are sometimes very imperfect; and even the absence of both has been recorded. But here again there is danger of falling into error, through examining the parts under such artificial conditions.

Types of Cæcum.—Three chief types of cæcum may be distinguished—the *fœtal type*, conical in shape and nearly symmetrical, with the inferior end gradually passing into the vermiform process; the *infantile*, in which the passage from the cæcum to the vermiform process becomes more abrupt, the lateral wall more prominent, and the whole sac more asymmetrical; and the lop-sided *adult form*, as described above, which is the condition found in 93 or 94 per cent of adults.

Structure.—Nothing in the arrangement of the mucous and submucous coats calls for special notice. The tæniæ or longitudinal bands of the muscular coat all spring from the base of the vermiform process (Fig. 931); the anterior runs up on the front, medial to the main prominence of the cæcum; the postero-lateral runs up behind this prominence; whilst the postero-medial passes directly upwards behind the ileum (Fig. 934). The longitudinal fibres on the superior aspect of the ileum partly join the postero-medial tænia; those on the anterior and posterior aspects join the circular fibres of the large gut.

The serous coat has, in connexion with it, certain folds and fossæ which are described at p. 1208.

Processus Vermiformis (Fig. 934).—The **vermiform process** (O.T. **appendix**, or **vermiform appendix**) is a worm-like tubular segment which springs from the medial and posterior part of the cæcum about 1 to 1½ inches (2·5 to 3·75 cm.) below the ileo-cæcal orifice. From that point it generally runs in one of three chief directions, namely—(1) over the brim, into the pelvis; (2) upwards behind the cæcum; or (3) upwards and medially, thus pointing towards the spleen; each of which has been considered to be the normal position by one or more observers. In the first of these situations it is quite evident as it hangs over the pelvic brim; in order to expose it in the second, the cæcum must be turned upwards; whilst in the third position it lies behind the end of the ileum and its mesentery, and these must be raised up in order to display it. In addition to the positions just mentioned, it has been found in almost every possible situation in the abdomen which its length and the extent of its mesentery would allow it to attain. In every case the anterior tænia of the cæcum, which is always distinct, offers the surest guide to the vermiform process, and its base can be located with certainty by following this tænia to the back of the cæcum (Fig. 934).

Its size is almost as variable as its position. Taking the average of numerous measurements, its length may be given as about 3½ inches (92 mm., Berry), and its breadth as ¼ inch (6 mm., Berry). On the other hand, it has been found as long as 9 inches (230 mm.), and as short as ¾ inch (18 mm.). Even its absence has been recorded (Fawcett), but this must be looked upon as an extremely rare occurrence.

Its *lumen* or *cavity* is variable in its development, and is found to be totally or partially occluded in at least one-fourth of all adult and old bodies examined. It opens into the cavity of the cæcum on its medial, or medial and posterior aspect (Fig. 932), at a point 1 to 1½ inches (25 to 38 mm.) below, and somewhat posterior to the ileo-cæcal orifice. These are the relative positions of the two orifices, as seen from the interior of the cæcum; viewed from the exterior, the base of the vermiform process is within ¾ inch of the lower border of the ileum. This apparent difference is due to the fact that the ileum adheres to the medial side of the cæcum for a distance of nearly 1 inch before it opens into it.

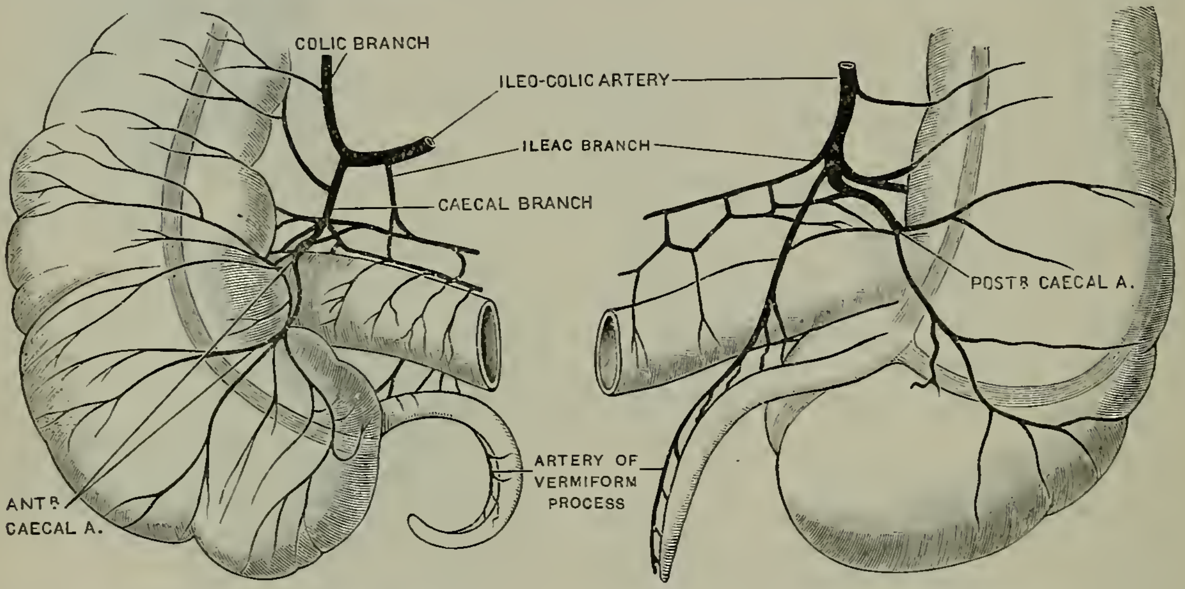


Fig. 934.—The Blood-Supply of the Cæcum and Vermiform Process.

The illustration to the left gives a front view; in that to the right the cæcum is viewed from behind. In the latter the artery of the process, and three tæniæ coli springing from the base of the vermiform process, should be specially noted. (Modified from Jonnesco.)

The orifice of the vermiform process has a crescentic fold or valve, the **valvula processus vermiformis**, placed at its superior border; but it is probably of very little functional importance, for the aperture of the process is usually so small that its cavity is not likely to be invaded by the contents of the cæcum.

The vermiform process is completely covered with peritoneum, and has a considerable mesentery, the *mesenteriolum processus vermiformis* (O.T. *meso-appendix*), which extends to its tip as a rule, and connects the process to the inferior surface of that part of the mesentery proper which goes to the inferior extremity of the ileum.

The vermiform process is relatively, to the rest of the large intestine, longer in the child at birth than in the adult, the proportion being about 1 to 16 or 17 at birth and 1 to 19 or 20 in the adult. The process attains its greatest length and diameter during adult and middle age, and atrophies slowly after that time. It is said to be slightly longer in the male than in the female.

Total occlusion of its cavity is found in 3 or 4 per cent of bodies; it is then converted into a fibrous cord. Partial occlusion is present in 25 per cent of all cases, and in more than 50 per cent of those over 60 years old, whilst it is unknown in the child. This frequency of occlusion, the physiological atrophy which takes place after middle life, the great variations in length, and other signs of instability, have been considered to point to the retrogressive character of the vermiform process.

A vermiform process is found only in man, the higher apes, and the wombat, although in certain rodents a somewhat similar arrangement exists. In carnivorous animals the cæcum is very slightly developed; in herbivorous animals (with a simple stomach) it is, as a rule, extremely large. It has been suggested that the vermiform process in man is the degenerated remains of the herbivorous cæcum, which has been replaced by the carnivorous form. Another and perhaps more probable view regards the process as a lymph organ, having the same functions as lymph nodules, and, like these, undergoing degeneration after middle life (Berry).

In the fœtus and child, as well as in the adult with the infantile type of cæcum, the vermiform process springs from the true apex, not from the medial and posterior aspect.

Foreign bodies, although reputed to find their way very easily into the vermiform process, are rarely found there after death. On the other hand, concretions or calculi, formed of mucus, fæces, and various salts, are often present (Berry).

Structure (Fig. 935).—The tunica serosa is complete, and forms a perfect investment for the process. The tunica muscularis, unlike that of the rest of the large intestine, has a continuous and stout layer of longitudinal fibres, which passes at the root of the process into the three tæniæ coli (Fig. 934). The layer of circular fibres is well developed. The tela submucosa is almost entirely occupied by large masses of lymph tissue surrounded by sinus-like lymph spaces. Owing to the large size of these lymph nodules, the areolar tissue of the submucosa is compressed against the inner surface of the muscular coat, and forms a well-marked fibrous ring, which sends processes at intervals between the lymph masses towards the mucous membrane. These lymph nodules, which correspond to solitary lymphoid nodules, have, owing to their great number, been almost completely crushed out of the mucosa (in which they chiefly lie in the intestine) into the submucosa.

The mucous coat corresponds to that of the large intestine in its general characters, but the intestinal glands are fewer, and irregular in their direction; the lamina muscularis mucosæ is thin and ill-defined; it lies just internal to the lymphoid nodules of the submucosa, and immediately outside the base of the intestinal glands. Some few lymph nodules lie in the mucous coat also.

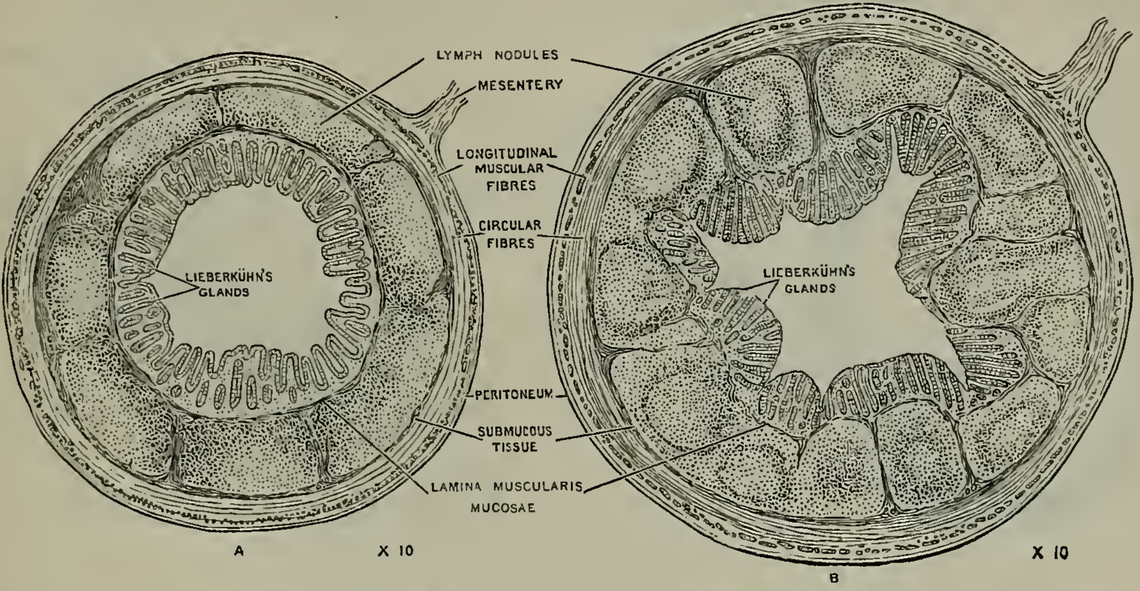


Fig. 935.—Structure of the Vermiform Process.

A. From a child two years old. B. From a male, age 56.

It will be observed that the tela submucosa is almost entirely occupied by lymph nodules and patches. The lamina muscularis mucosæ is very faint, and lies quite close to the bases of the intestinal glands. The longitudinal layer of muscular fibres forms a continuous sheet.

Blood-vessels of the Cæcum and Vermiform Process (Fig. 934).—These parts are supplied with blood by the ileo-colic artery. This gives off, near the upper angle formed by the junction of the ileum with the small intestine—(*a*) an *anterior ileo-cæcal artery*, which passes down on the front of the ileo-cæcal junction to the cæcum, and breaks up into numerous branches for the supply of that part; (*b*) a *posterior ileo-cæcal artery*, similarly disposed on the back; and (*c*) the *artery for the vermiform process.* The last-named branch passes down behind the ileum (Fig. 934), then enters the mesentery of the process, and running along this near its free border, sends off several branches across the little mesentery to the process, before finally ending in it. The course of the artery behind the ileum is said to render it subject to pressure from fæcal masses in that gut, and thus to predispose to an interference with the blood supply of the vermiform process, and to morbid changes in it.

The **lymph vessels** of the cæcum and vermiform process arise mainly from networks in the mucous and serous coats.

The first of these networks communicates with a lymph sinus which is found at the base of the lymph nodules in the process, and the vessels from it pierce the muscular coats, and pass in company with the blood-vessels. They are connected with mucous lymph glands found near the ileo-cæcal junction, especially on the posterior and medial aspect, in the angle between the ileum and colon.

Small isolated glands may be found lying in close contact with the medial part of the cæcum, on its anterior and posterior aspects. From these glands, the lymph stream is directed upwards and medially towards the cœliac and lumbar glands. The lymph vessels of the vermiform process may also communicate with the lymph nodes in the iliac fossa, and also, it has been stated, with the lymph vessels of the right ovary.

Cæcal Folds and Fossæ.—The peritoneum in the neighbourhood of the cæcum forms certain fossæ, of which the most interesting and important are—(*a*) the fossa cæcalis; (*b*) the recessus ileocæcalis inferior; (*c*) the recessus ileocæcalis superior; and (*d*) the recessus retrocæcalis.

(*a*) The **fossa cæcalis** (Fig. 936, B) is only occasionally present, and can be exposed by turning the cæcum and adjacent part of the ileum upwards. It is a fossa in the parietal peritoneum on the posterior abdominal wall, open above, in which the lower end of the cæcum occasionally lies. It is produced by the *plica cæcalis*, a peritoneal fold which passes from the surface of the iliacus to the right lateral aspect of the cæcum. Two forms, lateral and medial, are described; the first lies behind the lateral part of the ascending colon, immediately above the cæcum; the second behind its medial part. These fossæ are specially interesting because, when present, they frequently lodge the vermiform process (see Fig. 936, B), a condition which is said to favour the production of appendicitis.

(*b* and *c*) **Recessus Ileocæcales and Plica Ileocæcalis.**—If the vermiform process is drawn down, and the finger run towards the cæcum, along the *inferior* border of the terminal part of the ileum, its point will generally run into a fossa situated in the angle between the ileum and cæcum (Fig. 936, A), which is known as the *recessus ileocæcalis inferior.* The fold which bounds the fossa in front is the *plica ileocæcalis* (O.T. *the "bloodless fold of Treves"*). It passes from the ileum to the front of the mesentery of the vermiform process, which forms the posterior wall of the fossa.

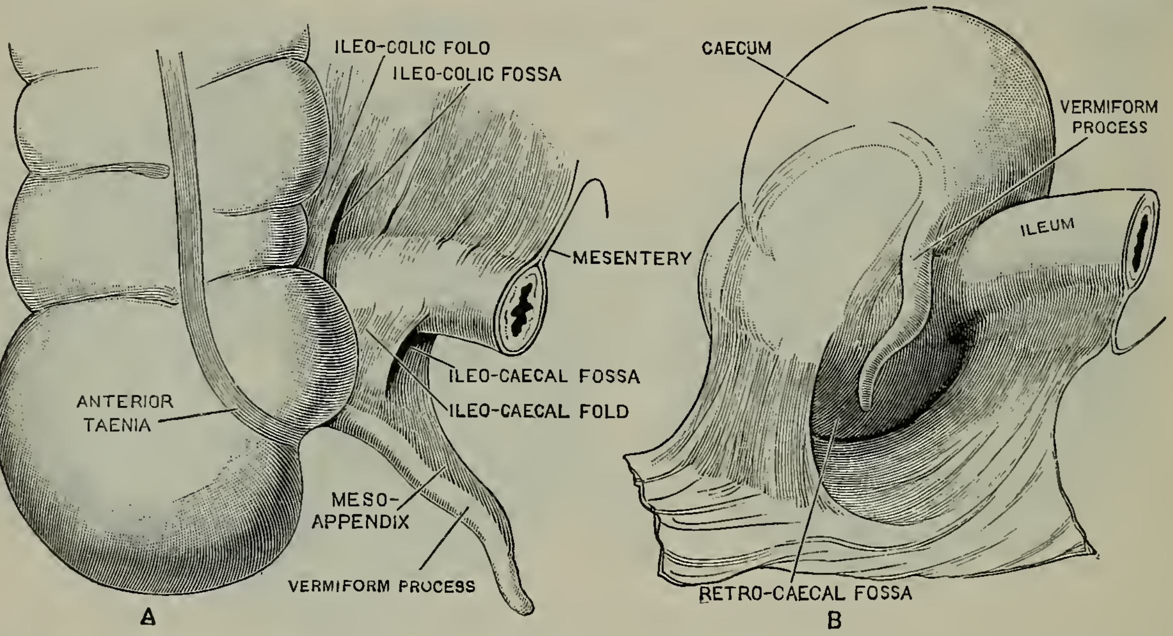


FIG. 936.—THE CÆCAL FOLDS AND FOSSÆ.

In A, the cæcum is viewed from the front; the mesentery of the vermiform process is distinct, and is attached above to the inferior surface of the portion of the mesentery going to the end of the ileum. In B, the cæcum is turned upwards to show a retro-cæcal fossa, which lies behind it and behind the beginning of the ascending colon.

The plica ileocæcalis contains some unstriped muscle fibres continuous with the longitudinal muscle coat of the cæcum, and some fat especially at its free margin.

The recessus ileocæcalis inferior is bounded above by the lower end of the ileum, to the right by the cæcum, in front by the plica ileocæcalis, behind by the root of the mesenteriolum of the processus vermiformis, while it is open to the left or medially.

Similarly, if the finger is run out along the *superior* border of the ileum towards the cæcum, it will usually lodge in a smaller fossa, the *recessus ileocæcalis superior,* which is bounded in front by a small peritoneal process, the ileo-colic fold (Fig. 936, A), containing the anterior cæcal artery.

The recessus ileocæcalis superior lies at the upper margin of the opening of the ileum into the colon, and is bounded behind by the ileum, to the right by the cæcum.

(*d*) **Recessus Retrocæcalis.**—This is an occasional recess which passes upwards between the ascending colon and the posterior abdominal wall. Its orifice looks downwards or to the left, and lies in the fossa cæcalis behind the cæcum.

COLON.

Colon Ascendens.—The ascending colon begins about the level of the intertubercular plane, opposite the ileo-cæcal orifice, where it is continuous with the cæcum. From there it runs upwards and somewhat posteriorly, with a slight concavity to the left, until it reaches the inferior surface of the liver, where it bends forwards and to the left, and passes into the right flexure of the colon (Fig. 937). In its course it lies in the angle between the quadratus lumborum and the more prominent psoas major medially.

It is situated chiefly in the right lumbar region, but it extends slightly into the hypochondrium above; and, although it usually begins about the level of the intertubercular plane, still with a low position of the cæcum it will extend further down, and may occupy a considerable part of the iliac region.

Its *length* is extremely variable, depending upon the extent to which the cæcum has descended from the position it occupied during development, viz., in contact with the under surface of the liver.

It is from 5 to 8 inches long, and it is wider and more prominent than the descending colon. It generally presents several minor curves or flexures, and it often has the appearance of being pushed into a space which is too short to accommodate it.

Relations.—*Anteriorly*, it is usually in contact with the abdominal wall, but the small intestine frequently intervenes, particularly above. To its *medial side* lie the coils of the small bowel and the psoas major; to the *lateral side* is the side wall of the abdomen. Its *posterior surface*, which is free from peritoneum as a rule (Fig. 925), is connected by areolar tissue to the iliacus muscle as far up as the crest of the ilium, to the quadratus lumborum above that, and finally to the inferior part of the right kidney.

In the great majority of cases only the two sides and the anterior surface are covered with peritoneum, the posterior surface being destitute of a serous coat (Fig. 925). In a small proportion of bodies, however, the ascending colon is provided with a complete peritoneal coat and a mesentery, but this latter is so short that it admits of but a slight amount of movement in the gut.

On the lateral aspect of the cæcum and colon there are occasionally found small peritoneal pockets termed **recessus paracolici.**

Like the cæcum, the ascending colon is frequently found distended with gas or fæces after death, hence in part its large size and prominence as compared with the descending colon, which is generally empty.

Flexura Coli Dextra.—The **right** (O.T. **hepatic**) **flexure of the colon** is the bent piece of the large intestine between the end of the ascending colon and the beginning of the transverse colon (Figs. 912 and 937).

When the ascending colon reaches the inferior surface of the liver, it bends—usually acutely, sometimes obtusely—forwards and to the left on the anterior surface of the right kidney, and on reaching the front of the descending portion of the duodenum, passes into the transverse colon.

The flexure is placed between the descending duodenum medially and the anterior thin margin of the liver, or the side wall of the abdomen, laterally; above, it corresponds to the colic impression on the liver, and posteriorly it rests on the kidney. Its peritoneal relations are similar to those of the ascending colon.

Colon Transversum.—This is the long and looped portion of the large intestine which lies between the right and left flexures. It begins at the end of the right flexure, at the point where the colon passes forwards from the anterior surface of the kidney, and, turning to the left, crosses the descending duodenum (Fig. 937). It runs at first transversely to the left, and for the first few inches is comparatively fixed, being united to the front of the descending part of the duodenum and the head of the pancreas either by a very short mesentery or by areolar tissue. Immediately to the left of the head of the pancreas a long mesentery is developed, which allows the colon to hang down in front of the small intestine, at a considerable distance from the posterior abdominal wall. The portion of the colon so suspended is therefore very movable, and consequently its position is very variable, and is influenced by posture and by the condition of the other viscera. Towards its left extremity the mesentery shortens again, thus bringing the gut towards the tail of the pancreas (Fig. 925), along which it runs upwards into the left hypochondrium, under cover of the stomach, as far as the inferior end of the spleen, where it passes into the left (O.T. splenic) flexure (Fig. 912). Its two ends lie in the right and left hypochondriac regions respectively, whilst its middle portion hangs down into the umbilical, or even the hypogastric region.

Its average *length* is about 19 or 20 inches (47·5 to 50·0 cm.), that is, more than twice the distance, in a direct line, between its two extremities. This great length is accounted for by the curved and somewhat irregular course which the bowel pursues.

Relations.—The greater part of the transverse colon lies behind the greater omentum, which must consequently be turned upwards in order to expose it. *Above*, it is in contact, from right to left (Fig. 928), with the liver and gall-bladder (which also descend in front of the colon), the stomach, and near its left end, with the tail of the pancreas and inferior end of the spleen (Fig. 912). *Anteriorly* are placed the omentum and the anterior abdominal wall; towards its termination the stomach also is anterior. *Posteriorly*, it first lies in contact with the descending duodenum and head of the pancreas; further to the left, where it hangs down, the small intestine is placed below and posteriorly, and it is connected to the posterior abdominal wall by the transverse mesocolon. It is also loosely connected to the stomach by the gastro-colic ligament which is attached to its anterior surface. The transverse mesocolon and the gastro-colic ligament are described with the peritoneum, p. 1155.

The transverse colon is completely covered with peritoneum, with the exception of the first few inches of its posterior surface, which are often, if not usually, uncovered.

The state of the peritoneal covering on the posterior surface of the first part of the transverse colon would seem to depend, in some degree, on the extent to which the liver passes downwards on the right side. With a small, high liver no mesentery is present, and the posterior surface is devoid of peritoneum; on the other hand, when the liver is enlarged in the vertical direction, it pushes the colon downwards before it, and brings the upper line of the peritoneal reflexion from its back, into contact with the lower, thus giving rise to the mesentery. In the fœtus of three or four months every part of the colon is supplied with a long mesentery; subsequently this, as a rule, disappears at the beginning of the transverse colon, but it may be reproduced in the manner stated.

Flexura Coli Sinistra (Left Flexure of the Colon (O.T. **Splenic Flexure**)).—The terminal portion of the transverse colon runs upwards (also posteriorly and to the left) until the inferior end or base of the spleen is reached; here it bends sharply, forming the left flexure, and runs down into the descending colon. The flexure is placed deeply in the left hypochondrium, posterior to the stomach, and in contact with the base of the spleen. It lies at a higher level than the right colic flexure, and is connected to the abdominal parietes by the phrenico-colic ligament, which helps to maintain it in this position.

Ligamentum Phrenicocolicum (Fig. 912).—This is a triangular fold of peritoneum, with a free anterior border, which is attached medially to the left flexure and laterally to the diaphragm opposite the ninth to the eleventh rib. (Owing to the fact that the base of the spleen rests upon it, the ligament has also received the older name of sustentaculum lienis.)

The phrenico-colic ligament is formed in the fœtus from the left margin of the greater omentum (Jonnesco).

The peritoneal covering of the left colic flexure is similar to that of the descending colon.

Colon Descendens.—The **descending colon** is much narrower and less obtrusive than the ascending colon: indeed in a large number of cases it is found firmly contracted. It begins in the left hypochondrium at the left flexure, passes down on the left side of the abdomen, and ends in the lumbar region, opposite the crest of the ilium, by passing into the iliac colon. Its course is not quite straight, for it first curves downwards and medially along the lateral border of the left kidney, and then descends almost vertically to the iliac crest (Fig. 937).

Its *length* is usually from 4 to 6 inches (10 to 15 cm.), and its *width*, which is less than that of the ascending colon, about 1½ inches (37 mm.).

Relations.—The descending colon first lies in contact with the lateral border of the left kidney; below that it is placed, like the colon of the opposite side, in the angle between the psoas and quadratus lumborum muscles. Posteriorly, it rests upon the lower part of the diaphragm above, and on the quadratus lumborum below. Anteriorly (and somewhat laterally also, except when the bowel is distended) are placed numerous coils of small intestine, which hide the colon completely from view, and compress it against the posterior abdominal wall. To its *medial side* lies the inferior part of the kidney above, the psoas major below.

In the great majority of bodies only the front and sides of the descending colon are covered with peritoneum; the posterior surface, being destitute of a serous coat, is connected to the posterior wall of the abdomen by areolar tissue. In a small proportion of cases, on the other hand, the serous coat is complete, and the colon is furnished with a short mesentery.

Up to the fourth or fifth month of fœtal life the descending colon has a complete investment of peritoneum and a long mesentery. After the fifth month the mesentery adheres to, and soon blends with, the parietal peritoneum on the posterior abdominal wall, and is completely lost as a rule. The persistence of this mesentery, in a greater or less degree, explains the occasional presence of a descending mesocolon in the adult.

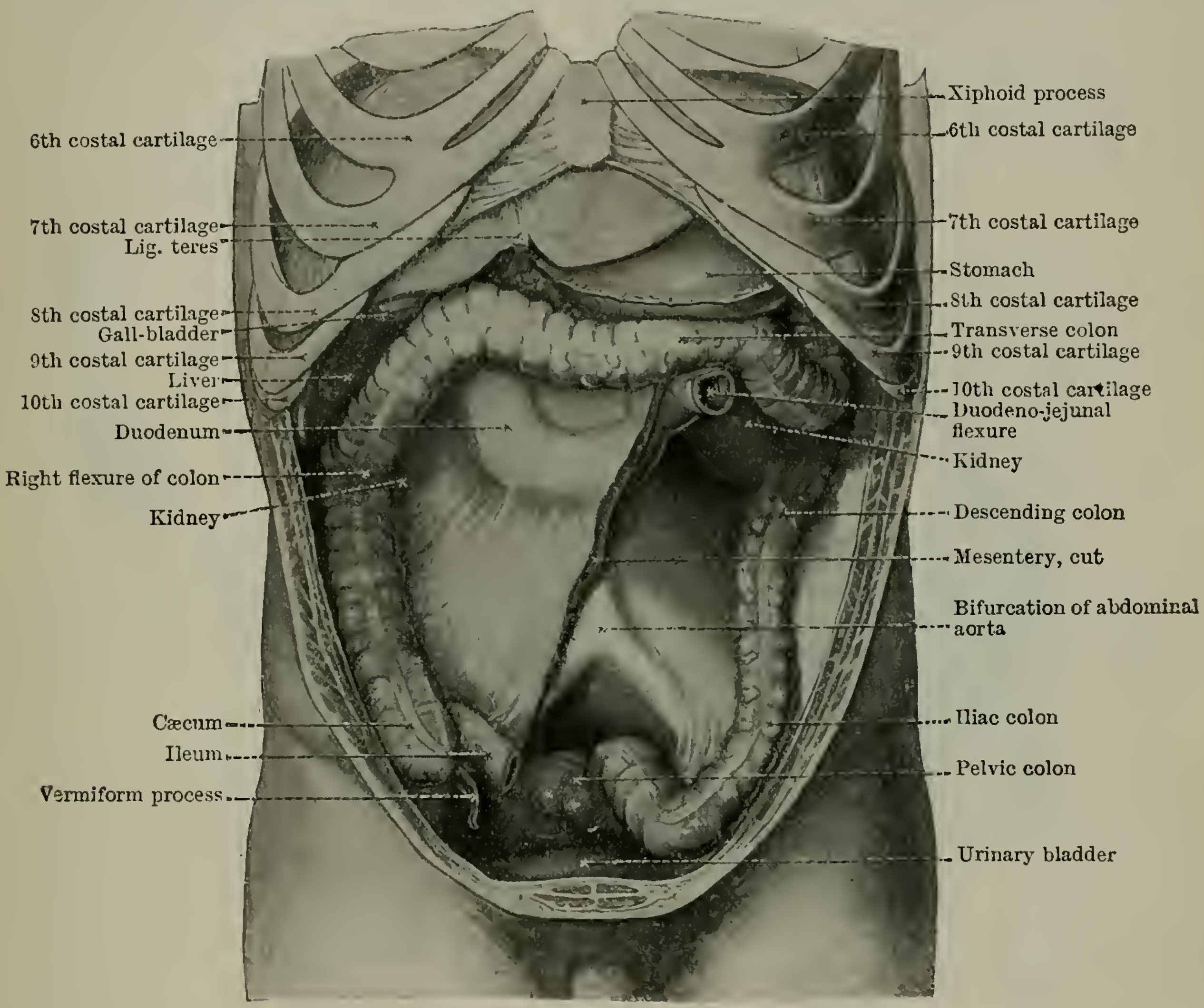


Fig. 937.—The Abdominal Viscera after the Removal of the Jejunum and Ileum (from a photograph of the same body as depicted in Fig. 928). The transverse colon is much more regular than usual.

Iliac Colon.—This corresponds to the portion of the "sigmoid flexure" which lies in the iliac fossa, and it has no mesentery. It is the direct continuation of the descending colon, with which it agrees in every detail, except as regards its relations. Beginning at the crest of the ilium, it passes downwards and somewhat medially, lying in front of the iliacus muscle. A little way above the inguinal ligament it turns medially over the psoas major, and ends at the medial border of this muscle by dipping into the pelvis and becoming the pelvic colon (Fig. 937). It usually measures about 5 or 6 inches (12·5 to 15 cm.) in length, but it varies considerably in this respect.

Relations.—Posteriorly, it lies upon, and, as a rule, is connected by areolar tissue to, the front of the ilio-psoas muscle. It also crosses the left ureter, the left internal testicular or ovarian vessels, and the femoral nerve. Anteriorly, it is usually covered by coils of small intestine, which hide it from view; but when distended, or when it occupies a lower position than usual, it comes into direct contact with the anterior abdominal wall. As a rule (90 per cent of bodies—Jonnesco), it is covered with peritoneum only on its sides and anterior surface. Occasionally (10 per cent of cases) it is completely covered, has a short mesentery (1 inch, 2 to 3 cm.), and is slightly movable.

In its course it passes down over the iliac fossa near its middle, generally forming a curve with its concavity directed medially and upwards, and having reached a point $1\frac{1}{2}$ or 2 inches (4 to 5 cm.) above the inguinal ligament, it turns medially across the psoas major towards the pelvic cavity. Occasionally the iliac colon occupies a lower position than this, and runs along the deep surface of the inguinal ligament, immediately behind the anterior abdominal wall.

Pelvic Colon.—The pelvic colon begins at the medial border of the left psoas major muscle, where it is continuous with the iliac colon, and ends at the level of the third sacral vertebra by passing into the rectum. Between those two points it has a well-developed mesentery, and forms a large and variously shaped coil, which usually lies in the cavity of the pelvis (93 per cent).

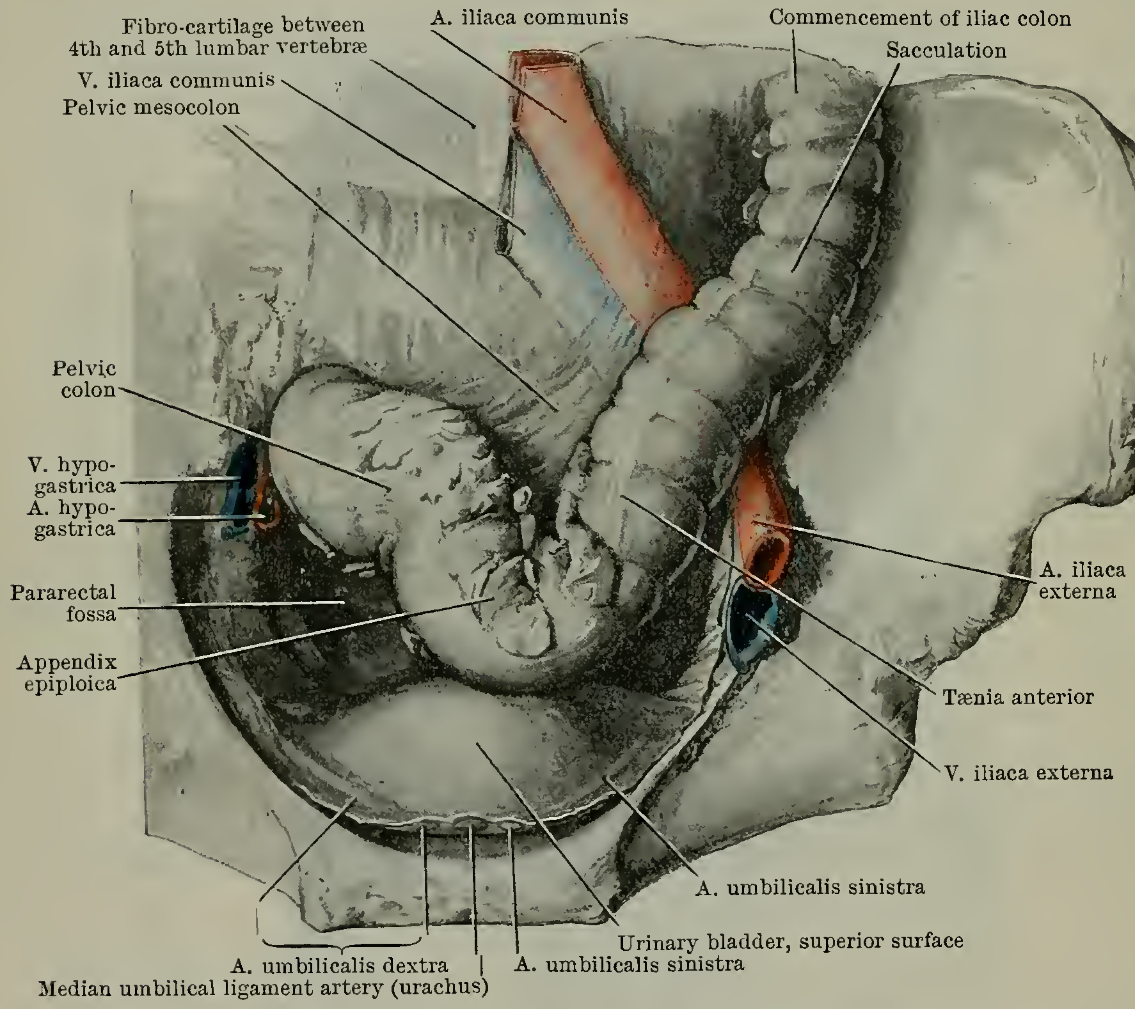


Fig. 938.—The Iliac and Pelvic Colon *in situ.*

Whilst the loop of the pelvic colon is very irregular in form, the following may be given as perhaps its most common arrangement. Beginning at the medial margin of the left psoas major, it first plunges over the brim into the pelvis minor, and crosses that cavity from left to right; it next bends backwards and then returns along the posterior wall of the pelvis towards the median plane, where it turns down and passes into the rectum (Figs. 937 and 938).

In *length,* the pelvic colon generally measures about 16 or 17 inches (40 to 42·5 cm.), but it may be as short as 5 inches (12 cm.), or as long as 35 inches (84 cm.).

Relations.—In its passage into the pelvis it crosses the external iliac vessels; in running from left to right across the cavity, it rests on the bladder or uterus, according to the sex; whilst the coils of the small intestine lie above it.

It is completely covered by peritoneum, and is furnished with an extensive mesentery —the pelvic mesocolon—which permits of considerable movement.

In cases where the pelvic colon is unusually long (Fig. 937), in returning from the right side of the pelvis it crosses the median plane, going even as far as the left wall, and then turns back a second time towards the middle of the sacrum, where it joins the rectum at the usual level, thus making an S-shaped curve within the pelvis. On the other hand, when the loop is short (a not infrequent occurrence), all its curves are abridged, and it fails to pass over to the right side, but runs more or less directly backwards after entering the pelvis.

From what has been said it will be seen that the loop of the pelvic colon is subject to numerous and considerable variations, which are dependent chiefly upon its length and that of its mesentery, and also upon the state of emptiness or distension of itself and of the other pelvic viscera. When the intestine is long the loop is more complex; when short, more simple. When the bladder and rectum are distended, or when the pelvic colon itself is much distended, it is unable to find accommodation in the pelvis minor, and consequently it passes up into the abdominal cavity, almost any part of the lower half of which it may occupy. But, as already stated, in the great majority of cases (92 per cent, according to Jonnesco) it is found after death lying entirely within the pelvic cavity.

The **pelvic mesocolon**, which corresponds to both the sigmoid mesocolon and the mesorectum, is a fan-shaped fold, short at each extremity, and long in its middle portion (Figs. 937 and 938). Its root is attached along an inverted V-shaped line, one limb of which runs up close to the medial border of the left psoas major, as high as the bifurcation of the common iliac artery (or often higher); here it bends at an acute angle, and the second limb descends over the sacral promontory and along the front of the sacrum to the middle of its third piece, where the mesentery ceases, and the pelvic colon passes into the rectum. When the pelvic colon ascends into the abdominal cavity this mesentery is doubled up on itself, the side which was naturally posterior becoming anterior.

Recessus Intersigmoideus.—When the pelvic colon with its mesentery is raised upwards, a small orifice will usually be found beneath the mesentery, corresponding to the apex of the V-shaped attachment of its root to the posterior abdominal wall. This orifice leads into a fossa which is directed upwards, and will often admit the last joint of the little finger. It is known as the *intersigmoid fossa*, and is due to the imperfect blending of the mesentery of the descending colon of the fœtus with the parietal peritoneum. The ureter is found lying behind the apex of this fossa. In the fœtus this mesentery is well developed, and extends from the region of the vertebral column out towards the descending colon. After a time it begins to unite with the underlying parietal peritoneum; but in the region of the intersigmoid fossa the union is rarely perfect, hence the presence of the fossa.

In the **child at birth** only the terminal part of the pelvic colon lies in the pelvis. This is chiefly owing to the small size of the pelvic cavity in the infant. Beginning at the end of the iliac colon, the pelvic colon generally arches upwards and to the right across the abdomen towards the right iliac fossa, where it forms one or two coils, and then passes down over the right side of the pelvic brim into the pelvic cavity. In cases of imperforate anus, it is important to remember, in connexion with the operation for forming an artificial anus, that, whilst the iliac colon is found in the left iliac region, the pelvic colon ("sigmoid flexure") usually lies on the right side, and passes over the right portion of the brim to enter the pelvis.

Structure of the Pelvic Colon.—Only the arrangement of the muscular coat need be referred to. As the tæniæ of the descending colon are followed down, it will be found that the postero-lateral band gradually passes on to the front, and unites with the anterior tænia to form a broad band, which occupies nearly the whole width of this bowel in its lower portion. The postero-medial tænia spreads out in a similar manner on the back; so that in the inferior half of the pelvic colon the longitudinal layer of the muscular coat is complete, with the exception of a narrow part on each side; there the circular fibres come to the surface, and the intestine presents a series of small sacculations. The sacculations disappear, and the longitudinal fibres, although thicker in front and behind, form a continuous layer all round, as the rectum proper is approached.

INTESTINUM RECTUM.

Intestinum Rectum.—The **rectum** is the portion of the large bowel which intervenes between the pelvic colon above and the anal canal—the slit-like passage through which it communicates with the exterior (Fig. 940).

Unlike the portion of the bowel which immediately precedes it, the rectum has but a partial covering of peritoneum, and is entirely destitute of a mesentery; sacculations, too, which are so characteristic of the large intestine, cannot properly be said to be present.

The rectum begins at the termination of the pelvic mesocolon, namely, about the level of the third sacral vertebra, and ends, where the bowel pierces the pelvic floor, opposite the inferior and posterior part of the prostate in the male, or at a point 1½ inches (3·7 cm.) in front of, but at a more inferior level than, the tip of the coccyx in both sexes. It first descends along the front of the sacrum and coccyx, following the curve of these bones; beyond the coccyx, it rests, for about 1½ inches (3·7 cm.), on the posterior part of the pelvic floor, there formed by the union of the two levatores ani; and finally, having reached the inferior part of the prostate, it bends rather abruptly backwards and downwards, pierces the pelvic floor, and passes into the anal canal (Fig. 939).

Its general direction is downwards, but this varies at its two extremities, being downwards and backwards above, downwards and strongly forwards below.

Curvatures.—The rectum is far from straight, notwithstanding its name, for it is curved in both the antero-posterior and the transverse planes. Viewed *from the side,* it forms a gentle curve, with the convexity posteriorly, which extends from the beginning of the rectum to the back of the prostate, and fits into the hollow of the sacrum and coccyx (**flexura sacralis**). At the back of the prostate a second curve (**flexura perinealis**) is formed where the rectum joins the anal canal. The convexity of the perineal flexure is directed forwards, whilst its concavity embraces the **ano-coccygeal body**—the mass of muscular and connective tissue which lies between the tip of the coccyx and the anal canal.

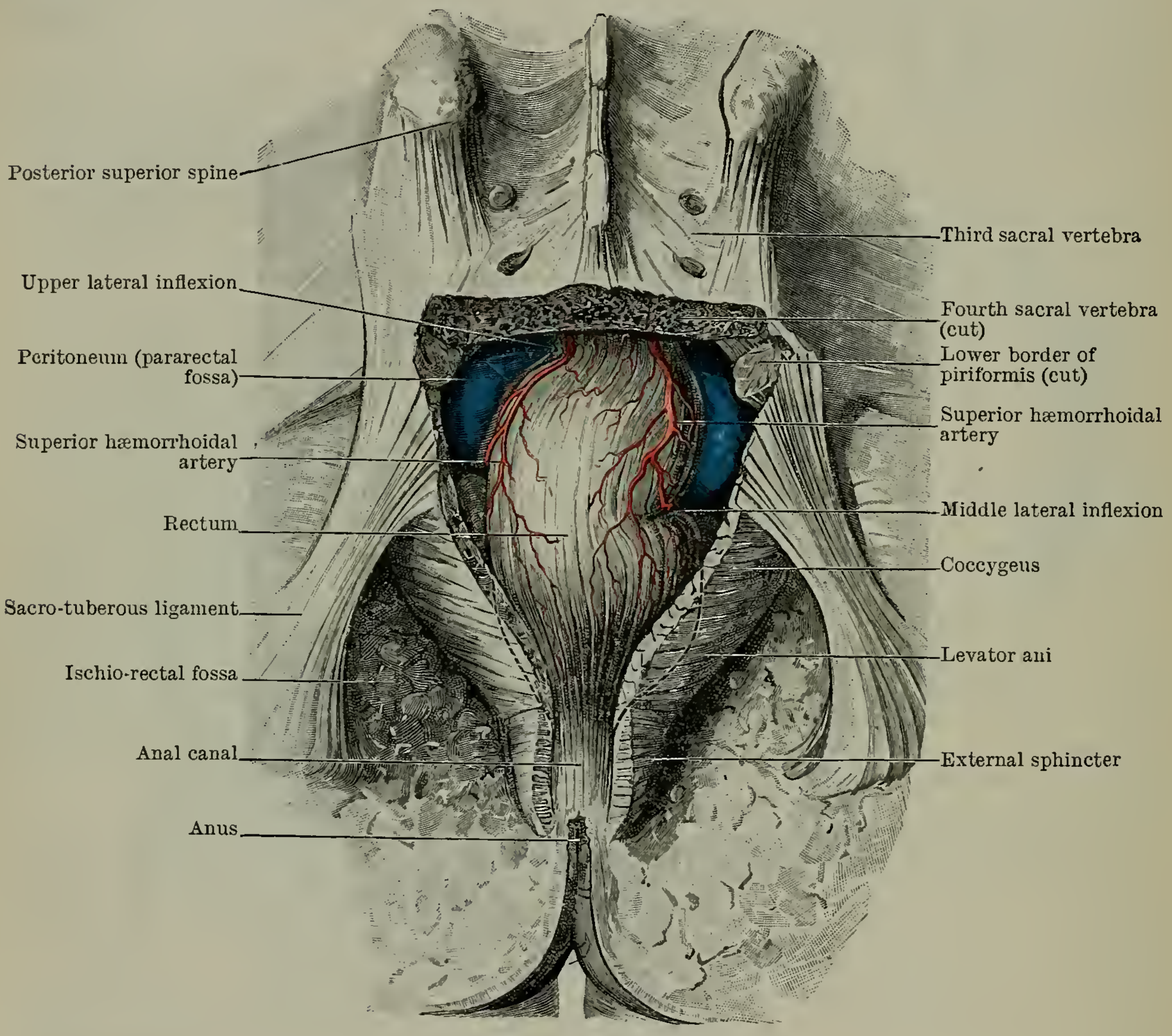


FIG. 939.—THE RECTUM FROM BEHIND.

The sacrum has been sawn across through the 4th sacral vertebra, and its inferior part removed with the coccyx. The posterior portions of the coccygei, levatores ani, and of the external sphincter have been cut away. The "pinching in" of the lower end of the rectum by the medial edges of the levatores ani, resulting in the formation of the flattened anal canal, is suggested in the illustration, which has been made from a formalin-hardened male body, aged 30. The lateral inflexions of the rectum, corresponding to the plicæ transversales recti, are also shown.

When *viewed from the front* the rectum is seen to be regularly folded from side to side in a zigzag fashion, the folding being slightly marked when the rectum is empty, but becoming much more distinct with distension (Figs. 940 and 941). In other words, when viewed from this aspect it presents, in the majority of cases, three more or less distinct lateral flexures or inflexions. Of these the upper and lower have their concavities directed to the left as a rule; the third flexure, which is the best marked, lies between the other two, but on the right side. Not infrequently, however, two are found on the right and one on the left side. The flexures are marked on the exterior by creases, which appear in the interior as three prominent crescentic shelves (Fig. 940), known as the **plicæ transversales recti**, which help to support the fæcal contents when the rectum is distended.

In *length* the rectum usually measures about 5 or 6 inches (12·5 to 15·0 cm.), but it may be much longer.

Its *diameter* is smallest above, near the junction with the pelvic colon, and is greatest below, near the anal canal, where there is a special enlargement known as the **ampulla recti (rectal ampulla)**. When empty the rectum measures little over an inch (2·5 cm.) in diameter, but in a state of extreme distension it may be as much as 3 inches (7·5 cm.) in width.

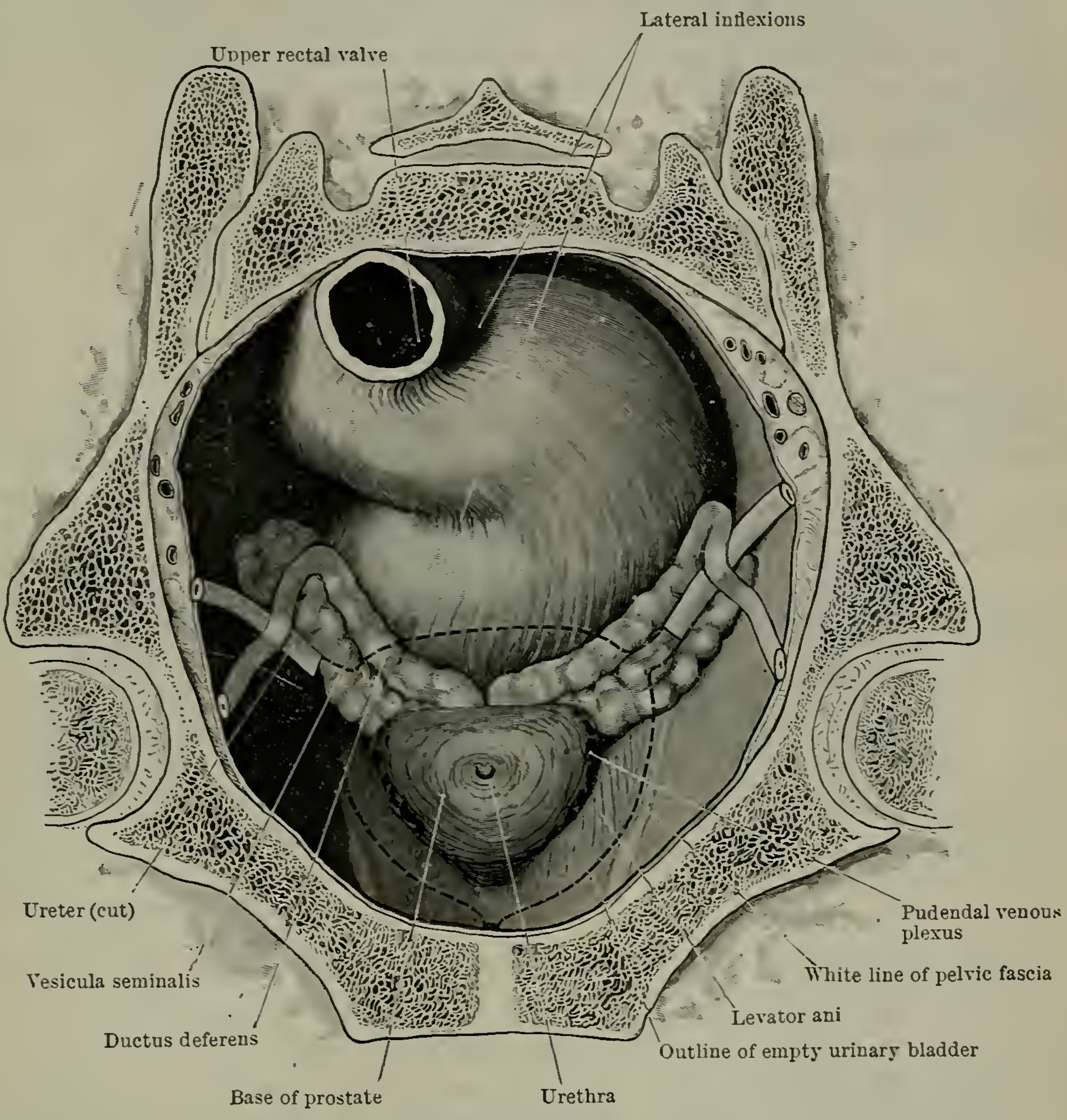


Fig. 940.—Distended Rectum *in situ*.

From a formalin-hardened male body, age 56. The peritoneum and extra-peritoneal tissue were removed, after the pelvis had been sawn along a plane passing through the superior part of the symphysis pubis in front and the lower part of the second sacral vertebra behind. The bladder, which was empty and contracted, has also been removed, but its form is shown by a dotted line. The rectum was very much distended, and almost completely occupied the pararectal fossæ.

This folding is maintained by the arrangement of the longitudinal muscular fibres, the majority of which are accumulated in the form of two wide bands, one on the front, the other on the back of the bowel. These two bands, which are continuous with, and comparable in their functions to, the tæniæ of the colon, are shorter than the other coats of the rectum; hence they give rise, as in the case of the colon, to a folding or sacculation of the tube, which can be effective only at the sides where the longitudinal fibres are fewest, for the front and back are occupied by the thickened longitudinal bands (see p. 1219).

In addition to supporting the fæces, these foldings greatly increase the capacity of the rectum without unduly dilating the tube. When the rectum is empty (Fig. 941) its course is comparatively straight, its lateral flexure being but slightly marked, and its whole calibre very much reduced. In this condition it occupies only a small portion of the posterior division of the pelvic cavity near the median plane, and at each side, between it and the side wall of the pelvis, is a large fossa of the peritoneum, which, when the bowel is empty, contains a mass of small intestine or pelvic colon (Figs. 938 and 941). When the rectum is distended the lateral flexures become much more marked, and the gut, projecting alternately to each side, passes out beneath the peritoneum, obliterating the pararectal fossæ (Fig. 940), and fills the greater part of the posterior division of the pelvis—a condition which could not be brought about with a straight rectum without an enormous increase in all the diameters of the tube.

At its superior end the rectum, following the curve of the sacrum, slopes downwards and at the same time slightly backwards; its middle portion is practically vertical, but the terminal third or more is directed downwards and forwards at an angle varying from 45° to 60° with the horizontal. The pelvic floor, upon which this latter part rests, forms here a similar angle with the horizontal. The bend which the bowel makes behind the inferior end of the prostate, where the rectum passes into the anal canal, is, as pointed out above, abrupt, and usually approaches a right angle, so that the anal canal itself slopes downwards and backwards at an angle of nearly 45° with the horizontal.

Not uncommonly the abrupt curve, at the junction of the rectum with the anal canal, presents in front a knuckle-like projection (well seen on median section), immediately above the canal. It is most marked in females, and sometimes appears as if the bowel were doubled back upon itself at this point. The floor of the pouch thus formed may dip down in front, even below the level of the upper aperture of the anal canal. This condition is most common in multiparæ, and is evidently due to the relaxed condition of the pelvic structures, and the slight support afforded by the perineal body to this part of the gut in these, and the great capacity and shallowness of the pelvis in the female.

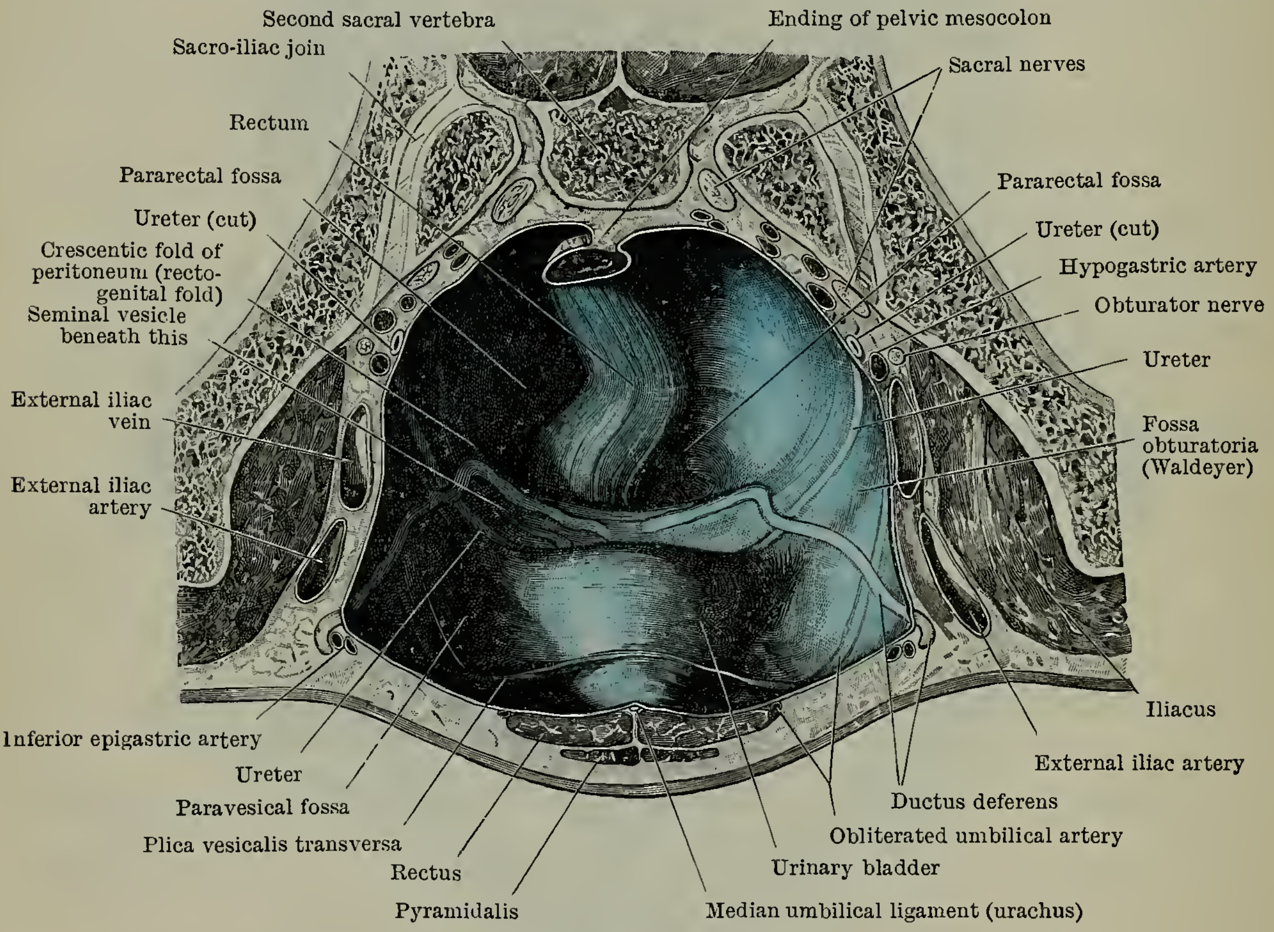


Fig. 941.—The Peritoneum of the Pelvic Cavity.

The pelvis of a thin male subject, aged 60, was sawn across obliquely. Owing to the absence of fat the various pelvic organs are visible through the peritoneum, though not quite so distinctly as presented here. The urinary bladder and rectum are both empty and contracted; the paravesical and pararectal fossæ, as a result, are very well marked.

Peritoneal Relations of the Rectum (Figs. 939, 941).—As a rule the superior two-thirds of the rectum has a partial covering of peritoneum—anteriorly and at the sides at first, lower down anteriorly only—whilst the lowest third has no peritoneal investment whatsoever. When the mesocolon ceases at the end of the pelvic colon, its two layers separate and leave the posterior aspect of the rectum destitute of peritoneum. Very soon the membrane quits its sides also, and is then found on the front only; so that the greater part of the rectum lies behind or beneath the pelvic peritoneum, as it were, and is capable of expanding and contracting without being in any way hampered by its partial peritoneal coat.

From the front of the rectum the peritoneum is carried forwards to the base of the bladder in the male, forming the floor of the **excavatio recto-vesicalis** (**recto-vesical** or **recto-genital pouch**, Fig. 941). In the female it passes to the superior part of the posterior wall of the vagina, forming the floor of the **excavatio recto-uterina [cavum Douglasi]** (O.T. **pouch of Douglas**). At each side, in both sexes, it passes from the front of the rectum on to the posterior wall of the pelvis, forming the bottom of a large fossa, seen at the sides of the rectum when that bowel is empty, and known as the **pararectal fossa**. As the rectum becomes distended this fossa is encroached upon by the enlarging bowel, and soon is obliterated.

The level at which the reflexion of the peritoneum takes place from the front of the rectum is of considerable practical importance in connexion with operations in this region. As a general rule that reflexion, that is, the bottom of the recto-vesical pouch, is placed at a distance of 1 inch (2·5 cm.) above the base of the prostate, or about 3 inches above the anus, but the level is subject to considerable variation, being as a rule relatively much higher in well-developed muscular or fatty subjects, whilst in emaciated bodies, owing to the thinness of the structures forming the pelvic floor, it is usually lower.

The bottom of the recto-vesical pouch may reach down in an extreme case to within an inch (2·5 cm.) of the anus, whilst it is not at all rare to find it within 2 inches (5·0 cm.) of that orifice; on the other hand, it may be considerably higher than normal, sometimes being placed at a distance of 4 or 4½ inches (10·0 to 11·2 cm.) from the anus. It should also be added that the level is generally believed to be somewhat raised by distension of the rectum and bladder, and lowered when they are empty.

In the child at birth, the peritoneum extends down to the base of the prostate (Symington), and is thus lower in relation to the bladder; but this may be partly accounted for by the high position of this organ in the child.

As a rule it will be found that 2 inches (5·0 cm.) of the front of the rectum, exclusive of the anal canal, are entirely free from peritoneum, and it is this and the adjacent portion of the bowel which, being free from the restraining influence of the peritoneum, are most distensible, and form the **rectal ampulla**. Including the anal canal, 3½ inches (8·7 cm.) of the rectum, *measured along the front of the tube*, have no serous covering. On the other hand, the back is free from peritoneum for 5 or 6 inches (12·5 to 15·0 cm.)—or sometimes much more—above the anus.

It is also of interest to notice that the connexion of the peritoneum to the rectum varies in its character at different parts: Above and in front it is closely adherent, and can be removed only with the greatest difficulty; at the sides and inferiorly the connexion is much looser. As a result, the peritoneum can be stripped off the rectum in its inferior third or half without much difficulty, whilst in its superior portion this is not the case—an arrangement which admits of the free expansion of the rectal ampulla.

General Relations of the Rectum (Figs. 939 and 940).—*Posteriorly*, the rectum rests on the front of the sacrum and coccyx, and below them upon the posterior part of the pelvic floor—formed by the meeting of the two levatores ani in the ano-coccygeal raphe. When much distended it also comes into relation, on each side, with the lower part of the piriformis and the sacral plexus, but is separated from them by a very considerable amount of connective tissue, arranged (apparently in several layers) around the tube. In this tissue the two chief branches of the superior hæmorrhoidal vessels lie behind the superior part of the bowel, but lower down they are placed in relation to its sides.

At its sides above are the pararectal fossæ and their contents (pelvic colon, or ileum); below the pararectal fossæ the rectum is in contact with the coccygei and levatores ani muscles, which run backwards to the coccyx on each side of the bowel. The branches of the superior hæmorrhoidal vessels are also found running down on its muscular coat, as far as the middle of the rectum, where they pierce the wall of the bowel.

Anteriorly, in the male the rectum is separated from the bladder, to within an inch of the prostate, by the recto-vesical pouch of peritoneum, which usually contains some coils of small intestine. Below the reflexion of the peritoneum the front of the bowel is in contact with the posterior aspect of the bladder, the deferent ducts, vesiculæ seminales, and the posterior aspect of the prostate gland (Fig. 940), from all of which it is separated by the recto-vesical layer of the pelvic fascia.

The lower portions of the rectum and bladder in the male are separated by the recto-vesical fascia only, over a narrow triangular area which measures about an inch (2·5 cm.) in vertical height. The base of the triangle corresponds to the reflexion of the peritoneum from one organ to the other, and the apex to the union of the sides formed by the deferent ducts, which lie very close to one another except above, near the base of the triangle, where they diverge rather abruptly (Fig. 940). Through the triangle the operation of tapping the bladder from the rectum used to be performed.

The vesiculæ seminales, unless when of a small size, slope laterally and posteriorly round the front and sides of the distended rectum (Fig. 940), which they thus embrace, as it were, within their grasp.

The ureters, as they run medially towards the base of the bladder, lie close in front of the deferent ducts, and are not far separated from the distended rectum (see Fig. 940).

In the female the rectum is separated from the posterior surface of the uterus and the upper end of the vagina by the recto-uterine pouch and the intestine which it usually contains. Below the peritoneal reflexion it is in direct contact with the posterior vaginal wall, to which it is connected loosely above, but more closely below.

The portion of the rectum below the level of the peritoneal reflexion is surrounded by the **rectal fascia**, a layer of connective tissue which is derived from the visceral layer of the pelvic fascia.

In the **child** the rectum, or at least its superior part, is relatively larger, and it pursues a much straighter course than in the adult. As pointed out above, its peritoneal covering likewise descends lower at birth, and reaches as far as the base of the prostate.

PARS ANALIS RECTI—ANAL CANAL.

Pars Analis Recti.—In order to reach the exterior, it is necessary for the lower end of the bowel to pierce the floor of the pelvis. This it does by passing through the narrow interval left between the medial borders of the levatores ani muscles (Fig. 939). As it passes between them, the two muscles pinch in the tube, and by the apposition of its side walls obliterate its cavity, reducing it to a mere slit-like passage. This passage, through which the rectum communicates with the exterior, is the "anal canal" (Symington).

The term **pars analis recti** refers, strictly, to the lower half only of this canal, which is lined by squamous epithelium, and shows the columnæ rectales.

Formerly this terminal portion of the tube was described as the "third part of the rectum," and, like the rest of that bowel, it was supposed to form a reservoir for the retention of the fæces. It is probable that only when the rectum is distended is the superior part of the anal canal occupied by the wedge-shaped lower end of the contained fæcal mass.

The anal canal *begins* where the rectum proper terminates, namely, at the level of the levatores ani muscles, opposite the inferior part of the prostate. Below, the anal canal *ends* at the anus, or anal orifice, by opening on the exterior.

Its *length* is usually from 1 to 1½ inches (2·5 to 3·7 cm.), being greater when the bowel is empty, and less when it is distended. Its antero-posterior diameter when closed varies between ½ and ¾ inch (12 to 19 mm.).

The *direction* of the anal canal, as already pointed out, is downwards and posteriorly, often forming an angle of nearly 45° with the horizontal, although it is usually somewhat nearer to the vertical.

Relations.—It is *surrounded* by both the external and internal sphincters, and above also by the borders of the levatores ani, these muscles forming a muscular cylinder around it (Fig. 943). *On each side* is situated the ischio-rectal fossa with its contained fat, which allows of the distension of the canal during the passage of fæces. *Posteriorly* is placed a mass of mixed connective and muscular tissue, known as the **ano-coccygeal body** (Symington), which intervenes between it and the coccyx. Finally, *anteriorly*, it lies close behind the bulb of the urethra and the base of the urogenital diaphragm in the male, and a sound in the urethra can be easily felt by the finger introduced into the anal canal, particularly in thin bodies. In the female it is separated from the vagina by the wedge-shaped mass of fatty and muscular tissue known as the "perineal body."

Structure of the Rectum and Anal Canal.—The wall of the rectum is made up of four coats, viz.: 1. The outer coat, formed in part by peritoneum (already described), and, where the peritoneum is absent, of connective tissue which can be dissected off in several layers. In this connective tissue the hæmorrhoidal vessels run until they pierce the wall of the tube. In it also, at the back and sides of the rectum, are found embedded a number of rectal lymph glands.

2. The **tunica muscularis**, which is much thicker than in any other portion of the intestine, is composed of two stout layers of unstriped muscle—an outer longitudinal and an inner circular—like that of the intestine generally. The *longitudinal fibres*, although present all round, are

accumulated chiefly on the front and back of the tube (see p. 1215), where they form two broad bands; at the sides they are reduced to a thin layer, the deepest fibres of which are folded in and take part in the formation of the rectal valves.

Where the rectum pierces the floor of the pelvis, the outer layer of longitudinal fibres is united to the deeper portion of the levator ani, partly by tendinous fibres and partly by an interchange of muscular fibres, between the levatores and the muscular coat of the rectum. Below, the longitudinal fibres pass between the external and internal sphincter muscles, or through the latter to join the skin around the anus.

In sagittal sections of the pelvis near the median plane there can generally be seen a distinct band of red, longitudinally arranged, muscular fibres, which descends on each side from the front of the coccyx to blend with the longitudinal fibres on the back of the rectum. This band is the **rectococcygeus muscle.** It is composed of striped fibres above, but becomes unstriped below.

Some unstriped muscular fibres which are found descending in the subcutaneous tissue of the lower part of the anal canal, to join the skin around the anus, have been described by Ellis as the **corrugator cutis ani.** According to Roux, they are some of the longitudinal fibres of the rectum which have passed through the internal sphincter to the submucous tissue, and then descended to the skin. The front of the rectum at the perineal flexure is, in the male, connected to the back of the membranous urethra by a band of muscle, termed the **recto-urethralis.**

The *circular fibres* form, along the whole length of the tube, a continuous layer, which is doubled inwards to assist in the formation of each rectal valve, and is thickened below to form the **internal sphincter** of the anus. The **sphincter ani internus,** as just pointed out, is formed by a great, and rather sudden, increase of the circular muscular fibres, which begins at the superior end of the anal canal. It surrounds the canal for about an inch (2·5 to 3·0 cm.), and terminates at its junction with the skin.

3. The **tela submucosa** is composed of loose areolar tissue, which allows of a free movement of the mucous layer on the muscular coat, and which also admits, under certain abnormal conditions, of a prolapse of the mucous membrane through the anal orifice. The hæmorrhoidal plexus of veins is contained in this layer.

4. The **tunica mucosa** must be considered separately in the rectum and pars analis recti. That of the rectum is redder in colour than the mucous membrane of the colon, as a result of its greater vascularity. It is also thicker, and owing to the looseness of the underlying submucosa, is thrown into numerous irregular rugæ when the rectum is empty; these disappear when the bowel is distended, and there then become evident three (sometimes more, sometimes less) crescentic folds, which are much less noticeable in the empty state, and which have been already referred to as the plicæ transversales recti. Lymph nodules and intestinal glands are present; but these latter are not so numerous as in the colon, although their calibre is greater.

The *mucous membrane of the pars analis recti* presents a number of vertical ridges known as the *columnæ rectales* (Morgagnii); between the lower ends of these are found a series of small semilunar folds which connect the lower ends of these columns together and are called the *anal valves* (Fig. 942). Above the level of the anal valves the canal is lined by a modified mucous membrane resembling that of the rectum; the portion below the valves (*i.e.* the lower 12 to 16 mm. of the canal) is covered by modified skin, continuous with that around the anus.

The term *annulus hæmorrhoidalis* is applied to the segment enclosed by the sphincter externus muscle. It extends from the region of the rectal sinuses to the anal orifice, and in its wall is found the large venous plexus termed the *plexus hæmorrhoidalis.*

The mucous membrane of the rectum presents a characteristic punctated appearance, which is due to the presence of a considerable number of rounded depressions, such as might be made by firmly pressing a finely pointed pencil against the membrane. These *rectal pits* are tubular in form, and have an accumulation of lymph tissue at the bottom of each, the whole appearance being such as might be produced if a small solitary nodule were drawn down from the surface into the intestinal wall.

Plicæ Transversales Recti (Houston).—These are crescentic shelf-like folds which project into the cavity of the rectum (Fig. 942). They are composed of an infolding of the mucous, submucous, and greater part of the circular muscular coats, and their form is preserved by the relative shortness of the anterior and posterior bands of longitudinal muscular fibres. They are produced, as pointed out above, by the projection, into the interior of the bowel, of the creases on the exterior which result from the lateral inflexions of the rectum. In the majority of cases three are present (there may be four, five, or, it is said, even more), but often the lowest of the three is small or absent; or all the valves may be ill-developed and indistinct. They are most evident in a distended rectum which has been hardened *in situ*; they can also be seen during life, *per anum,* with the aid of a rectal speculum.

As a rule two valves are found on the left and one on the right side; this latter is generally the largest, and is situated a little above the level of the peritoneal reflexion, viz., 3 or 3½ inches (7·5 to 8·7 cm.) above the anus; the other two valves are found about 1 to 1½ inches (2·5 to 3·7 cm.) higher up and lower down respectively. The valves are distinctly marked in the fœtus, and seem to constitute an essential part of the human rectum, their use being to support the contents of the rectum, which they break up into segments, each supported by a valve. They are said to interfere sometimes with the introduction of an enema tube.

Columnæ Rectales [Morgagnii].—The mucous membrane of the pars analis recti, or lower portion of the anal canal, presents a number (5 to 10) of *permanent* vertical folds, separated by grooves, and known as the **columnæ rectales** (O.T. **columns of Morgagni**) (Fig. 942). They are usually ⅓ to ½ inch (8 to 12 mm.) in length, ⅛ to ¼ inch (3 to 6 mm.) in width, and they extend down to within ½ or ⅔ inch (12 to 20 mm.) of the anal aperture. They are formed by infoldings of the mucous membrane, containing in their interior some bundles of longitudinal muscle and also, as a rule, an artery and a vein.

Very often the contained vein presents an enlargement, or a knob-like tortuous plexus in the lower part of the column; below this the plexus is continued down *external* to the mucous membrane of the lower zone of the anal canal into the anal veins. This portion has accordingly been described as the hæmorrhoidal zone of the anal canal. Sometimes the columns are very indistinct; occasionally no trace of them can be found, although in the fœtus they are usually well marked.

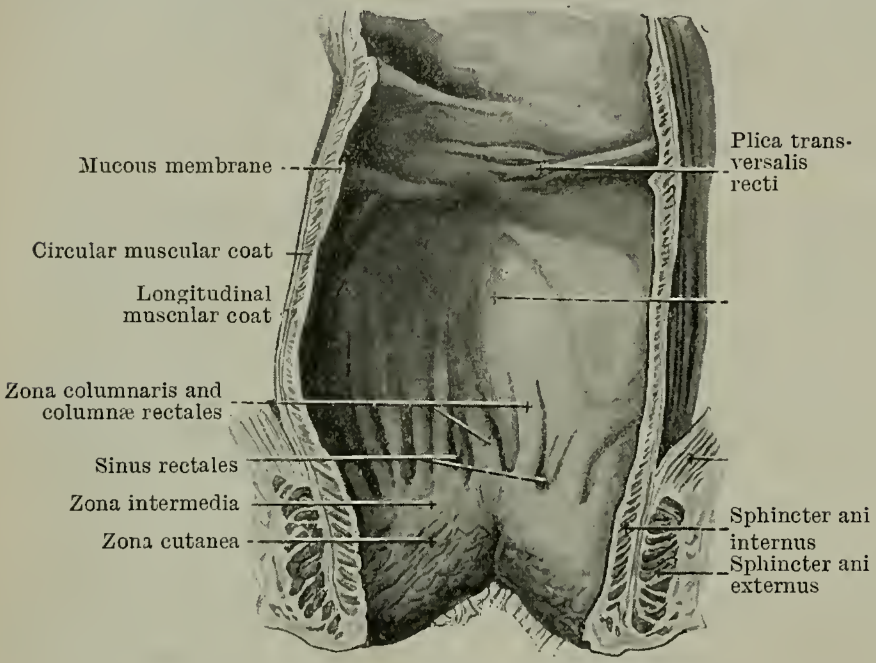


FIG. 942.—INTERIOR OF THE ANAL CANAL.

Anal Valves.—If a probe is passed downwards along the groove which separates two adjacent columnæ rectales (Fig. 942), its point will usually catch in a small crescentic fold which joins the lower ends of the two columns. These little folds, which resemble in miniature the segments of the semilunar valves of the heart, are the anal valves. They project inwards and upwards, and behind each is found a little pocket-like sinus (**sinus rectalis**).

Anus or Anal Orifice.—At the inferior aperture of the anal canal, the modified skin of its lower zone passes into the ordinary skin.

The junction of the parts derived from endoderm and ectoderm respectively (see Development of Cloaca, p. 53) cannot be readily determined. The skin round the margin of the anus possesses hair follicles and glands (circum-anal glands) and forms a zone, termed the cutaneous zone.

Within this zone is a second one, zona intermedia, not sharply marked off, but separated by the ano-cutaneous line, which is taken to be the line beyond which hairs occur. It is lined by a stratified squamous epithelium.

The third zone—the zona columnaris—corresponds to the region of the rectal columns, and is lined by columnar epithelium.

It is clearly marked off from the intermediate zone by a line which is abrupt, and follows the level of the anal valves, and crosses the bases of the columns between the valves.

This sinuous line is the "ano-cutaneous line" of Hermann or the "white line" of Hilton.

Action of the Sphincters.—In connexion with the anal canal are found three muscles—namely, the paired levatores ani, the external sphincter, and the internal sphincter—the action of which may be briefly referred to here.

Levator Ani.—The fibres of the levator which arise from the pubis (pubo-coccygeus or sphincter recti portion) pass backwards on each side of the beginning of the anal canal, and, in great part, meet behind the passage. These two muscular bands—which are but a little distance apart at their origin, and are actually united behind the bowel—are closely approximated during the contraction of the muscles, like the limbs of a clamp, and, pressing on the sides of the anal canal, they assist in closing the upper part of that passage, whilst at the same time drawing it slightly towards the pubes. There is little doubt that the levator ani in this way acts as one of the chief sphincters of the bowel; and it should be noticed that it is placed where its action would be most effective, namely, opposite the point at which the rectum is narrowed or "pinched in" to form the anal canal. In addition to its sphincter action the muscle supports the expanded bowel immediately above the anal canal, and in this way sustains the weight of the fæces when the rectum is distended. It is probably relaxed during defæcation, except perhaps at the completion of the act. The muscle is under the control of the will.

The **m. sphincter ani externus** forms a muscular cylinder around the inferior two-thirds of the anal canal, with (except in the case of some of its inner fibres) an anterior and a posterior attachment. When the muscle contracts, its fibres are tightly stretched between its two attachments, and the space between them is reduced to a narrow antero-posterior slit. By this action the anal canal is flattened from side to side and closed, so that, whilst the levator ani is the sphincter of the upper aperture of the anal canal, the external sphincter closes its inferior and greater part. It is under the control of the will, but under ordinary circumstances it is in a state of tonic contraction.

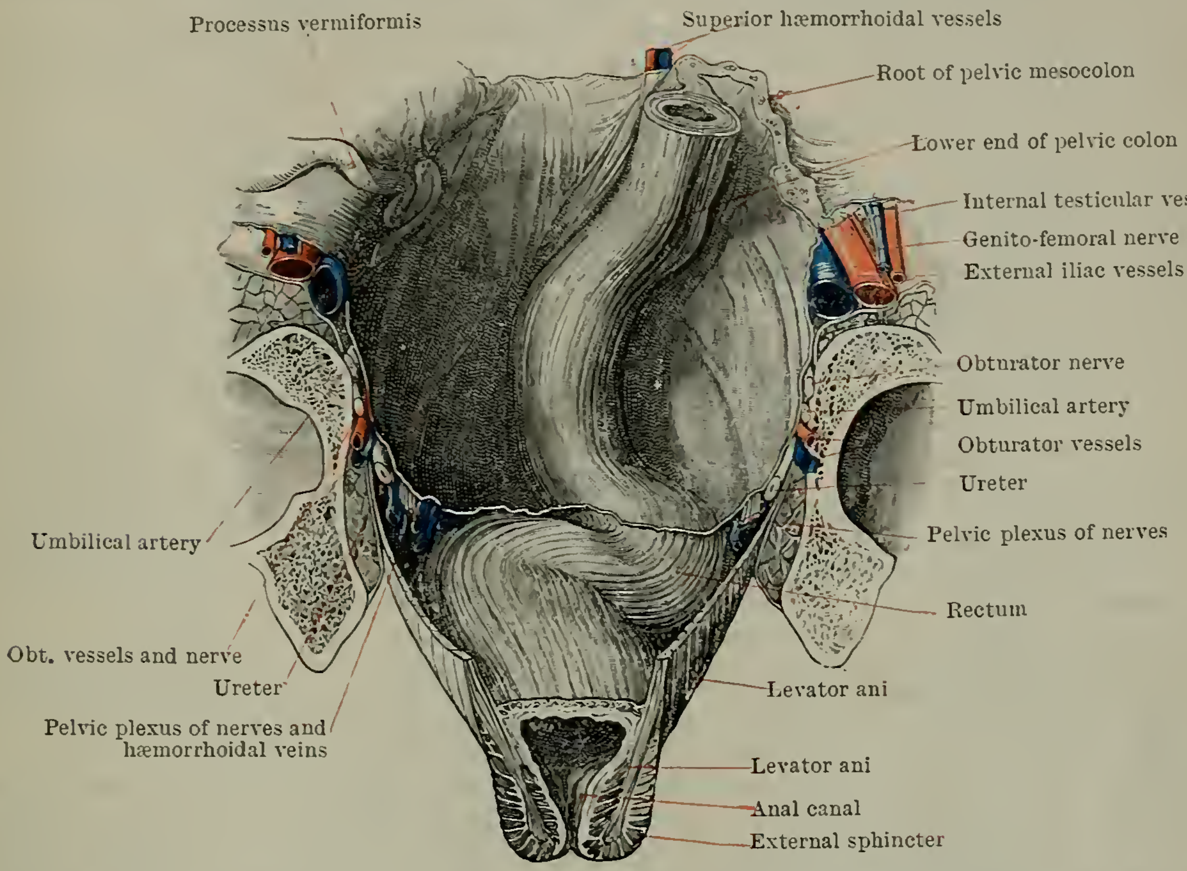


FIG. 943.—DISSECTION OF THE RECTUM FROM THE FRONT IN A SPECIMEN HARDENED BY FORMALIN INJECTION.

The front wall of the pelvis has been removed, and the bladder, prostate, and seminal vesicles taken away.

The **m. sphincter ani internus** is merely a thickening of the circular muscular coat at the inferior end of the bowel. It is continuous with the circular fibres of the gut, not only in structure, but probably also in action, its chief use being to empty the anal canal completely, after the passage of each fæcal mass. Owing to the fact that the canal is an antero-posterior slit, not a circular orifice, and that the internal sphincter forms a muscular ring around it, acting alone, it is scarcely competent to keep the sides of the canal in apposition, and probably it acts rather as a detrusor than a true sphincter of the anal passage.

Vessels.—The rectum and anal canal receive their blood supply from three chief sources, namely, the three hæmorrhoidal arteries; to these another less important, though constant, source may be added—the middle sacral artery.

1. The **superior hæmorrhoidal artery**, the principal artery of the rectum, is the prolongation of the inferior mesenteric. At first it descends in the root of the pelvic mesocolon until the rectum is reached. Here it divides into two chief branches which run downwards and forwards around the sides of the rectum—the right, usually the larger, lying more posteriorly, the left more anteriorly, and the two, as it were, embracing the bowel between them. From these two arteries come off secondary branches (about five to eight in all), which pierce the muscular coat about the middle of the rectum, and then descend in the submucosa as a series of longitudinally running "terminal branches" as far as the anal valves, above the level of which one is usually found beneath each of the rectal columns. These terminal branches give off numerous twigs in their course, which form a hæmorrhoidal plexus in the submucosa by

anastomosing with one another, and also with branches of the middle, and, in the inferior part of the bowel, of the inferior hæmorrhoidal artery.

2. The **middle hæmorrhoidal arteries**, two in number—one on each side—are usually branches of the hypogastric or of the internal pudendal; they run on the wall of the inferior part of the rectum, and each breaks up into four or five small branches, some of which supply the muscular wall of the inferior part of the rectum, whilst the others pierce the muscular coat near the superior end of the anal canal, and join in the submucosa with the plexus formed by the superior hæmorrhoidal artery already described.

3. The **inferior hæmorrhoidal arteries**, generally two or three in number on each side, arise at variable levels from the internal pudendal. They are distributed to the levatores ani and the sphincters. Other branches pierce the sphincters and break up in the submucosa into a close network which supplies the inferior part of the anal canal, and communicates above with the plexus formed by the superior and middle hæmorrhoidal arteries. The inferior hæmorrhoidal artery is distributed chiefly on the posterior, and the middle hæmorrhoidal chiefly on the anterior aspect of the lower part of the bowel.

4. One or more small branches of the **middle sacral artery** reach the posterior surface of the rectum, where they are distributed chiefly, if not solely, to the muscular coat.

Anastomosis of the Hæmorrhoidal Arteries.—The superior and middle hæmorrhoidal arteries anastomose freely in the hæmorrhoidal plexus of the submucosa, and also by a few large branches on the exterior of the bowel: some perforating branches of the middle sacral and inferior hæmorrhoidal arteries also join the plexus in the submucous layer at the lower part of the rectum. In addition, small branches of these several arteries unite with one another in the muscular coat. It should be remarked that the superior hæmorrhoidal artery supplies both the muscular and mucous coats in the superior part of the rectum, but the muscular coats in the inferior part are supplied by the middle and inferior hæmorrhoidal vessels only.

Veins of the Rectum and Anus.—These form two chief plexuses of large vessels devoid of valves, namely, the internal hæmorrhoidal plexus situated in the submucous coat, and the external hæmorrhoidal plexus in the outer coat. The **internal hæmorrhoidal plexus** takes origin near the margin of the anus in a number of small (anal) veins, which are radially disposed beneath the skin of the anus, and communicate below with the rootlets of the inferior hæmorrhoidal vein over the external sphincter. These **anal veins**, traced upwards, join together, and are joined by others from the surrounding parts to form larger and often tortuous vessels, which ascend in the columnæ rectales, where they frequently present ampullary enlargements, varying in size up to that of a small pea, which are said to be the starting-points of hæmorrhoids. Passing upwards, the veins are known as the "terminal veins"; they communicate freely with one another, forming the plexus, and unite into still larger vessels, which pierce the muscular coat about the middle of the rectum, and join to form the superior hæmorrhoidal vein.

From the inferior part of the internal hæmorrhoidal plexus numerous vessels pass through the external sphincter to join a venous network on the outer surface of that muscle, from which the **inferior hæmorrhoidal veins** arise. This network, as pointed out above, also communicates with the internal hæmorrhoidal plexus, through the anal veins which descend from the latter beneath the skin of the anal canal, to the exterior of the sphincter.

The various veins which pass out through the walls of the rectum unite freely on its exterior to form a rich venous plexus (**external hæmorrhoidal plexus**), through which the three hæmorrhoidal vessels are brought into free communication with one another. Passing off from this plexus, the **superior hæmorrhoidal** joins the left colic vein and forms with it the inferior mesenteric vein, which opens into the splenic; the middle hæmorrhoidal joins the hypogastric, from which the blood passes through the common iliac to the vena cava inferior; and the inferior hæmorrhoidal joins the internal pudendal, a tributary of the hypogastric vein. Thus, on the rectum, a free anastomosis is established between the veins of the portal and systemic circulations.

Lymph Vessels.—Most of the lymph vessels of the rectum pass to the lymphoglandulæ sacrales, of which some lie close to the muscular coat on the side of the rectum along the superior hæmorrhoidal vessels, while others, four or five in number, and of a larger size, lie in front of the promontory of the sacrum, between the layers of the pelvic mesocolon. The glands of opposite sides are connected with one another by the middle sacral plexus and with the hypogastric and mesocolic lymph glands. The efferent vessels from these pass to the lumbar glands. Some of those from the lower part of the anal canal join the cutaneous lymph vessels round the anus, and pass with them to the inguinal and subinguinal glands. A few of the lymph vessels from the lower portion of the rectum are said (by Quenu) to join the hypogastric glands.

Nerves.—The nerves of the rectum come partly from the sympathetic and partly from the cerebro-spinal system. The sympathetic fibres are derived from the inferior mesenteric plexus, through the superior hæmorrhoidal nerve and the corresponding plexus, and from the upper and lower divisions of the hypogastric plexus, the former accompanying the superior hæmorrhoidal, the latter the middle hæmorrhoidal vessels, to the rectum. The cerebro-spinal fibres arise from the second, third, and fourth sacral nerves soon after these leave the sacral foramina (and constitute the "pelvic splanchnics" of Gaskell). They run forward in the pelvic connective tissue, and joining the pelvic plexuses, reach the side of the rectum. Fibres of the inferior hæmorrhoidal branches of the pudendal nerve (third and fourth sacral) are also distributed to the lower part of the anal canal as well as to the external sphincter.

It has been shown by experiments on animals, that the cerebro-spinal nerves (from the second, third, and fourth sacral) convey motor impulses to the longitudinal fibres, but inhibitory impulses to the circular muscular fibres. In like manner the branches from the sympathetic convey motor fibres (derived from some of the lumbar rami communicantes) to the circular muscle, and inhibitory fibres to the longitudinal muscle of the rectum.

The reflex centre which governs the action of the sphincters and the muscular fibres of the rectum ("defæcation centre") is situated in the lumbar region of the spinal medulla, and appears to be capable of carrying out the whole act of defæcation even when separated from the brain.

Variations.—The best known anomalies found in connexion with the rectum are those classed under the term **imperforate anus** or **atresia ani.** The atresia may be simply due to a partial or complete persistence of the anal membrane (see p. 46), which separates the proctodæum from the hind-gut in the embryo (atresia ani simplex); or the hind-gut may be deficient in its lower part, when there is a considerable interval between the proctodæum and the gut (defectus recti partialis, vel totalis); or the rectum may open into the vagina, the uterus, the bladder, or the ureters, when usually no anus is evident; or finally the cloaca may persist. Other forms are also described, but the foregoing are those most commonly found.

For the **development** of the rectum and anus, see pp. 53 and 55.

PERITONEUM.

As already explained, the peritoneum is the serous membrane which, on the one hand, lines the abdominal cavity, and on the other forms a more or less complete covering for the contained viscera. The portion which lines the walls of the cavity is known as the **parietal peritoneum**; that which clothes the viscera is called the **visceral peritoneum.** The membrane is connected to both walls and viscera by a layer of areolar tissue—**tela subserosa**, the extra or subperitoneal connective tissue.

The peritoneal cavity is described as consisting of two portions—the general peritoneal or **great sac** and the **bursa omentalis.** The great sac is opened when the anterior abdominal wall is removed or incised, and the peritoneum which encloses it lines the greater portion of the wall of the abdominal cavity, and invests most of the abdominal viscera; the omental bursa lies chiefly on the posterior aspect of the stomach, and is much smaller. It must be clearly understood that these two sacs are not two separate cavities, but simply subdivisions of one great cavity; for the omental bursa is merely a recess of the greater sac, from which it has become partly shut off largely by changes that take place in the position of the adjacent viscera during their development. If the general peritoneal cavity is compared to a bag, the bursa omentalis might be represented as a pocket lying behind, and opening into it by a narrow orifice—the foramen epiploicum [Winslow].

The **general peritoneal sac** is placed between the parietes anteriorly and the abdominal viscera posteriorly. It is composed of two layers: an anterior, which lines the anterior abdominal wall; and a posterior, which mainly covers the viscera; but this posterior layer is carried forwards by the viscera, so that the two layers come in contact, and the cavity of the sac is practically obliterated.

The **anterior layer of the peritoneum** covers the anterior abdominal wall completely, from the diaphragm above to the pelvis below. Over the greater part of its extent the connexion of the serous membrane to the wall is by a small amount of fatty extra-peritoneal connective tissue; but below, near the pubic region, the fat is more abundant, and the connexion between the two becomes much looser. This is to allow of the movement of the peritoneum which takes place there during distension of the bladder. As the bladder enlarges it passes up in the extraperitoneal tissue of the lower part of the anterior abdominal wall, off which it raises the peritoneum, so that, in the fully distended condition, the anterior surface of the bladder is in contact with this wall, without the interposition of peritoneum, for a distance of two inches (5·0 cm., or occasionally more) above the pubes (Fig. 944).

Running up in the fatty subserous tissue are found five cord-like structures, one placed in the median plane, and two at each side. These are (*a*) the **lig. umbilicale medium** (O.T. **urachus**)—the remains of the allantois of the fœtus—which in the adult is a slender fibrous band connected to the umbilicus above, and to the apex of the bladder below, where it usually becomes much stouter. Lateral to the urachus, and some distance from it (Fig. 941), will be found, in the same fatty tissue, (*b*) two stouter fibrous cords, the obliterated **umbilical arteries** (O.T. **obliterated hypogastric arteries**), forming the **plica umbilicalis lateralis dextra** and **sinistra.** Traced upwards, these also become more slender, and approach the urachus, along with which they are connected to the umbilicus. Below, they grow thicker, and can be followed backwards along the side wall of the pelvis to the hypogastric arteries, which they join. (*c*) More laterally still, the **inferior epigastric arteries** are seen running upwards and medially from the external iliac trunk on each side.

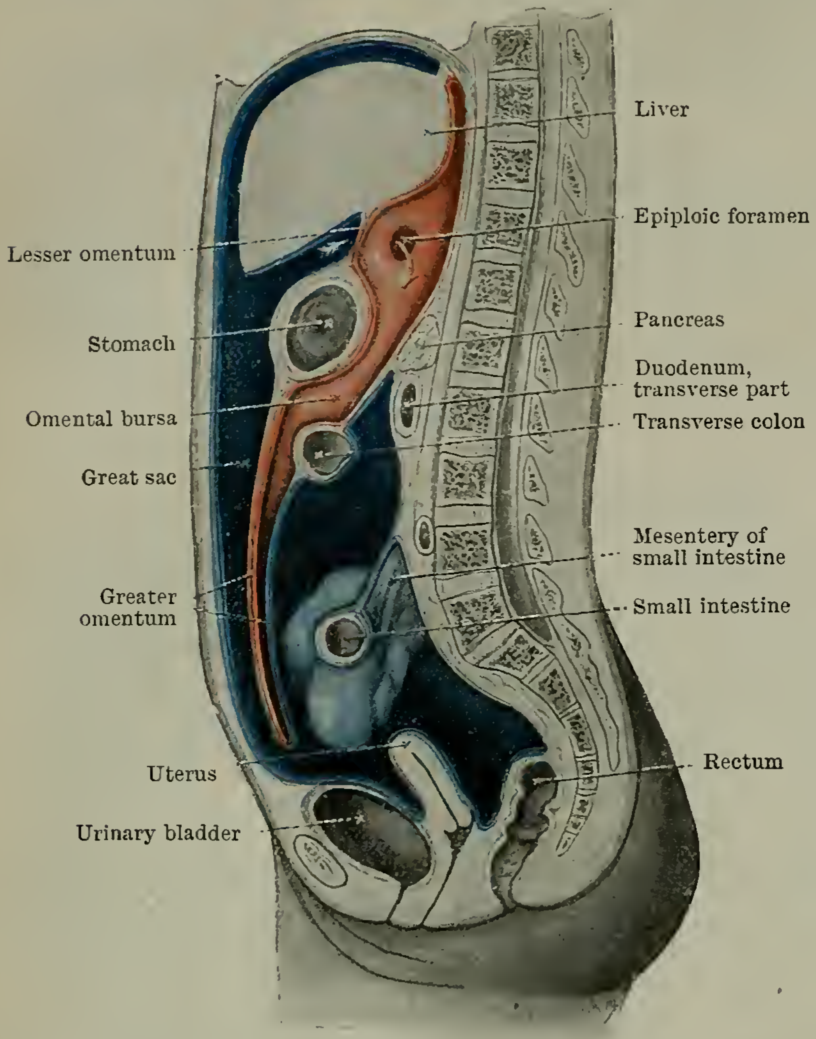


Fig. 944.—Diagrammatic Median Section of Female Body, to show the abdomino-pelvic cavity and the peritoneum on vertical tracing. The great sac of the peritoneum is blue and is represented as being much larger than in nature; the bursa omentalis is coloured red; the peritoneum in section is shown as a white line: and a white arrow is passed through the epiploic foramen from the great sac into the bursa omentalis.

When the anterior abdominal wall is examined from behind, it will be seen that these five structures, which lie on the front of the peritoneum, carry that membrane inwards towards the abdominal cavity in the form of five more or less distinct ridges, known as the **plica umbilicalis media, plicæ umbilicales laterales,** and **plicæ epigastricæ,** respectively. In relation to these are found on each side three peritoneal fossæ, known as the **foveæ inguinales** (O.T. **inguinal pouches** or **fossæ**).

The **fovea inguinalis lateralis** lies lateral to the inferior epigastric artery, and corresponds to the position of the abdominal inguinal ring. At its bottom is often found a dimple-like depression of the peritoneum, indicating the point from which the processus vaginalis passed down, in connexion with the descent of the testis. The **fovea inguinalis medialis** is situated between the inferior epigastric and the obliterated umbilical arteries; whilst the **fovea supravesicalis** lies to the medial side of the obliterated umbilical artery, namely, between it and the urachus.

Between the inferior epigastric artery laterally, the margin of the rectus abdominis muscle medially, and the inguinal ligament below, there is a small triangular region, called Hesselbach's triangle. The obliterated umbilical artery, in passing upwards, crosses this triangle, dividing it into a lateral and a medial part. The middle inguinal fossa corresponds to the lateral division of the triangle, and the medial fossa to its medial division.

Still another fossa of the peritoneum is seen in this region, just beneath the medial part of the inguinal ligament, corresponding to the position of the femoral ring, and consequently known as the **fovea femoralis.** It may be added that the ductus deferens crosses the lateral part of the fovea femoralis, and the obliterated umbilical artery its medial part. The significance of those fossæ is referred to in connexion with the applied anatomy of the inguinal and femoral regions.

Near the median plane, above the umbilicus, the peritoneum is carried back from the anterior abdominal wall and diaphragm to the parietal surface of the liver in the form of a crescentic fold, the **falciform ligament** of the liver (described with the liver), which connects the liver to the abdominal wall. This fold lies somewhat to the right of the median plane, and extends almost as low down as the umbilicus. It consists of two layers of peritoneum, between which, in the lower border of the fold, runs the round ligament of the liver—the remains of the left umbilical vein of the fœtus.

Posterior Wall of the General Peritoneal Cavity.—The peritoneum clothing the anterior abdominal wall is continued on to the inferior surface of the diaphragm. Thence it is reflected on to the superior surface of the liver, turns round its anterior border, and is continued back on the inferior surface as far as the attachment of the lesser omentum, where it quits the liver and passes down, as the anterior layer of the lesser omentum, to the stomach and the duodenum.

The line of reflexion of the peritoneum from diaphragm to liver is interrupted near the median plane by the falciform ligament. The portion lying to the right of this fold forms the superior layer of the coronary ligament; that to the left of it, the superior layer of the left triangular ligament of the liver.

The extent to which the peritoneum passes uninterruptedly back on the inferior surface of the liver varies according as it is traced at the right, the left, or the middle portion of the liver. It clothes the right portion as far back as the inferior edge of the uncovered area of the liver, where it is reflected on to the posterior wall of the abdomen and the superior extremity of the right kidney (constituting the hepato-renal ligament), as the inferior layer of the coronary ligament. On the left portion it is continued back as far as the posterior border of the left lobe—or even a little way on to its superior surface—whence it passes to the diaphragm as the inferior layer of the left triangular ligament. The middle region of the under surface it clothes only as far as the porta hepatis and the fossa of the ductus venosus; from those the peritoneum is carried down as the anterior layer of the lesser omentum.

The peritoneum, on the inferior surface of the diaphragm to the left of the liver, is continued down on the posterior abdominal wall, behind the fundus of the stomach and the spleen, until the left kidney is reached. It covers the superior and lateral part of the kidney, and is then carried forwards as the **lieno-renal ligament** to the spleen, around which it passes —clothing its renal, phrenic, and gastric surfaces—as far as the hilum (Fig. 946); from that it is carried to the stomach as the left layer of the **gastro-splenic ligament**. Similarly, the inferior layer of the left triangular ligament is continued down on the posterior part of the diaphragm to the œsophagus, the anterior and left sides of which it clothes. It also forms a little fold at the left of the œsophagus, known as the **gastro-phrenic ligament** (see p. 1163 and Fig. 912).

At the right side, the portion of the peritoneum which forms the inferior layer of the coronary ligament is carried down over the right kidney (and inferior part of the supra-renal gland) to the duodenum and right colic flexure, over both of which it passes.

We shall now follow down the peritoneum forming the posterior wall of the general peritoneal cavity—which we have already traced to the stomach—as seen in a sagittal section (Fig. 944).

Having reached the lesser curvature of the stomach, it passes down over the front of that organ, clothing it completely as far as the greater curvature. From that it descends, and is usually adherent to the transverse colon, forming the anterior layer of the gastro-colic ligament. Thence it passes onwards as the most anterior fold of the greater omentum. Arrived at the inferior border of the greater omentum, the membrane returns on itself, and passes upwards towards the transverse colon, forming the most posterior layer of the omentum. After covering the posterior aspect of the transverse colon (Fig. 944), it is continued, as the posterior layer of the transverse mesocolon, to the posterior abdominal wall, which it reaches at the anterior border of the pancreas (Fig. 944).

From the anterior border of the pancreas it is continued downwards again, clothing first the lower surface of the pancreas, then the front of the third portion of the duodenum, and, below that, the posterior abdominal wall. From the latter, however, it is soon carried forwards again by the branches of the superior mesenteric vessels passing to the small intestine. Running out along those, it forms the superior (or, more correctly, the right) layer of the obliquely placed mesentery (Fig. 944): on reaching the small bowel at the border of the mesentery, it invests that tube, giving it its serous coat, and then returns—as the inferior, or left, layer of the mesentery—to the posterior abdominal wall, on which it runs down, covering the great vessels near the median plane, and the psoas major muscle and ureter at each side, to enter the pelvis. The mesentery is described at p. 1198.

Pelvic Peritoneum.—The arrangement of the peritoneum in the pelvis minor is somewhat complicated, and is fully described in connexion with the several pelvic organs. A general account will suffice here.

Having passed over the superior aperture all round, it enters the pelvis minor, and covers its walls as low as the pelvic floor, across which it passes to the various organs. Behind, it invests the pelvic colon completely, and forms a mesentery (pelvic mesocolon) for it, as far down as the third sacral vertebra. There the colon joins the rectum proper, and the complete investment of the bowel ceases.

As the end of the pelvic colon is approached the two layers of its mesocolon become shorter, and when the rectum is reached, they separate, leaving its posterior surface uncovered, whilst the bowel is clothed in front and at the sides. Lower down, the membrane leaves the sides, and finally, at a point which is usually about 3 inches (7·5 cm., see p. 1216) above the anus, it leaves the anterior surface of the bowel, and in the male is carried on to the posterior part of the bladder (here covered by the seminal vesicles and deferent ducts), forming the floor of the **excavatio recto-vesicalis (recto-vesical pouch)**, between those organs. It then covers the superior surface of the bladder, and passing off from its sides to the walls of the pelvis, constitutes the so-called false ligaments of the bladder. From the apex of the bladder it is carried on to the anterior abdominal wall by the middle umbilical ligament, thus forming the **plica pubovesicalis** (O.T. the **superior or anterior false ligament** of the bladder).

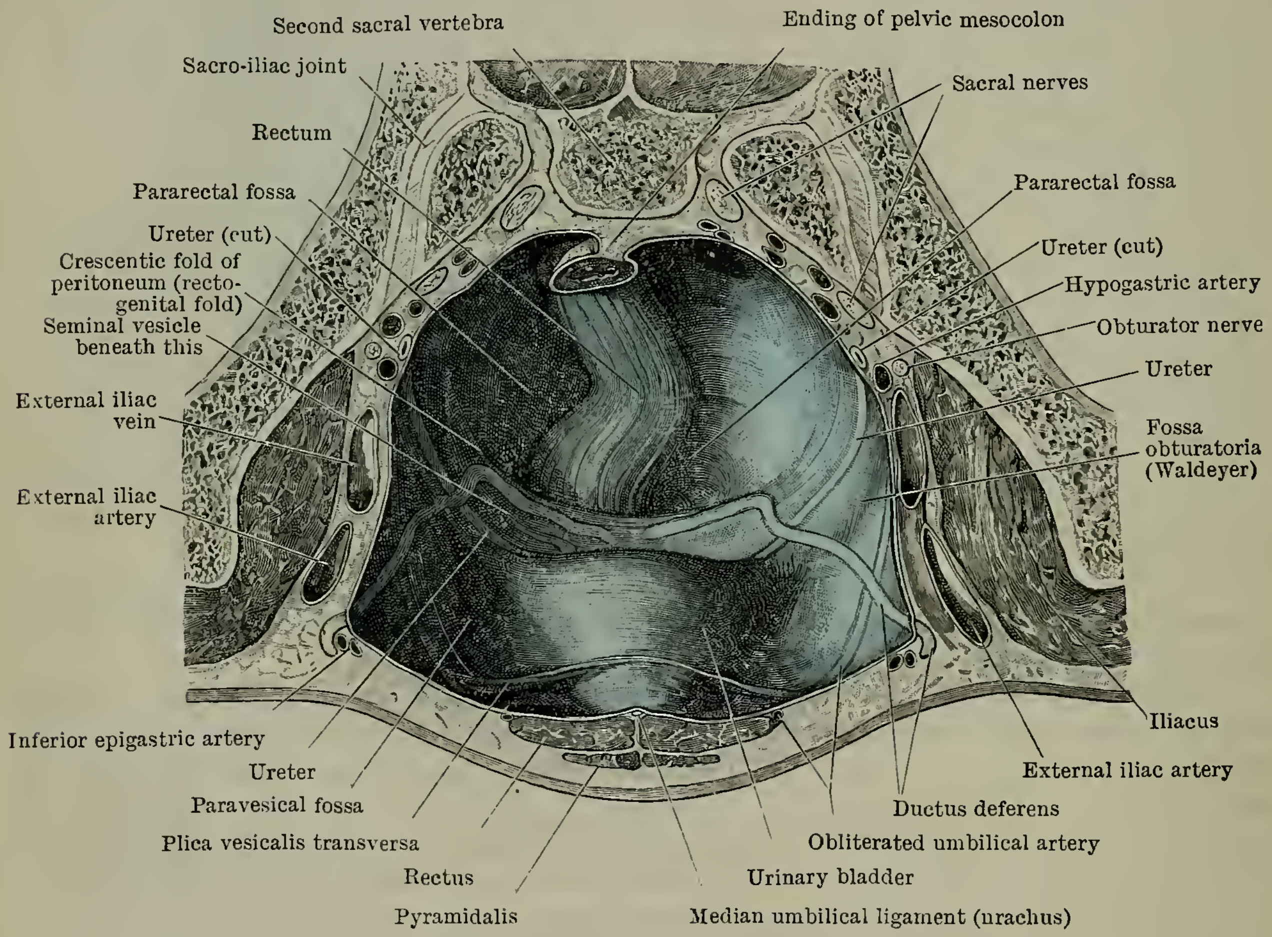


Fig. 945.—The Peritoneum of the Pelvic Cavity.

The pelvis of a thin male subject aged 60 was sawn across obliquely. Owing to the absence of fat the various pelvic organs are visible through the peritoneum, though not quite so distinctly as represented here. The urinary bladder and rectum were both empty and contracted; the paravesical and pararectal fossæ, as a result, are very well marked.

In the female (Fig. 944), the peritoneum, on leaving the rectum, passes to the posterior wall of the vagina, the superior portion of which it covers. From that it is continued up over the posterior surface and fundus of the uterus, and down on its anterior surface as far as the junction of the cervix and body (Fig. 944). Here it passes from the uterus to the bladder, which it partly covers, as in the male, and is then carried on to the anterior abdominal wall. Between the rectum behind, and the uterus and vagina in front, is situated the **excavatio rectouterina [cavum Douglasi]** (O.T. **pouch of Douglas**), the entrance of which is limited, on each side, by a fold passing from the cervix of the uterus around the sides of the pouch towards the rectum; these are the **plicæ rectouterinæ [Douglasi]**, and they contain in their interior the **musculi rectouterini**, two bands of fibrous tissue with plain muscle fibres intermixed, which pass from the cervix of the uterus, backwards on each side of the rectum, to blend with the connective tissue on the front of the lower part of the sacrum.

Similarly, in front of the uterus, between it and the bladder, is found the much smaller **excavatio vesico-uterina (utero-vesical pouch).** Finally, the peritoneum is prolonged as a wide fold from each margin of the uterus to the side wall of the pelvis, constituting the **ligamentum latum uteri (broad ligament of the uterus),** within which are contained the uterine tube, the ovary, the ligamentum teres, and other structures (see Uro-genital System).

When the bladder is empty, there is seen at each side, between it and the pelvic wall, a considerable peritoneal depression—the **paravesical fossa** (Fig. 945). This fossa is traversed by a peritoneal fold—the **plica vesicalis transversa**—which runs transversely laterally from the superior surface of the empty bladder, and, when well marked, passes to the neighbourhood of the abdominal inguinal ring.

Above the bladder, on each side of the middle umbilical ligament, is found the **internal inguinal fovea** already referred to (p. 1224). Both of these fossæ are practically obliterated by distension of the bladder.

Similarly, there is seen at each side of the empty rectum, on the posterior pelvic wall, a large depression, which may be known as the **pararectal fossa** (Fig. 945). When the rectum is empty and contracted, these fossæ are occupied by intestine; during distension, the rectum, increasing in width, expels the intestine and practically obliterates the fossæ.

Transverse Tracing of the Peritoneum.—If the peritoneum is followed transversely around the abdomen, just above the level of the iliac crest (Fig. 948), few difficulties will be encountered. From the anterior abdominal wall it passes round on each side to the back, lining the sides and the posterior wall. Passing medially on the posterior wall, it meets the colon—ascending on the right side, descending on the left—over which it is carried, in each case covering the bowel in front and at the sides only, and leaving the posterior surface bare, as a rule. Sometimes, however, the covering is complete, and a short mesentery is formed. It is next continued *medially* over the psoas muscles, the ureters, and the great vessels, on the front of which it meets the superior mesenteric artery and vein running downwards to the intestines. From both sides it passes forwards on these vessels, forming the right and left layers of the mesentery; and finally, having reached the intestine, it clothes it completely, and the two portions become continuous on the bowel.

A transverse tracing at a higher level would include the bursa omentalis; it will, therefore, be well to study this portion of the peritoneal cavity before describing such a tracing.

Bursa Omentalis (O.T. **Lesser Sac of the Peritoneum**).—The **omental bursa,** as already pointed out, is a diverticulum of the great sac. It lies behind the stomach and adjacent organs, and communicates with the general cavity by a constricted passage, called the **foramen epiploicum [Winslow].** If the general cavity is compared, as already suggested, to a bag, the anterior layer of which clothes the anterior wall and sides of the abdomen, and the posterior layer covers the viscera lying on the posterior wall, the bursa omentalis would correspond to a pocket lying behind the stomach, lesser omentum and part of the liver, and opening into its cavity by a narrow mouth, on the right side, just below the liver. From this opening the pocket passes to the left behind the lesser omentum and stomach, as far as the spleen, up behind the caudate lobe of the liver, and down behind the stomach and gastro-colic ligament.

As in the case of the general peritoneal cavity, it will, of course, be understood that the two walls of the bursa omentalis and the boundaries of the epiploic foramen are normally in contact. We shall first consider this opening, and then trace the layers of the omental bursa.

Foramen Epiploicum (Winslow) (Fig. 946).—This, the constricted passage which leads from the general peritoneal cavity into the bursa omentalis, is situated just below and behind the porta hepatis. It is *bounded anteriorly* by the right, free border of the hepato-duodenal ligament, passing up from the superior part of the duodenum to the porta hepatis, and containing between its two layers the portal vein, hepatic artery, and bile-duct. *Posteriorly,* lies the inferior vena cava, covered, of course, by peritoneum. *Above,* is placed the caudate process of the liver. And *below*, lies the superior part of the duodenum with the hepatic artery running forwards and to the right beneath the foramen, before turning up into the lesser omentum. It should be remembered that, normally, the various boundaries of the foramen lie in contact, and that its cavity can only be said to exist as such when its walls are drawn apart.

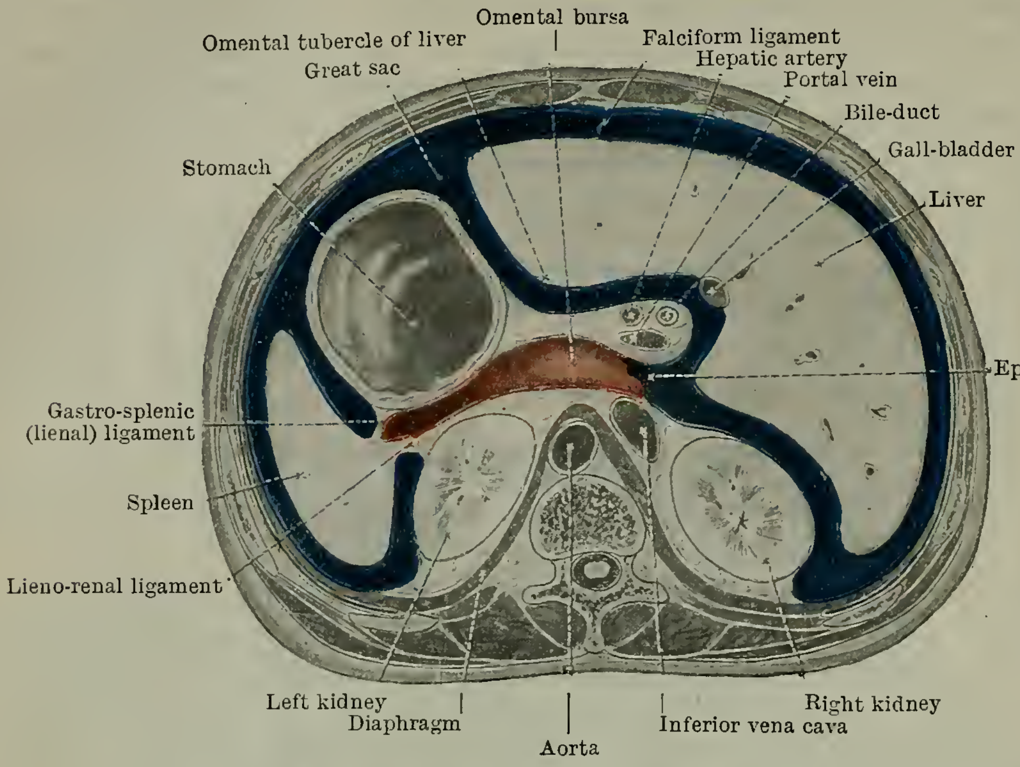


FIG. 946.—TRANSVERSE SECTION OF ABDOMEN AT LEVEL OF EPIPLOIC FORAMEN.

Beyond the foramen epiploicum is a small portion of the omental bursa termed the **vestibulum bursæ omentalis**, lying below the processus caudatus of the caudate lobe of the liver, and above the superior part of the duodenum and the head of the pancreas. The anterior wall of this portion is formed by the hepato-duodenal ligament, with the bile-duct, hepatic artery, and portal vein. The vestibule is continued beyond a fold termed the **plica gastropancreatica** into the true bursa omentalis, which presents two main parts, the recessus superior and recessus inferior. The **recessus superior** passes from the vestibule upwards behind the porta hepatis to the dorsal surface of the lobus caudatus. Posteriorly it is in

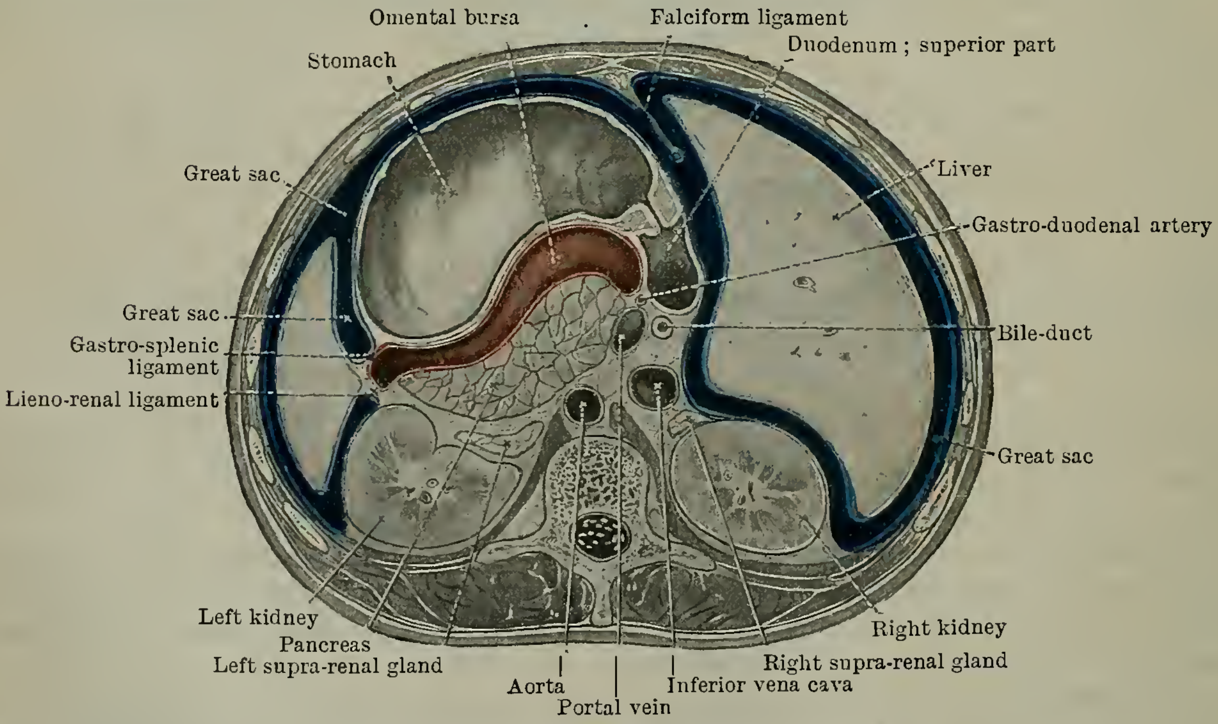


FIG. 947.—TRANSVERSE SECTION OF ABDOMEN IMMEDIATELY BELOW EPIPLOIC FORAMEN.

contact with the diaphragm and aorta. The **recessus inferior** extends medially in front of the pancreas, and behind the stomach, and passes to the left towards the spleen as the **recessus lienalis.**

The recessus inferior omentalis and the vestibulum bursæ omentalis communicate with one another by a rounded orifice, which is constricted by the sickle-shaped forward projecting fold, the plica gastropancreatica. This fold is an elevation of the peritoneum of the posterior wall of the omental bursa, raised up by the arteries of the stomach as they pass forwards to that organ from the posterior wall.

As the peritoneal wall of the omental bursa is described in two main parts, an anterior and a posterior, it will be necessary to follow each of these separately. Above, the peritoneum forming the **anterior wall** clothes the caudate lobe; it then passes down (from the posterior margin of the porta hepatis, and the fossa of the ductus venosus) to the lesser curvature of the stomach and the duodenum as the posterior layer of the lesser omentum. Continued on from this, it clothes the posterior (or visceral) surface of the stomach as far as the greater curvature, with the exception of the small "uncovered area" below and to the left of the cardia (Fig. 949), but it does not actually come in contact with the œsophagus itself, the back and right side of which are uncovered. On the left, it is reflected from the back of the stomach to the spleen as the deeper layer of the gastro-splenic ligament.

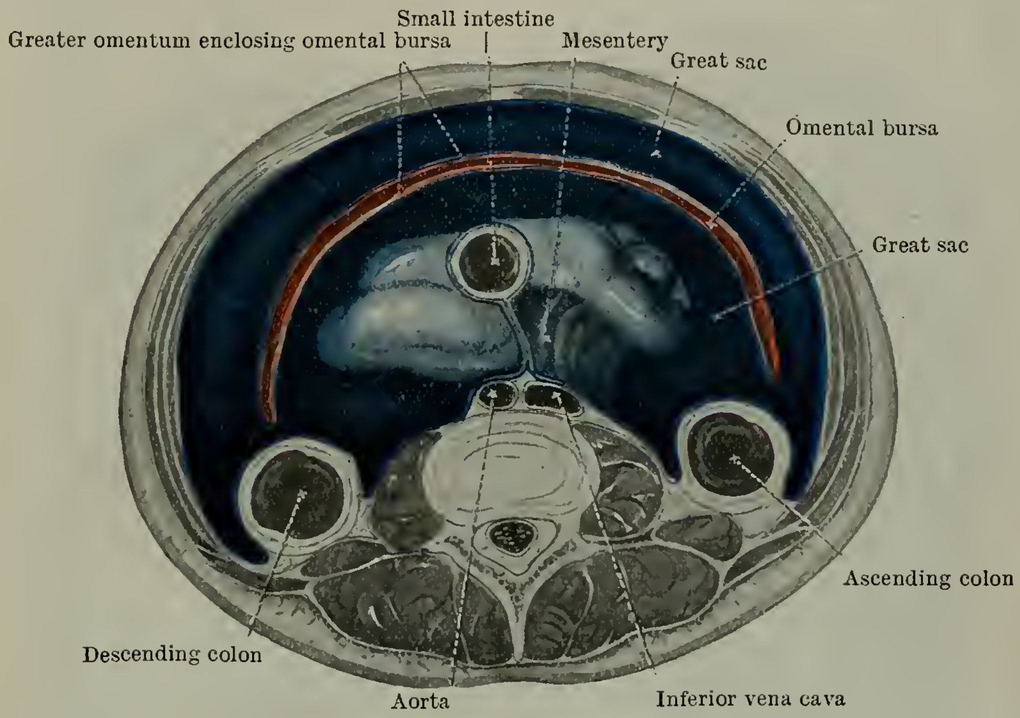


Fig. 948.—Transverse Section of Abdomen through the Fourth Lumbar Vertebra.

From the greater curvature of the stomach it is continued down, forming the posterior layer of the gastro-colic ligament as far as to the transverse colon. In some cases it is not attached to the colon, but is continued onwards as the posterior of the anterior two layers of the omentum, and in such cases at the inferior part of the omentum it meets and becomes continuous with the posterior layer of the omental bursa.

The peritoneum forming the **posterior wall of the bursa omentalis,** in passing through the epiploic foramen, clothes the front of the inferior vena cava (Fig. 946); beyond this, it covers the cœliac artery, and passes upwards to line the slight depression on the posterior abdominal wall (diaphragm), against which the caudate lobe rests. Then, passing over to the left, it covers the superior surface of the pancreas, the top of the left kidney and suprarenal gland, and the medial part of the gastric surface of the spleen (Fig. 946). From the anterior border of the pancreas it is prolonged anteriorly and downwards—as the anterior or upper layer of the transverse mesocolon—to the transverse colon (Fig. 944). Here it usually joins the gastro-colic ligament, but in English text-books it is described, and here it is figured, as being continued down as the anterior layer of the posterior fold of the greater omentum, almost to its inferior border, where it becomes continuous with the anterior layer of the omental bursa already described.

The transverse tracings at the level of the epiploic foramen and pylorus are shown in Figs. 926 and 946, and can be easily followed without any further description than is there given.

The **lesser omentum** is described at p. 1155; it need only be pointed out now that it is composed of two layers, the anterior belonging to the general peritoneal cavity, and the posterior belonging to the omental bursa; and both layers are extremely thin—sometimes even cribriform.

The **greater omentum** is a large apron-like fold of peritoneum, usually more or less loaded with fat, which is suspended from the transverse colon, and hangs down in front of the intestines to a variable extent. When the abdomen is carefully opened without disturbing the viscera, it is rare to find the greater omentum evenly spread over the front of the intestines. More commonly it is folded in between some of the coils of intestine, or tucked into the left hypochondrium; or perhaps it is carried upwards in front of the stomach by a distended transverse colon. The gastro-colic ligament continues the anterior layers of the greater omentum upwards to the stomach, and the gastro-lienal ligament continues them between the spleen and stomach. The greater omentum is thus commonly described as extending between the greater curvature of the stomach above and the transverse colon below, not taking the shortest course from one of these to the other, but hanging down as a loose fold between the two, and containing

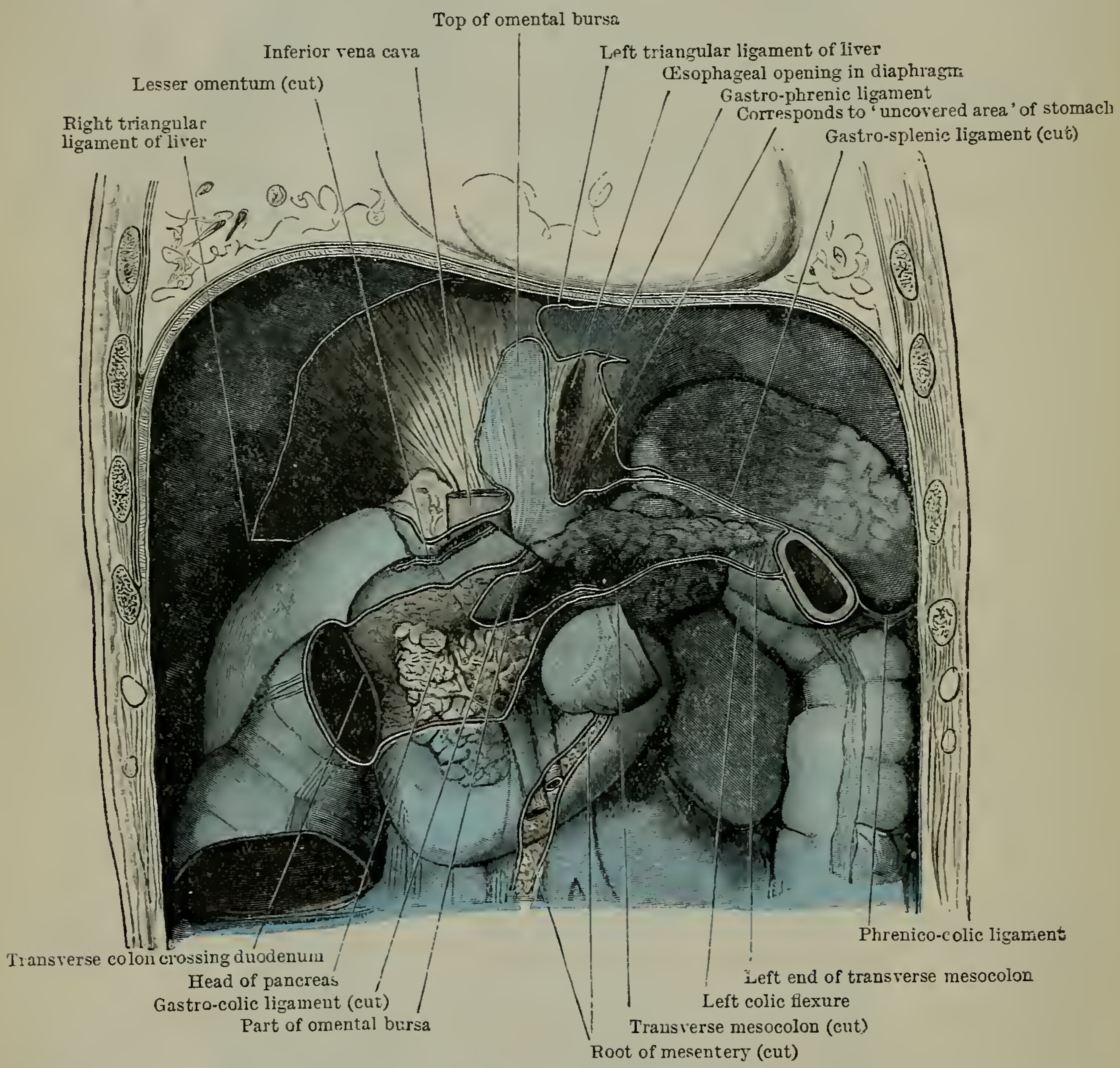

Top of omental bursa
Inferior vena cava
Left triangular ligament of liver
Lesser omentum (cut)
Œsophageal opening in diaphragm
Gastro-phrenic ligament
Right triangular ligament of liver
Corresponds to 'uncovered area' of stomach
Gastro-splenic ligament (cut)
Phrenico-colic ligament
Transverse colon crossing duodenum
Head of pancreas
Gastro-colic ligament (cut)
Part of omental bursa
Left end of transverse mesocolon
Left colic flexure
Transverse mesocolon (cut)
Root of mesentery (cut)

Fig. 949.—The Peritoneal Relations of the Duodenum, Pancreas, Spleen, Kidneys, etc.

between the anterior and posterior folds a cavity continuous with the omental bursa (Fig. 944).

This is the condition in the embryo, but in the adult the anterior fold usually becomes adherent to the colon, and, below it, also to the posterior fold, and hence the cavity becomes largely obliterated. If the gastro-colic ligament be included as part of the greater omentum, and the embryonic condition is retained, as is usually described in English text-books, the greater omentum may be said to consist of two folds, each formed of two layers, one derived from each sac of the peritoneum. The **anterior** or **descending fold** begins at the greater curvature of the stomach, where it is formed by the meeting of the two layers from the anterior and posterior surfaces of that organ respectively; from there it descends to the front of the transverse colon. Leaving the colon, or passing anterior to it (see Fig. 944), the two layers proceed to the lower border of the omentum, where, turning back (Fig. 944), they pass up as the **posterior** or **ascending fold**. That runs upwards until it meets the transverse colon; there its two layers separate to enclose and cover that colon—and the greater omentum, properly so called, ceases. Its two layers, however, unite at the superior margin of the colon (Fig. 944) to form the **transverse mesocolon**, which is continued upwards and posteriorly to the anterior border of the pancreas. There the layers of the transverse mesocolon again separate—the superior running upwards over the anterior surface of the pancreas to the posterior abdominal wall and lining the omental bursa; the lower passing downwards on the posterior abdominal wall, as already explained.

The greater omentum is continued to the right for a short distance (25 mm.) along the inferior border of the duodenum. At the left end it shortens very much, and is directly continued into the gastro-lienal ligament; the spleen, as it were, being introduced between the two layers instead of the colon.

Functions of the Greater Omentum.—Numerous uses have been assigned to the great omentum; the chief seem to be: (1) To act as a movable and easily adjustable packing material, capable of filling all temporarily-produced spaces in the abdomen. In this respect it may be compared with the Haversian fatty pads in joints. (2) It probably, to some extent, prevents the passage of the small intestines up into the stomach chamber, and helps to keep them from getting entangled there. (3) It is a storehouse of fat. (4) It is said to be "the great protector against peritoneal infectious invasions." Being freely movable, it can pass to almost any part of the abdomen, and there "build up barriers of exudations to check infection."

Mr. Lockwood has made the interesting observation (in connexion with the contents of herniæ) that, in bodies under forty-five years of age, the omentum can rarely be drawn down below the level of the pubic tubercle; in older bodies the reverse is the rule.

The **gastro-lienal ligament** is a short fold composed of two layers—an anterior, lining the general peritoneal sac, and a posterior, lining the omental bursa (Fig. 946). It is attached by one margin to the fundus and greater curvature of the stomach, and by the other to the gastric surface of the spleen just in front of the hilum. Between its two layers the vasa brevia of the splenic artery pass from the spleen to the stomach. Below and in front, its layers are continued into the corresponding layers of the gastro-colic ligament; above and behind, they separate at the "uncovered area" of the stomach (Fig. 949).

Minor Folds of Peritoneum.—The **phrenico-colic ligament**, passing from the left flexure of the colon to the diaphragm opposite the 10th or 11th ribs, has been described, and also the mesentery of the vermiform process, the lieno-renal and hepato-renal ligaments.

DEVELOPMENT OF THE DIGESTIVE SYSTEM.

In the section on General Embryology it has been pointed out that the alimentary canal is formed from three separate parts: (1) A middle large entodermal portion, and (2) two smaller ectodermal parts, one anterior, the oral sinus or stomatodæum, and one posterior, the proctodæum.

It has been further shown that the three portions are at first separated from one another by septa, the pharyngeal membrane and the proctodæal membrane, respectively, but the septa disappear at an early date, and the three parts are thrown into continuity.

There is thus formed a tube, the primitive alimentary canal, extending through the body from the mouth aperture in front to the anal orifice posteriorly.

The entodermal segment of the primitive alimentary canal is derived from the dorsal portion of the yolk sac and divided into three portions as follows:—

That portion which is enclosed within the head fold is termed the foregut; the portion within the tail fold is termed the hindgut; and the intermediate portion is termed the midgut. The midgut at first lies opposite the communication with the yolk sac, and the other portions cephalic to and caudal to this level.

From the foregut are formed the posterior part of the mouth, the pharynx, œsophagus, stomach, and the greater part of the duodenum. From the mid and hindgut are formed the rest of the small intestine, and the whole of the large intestine, as far as to the "white line" of the anal orifice. There is no sharp limit between the mid and hindgut or between the portions of the intestinal canal formed from them.

This primitive intestinal tube forms the basis, not only of the alimentary canal and its associated organs, but it also is the source from which many other organs, not ultimately connected with digestion, are formed.

Thus, the respiratory tract below the level of the orifice of the larynx is formed as an outgrowth from the ventral wall of the primitive foregut, and remains permanently connected with it at that point, though in structure and function it becomes very different from the tube from which it is derived.

Other structures also, namely, the thyreoid gland, the parathyreoid glands, and the thymus, are formed as diverticula of the primitive pharynx, but they eventually lose their connexion with the wall of the tube.

Furthermore, the allantois, a diverticulum from the hindgut, and a part of the primitive hindgut is cut off from the primitive cloaca to form the urinary bladder and a portion of the urethra.

Accounts of the development of the organs mentioned which are not connected with the alimentary canal in the adult will be found in the sections dealing with them.

Development of Mouth and Pharynx.—The development of the mouth and of the pharynx from the oral sinus and anterior part of the foregut are intimately associated with one another, and with the formation of the mouth and nose.

The stomatodæum or oral sinus is a depression situated between the primitive forebrain above and the pericardial region below.

The floor of this depression is formed by the pharyngeal membrane, which consists of ectoderm and entoderm only, mesoderm being absent; the membrane separates the oral sinus from the anterior end of the foregut, but at an early stage it ruptures and disappears.

The mouth cavity of the adult is formed in part from the oral sinus, and in part from the anterior end of the foregut, or primitive pharynx. The line of division between the portions of the mouth derived from these two parts is difficult to trace, on account of the very extensive changes which occur after the pharyngeal membrane has disappeared, and which are associated with the formation of the face and of the nose. The portion of the mouth cavity derived from the primitive pharynx is lined with entoderm, and that from the oral sinus with ectoderm. The position of the original pharyngeal membrane may be represented by an imaginary plane extending from the anterior part of the body of the sphenoid to the base of the alveolar process of the mandible on its lingual surface.

Thus, the cavity of the nose is derived from the upper part of the oral sinus, while the floor of the mouth is formed from the pharynx. The adamant (O.T. enamel) of the teeth and the secreting epithelium of the parotid gland are ectodermal structures, while the epithelium of the tongue and submaxillary and sublingual glands is entodermal in origin.

The ectodermal or oral sinus portion of the mouth, then, gives origin to the lips, teeth, and parotid glands; while in the pharyngeal portion are developed the tongue, submaxillary and sublingual glands.

The **upper lip** is formed from the tissues covering the frontal and maxillary processes (see development of face).

The **lower lip** similarly is formed from the tissues covering the mandibular arches.

By an ingrowth of epithelium from the surface of the frontal and maxillary processes into the subjacent mesoderm and by subsequent desquamation of the superficial layers, a groove is formed between the lips and cheeks on the one hand, and the alveolar ridges on the other. This groove when deepened forms the vestibule of the mouth, and is termed the alveolo-labial sulcus, or labial groove.

The surface covered with mucous membrane becomes everted, to form the red portion of the lips, and at birth is divided into an outer smooth portion, and an inner portion whose surface is villous, termed pars villosa. The distinction between these two parts disappears shortly after birth.

Several explanations of the formation of the **philtrum** or groove on the front of the upper lip have been put forward; most probably it is produced by the union of the margins of the two processus globulares with one another, the floor of the groove being formed by their line of union, and the ridges bounding the groove at the sides corresponding to the medial portions of the globular processes.

The **parotid glands** are formed as outgrowths of the epithelium in the outer wall of the alveolo-labial sulcus.

The outgrowth in each side has been found in embryos 8 mm. long. It is at first a furrow. The posterior part of the furrow becomes closed off from the mouth cavity and forms a tube, which grows backwards for some distance on the surface of the first visceral arch.

The terminal portion of the tube formed in this way gives rise to a number of buds, which divide repeatedly, and form the lobules of the gland.

These are at first solid, and the alveoli do not become hollowed until about the twenty-second week.

The epithelium of the terminal buds forms the secreting glandular epithelium, while that of the stalk forms the lining epithelium of the duct.

DEVELOPMENT OF THE TEETH.

Development of Human Teeth.—The following is a brief summary of the chief events in the development of a human tooth. For convenience in expression and terms, the description refers to the development of a lower tooth. The upper teeth are, of course, developed in a manner exactly similar.

1. The first distinct evidence of the development of the teeth is to be found in a thickening of the mouth epithelium at the site of the future gum, and a downgrowth of its deeper portion into the substance of the primitive jaw (Fig. 950, I.). This epithelial downgrowth is continued along the whole length of the gum, and is known as the **dental lamina or tooth-band.** The dental lamina divides into two plates, a lateral vertical and a medial more horizontal in direction. The medial plate is the portion from which the teeth are formed, and is termed the **dental ledge.** On the under surface of the dental ledge there soon appears a series of knob-like projections—one for each of the milk teeth (Fig. 950, II.)—which are known as **adamant germs** or **adamant organs.** These organs are connected with the epithelium of the dental ledge by a constricted part, and although at first knob-like, they soon become bell-shaped owing to the invagination of the lower surface of the knobs, so that each may now be compared to an inverted egg-cup.

2. As soon as the adamant organs begin to assume a cup-like shape, the cellular connective tissue of the jaw beneath grows up and projects into the cavity of the cup (Fig. 950, III.) in the form of a papilla—the **papilla dentis.** The arrangement, pursuing our simile, may now be compared to an egg fitting into its cup—the papilla representing the egg, and the adamant organ the cup (Fig. 950, III.).

The adamant organ is a rounded sac, with an invaginated base. Three portions may be recognised in it: (1) An internal layer covering the surface of the papilla, termed the adamant membrane, from which the adamant is formed; (2) an external layer, in contact with the surrounding connective tissue; and (3) an intermediate portion which occupies the interior of the sac, and is soft and gelatinous in consistence and ultimately disappears.

3. The epithelial cells lining the concavity of the adamant organ, and the superficial cells of the tooth papilla, become elongated or columnar, and undergo other changes, preliminary to the production of the adamant by the former—which are now called **adamant cells** or **ameloblasts**—and the ivory by the latter, which are known as **odontoblasts.**

4. The **odontoblasts** form at their outer ends a layer of ivory (Fig. 950, IV.). Similarly, the adamant cells lining the cup form at their inner surface a layer of adamant on the top of the layer of ivory (Fig. 950, IV.), to which it adheres: in each case the deposit taking place first at the summit of the tooth.

5. The formation of these tissues proceeds apace, the ivory increasing at the expense of the papilla, the adamant similarly encroaching on the cup or adamant organ; and in each case the two layers of cells—odontoblasts and adamant cells—which produced the deposits retiring gradually from one another, as the space between them becomes occupied by the newly formed tissues (Fig. 950, V.).

The remains of the dental papilla persist as the **pulp** of the tooth, which is covered even in the adult by the odontoblasts, and occupies the **tooth cavity,** *i.e.* the central part of the tooth to which the formation of ivory has not extended.

6. Turning now to the jaw itself: The connective tissue of the gum surrounding the **tooth germ** (as the developing tooth with its adamant organ and dental papilla are called) early becomes condensed and vascular (Fig. 950, V.), and later on forms a membranous bag—the **tooth-sac** or **follicle**—which completely shuts off the developing tooth from the surrounding structures. On the floor of the sac the tooth germ sits, the base of its dental papilla being continuous with the tissue of the floor of the sac, and the young tooth being enclosed by the sac as a kernel is enclosed by its shell.

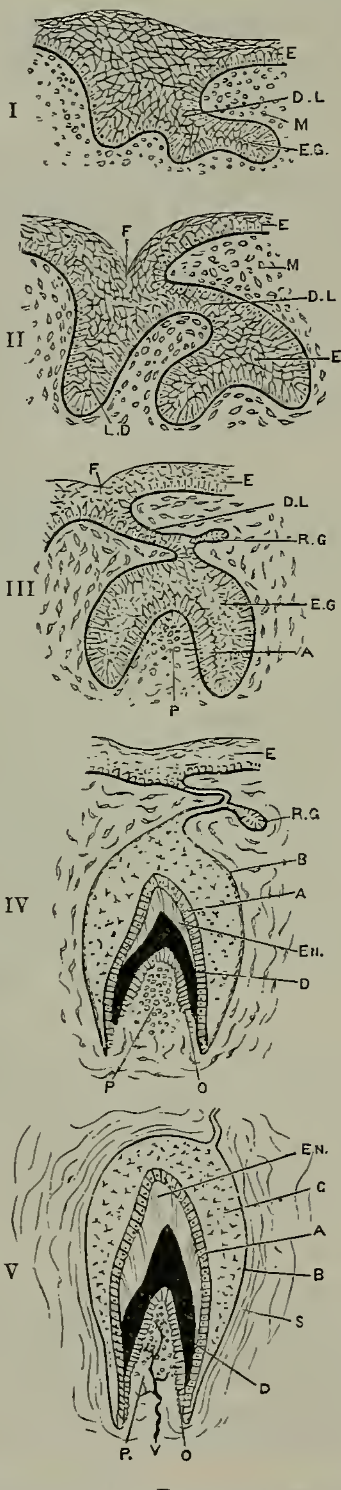
7. Reverting to the tooth: When the crown is completed the formation of ivory is continued downwards to form the **root.** As the ivory is formed, and the root is built up, the connective tissue of the tooth-sac comes to surround the root more closely, and deposits on its surface, after the manner of a periosteum, a layer of bone, the **substantia ossea.** After that layer has been formed, the connective tissue of the sac persists as the **alveolar periosteum.** The development of the root takes place very slowly, and its lower end is not completed as a rule for some time after the eruption of the tooth has taken place.

8. During the development of the teeth the ossification of the jaw has been going on, and as it grows up on each side, the young teeth, enclosed in their tooth-sacs, come to lie in an open bony groove, which is subsequently divided by septa into compartments—the **alveoli**—for the individual tooth-sacs. The bone continuing to grow after birth, these compartments become more perfect, but are never entirely closed in over the crowns of the teeth. During the eruption of the teeth the upper and anterior part of each of the bony cells is absorbed; subsequently, however, it is re-formed around each tooth when it has taken its final position.

9. **Eruption.**—Long before the root is completed, the crown, by some force which is not properly understood, but which does not seem to depend on additions to the root, is pushed

through the top of the tooth-sac, and—the upper and anterior wall of the roomy alveolus having been absorbed at the same time—onwards through the gum until the mouth is reached. Later, when the tooth has assumed its final position, the alveolus, as already stated, is re-formed, and closely embraces the completed root.

10. After the adamant organs of the deciduous teeth have been formed on the inferior aspect of the dental lamina, as described above, the neck of epithelium by which the lamina is still connected with the surface becomes broken up into a cribriform sheet. Its free posterior border, on the other hand, continues to grow inwards in the tissue of the gum towards the cavity of the mouth (Fig. 950, III. and IV.), and at a later date there appear on its under surface, near the free edge, and behind the several developing milk teeth, the adamant organs—or so-called "reserve germs"—for the corresponding **permanent teeth,** which are developed in exactly the same manner as the deciduous teeth described above.



I. Shows the downgrowth of the dental lamina D.L from the surface epithelium E and the beginning of the adamant germ E.G.

II. Shows the further growth of the adamant germ and its invagination.

III. The adamant germ is more invaginated, and its inner layer of cells becomes columnar. A, the dental lamina, grows thinner, but near its posterior or lingual edge there is an enlargement R.G which is the reserve germ for a permanent tooth. The superficial cells of the ivory papilla P are becoming columnar.

IV. The inner columnar cells of the adamant germ (called adamant cells) A have formed a cap of adamant En, inside which the superficial cells of the papilla, the odontoblasts O, have formed a layer of ivory D.

V. Shows a more advanced stage still. The deposit of ivory is extending downwards, and enclosing the papilla to form the future pulp, in which a vessel V is seen.

Fig. 950.—Diagram to illustrate Development of a Tooth.

A, Inner layer of adamant germ; B, Outer layer; C, Remains of intermediate cells; D, Ivory; D.L, Ivory lamina; E, Epithelium; E.G, Adamant germ; En, Adamant; F, Dental furrow; L.D, Labio-dental furrow; M, Connective tissue cells; O, Odontoblasts; P, Ivory papilla; R.G, Reserve germ; V, Blood-vessel.

In connexion with the development of the **permanent molars,** which have no corresponding teeth in the deciduous set, there takes place a prolongation backwards of the posterior extremity of the dental lamina into the tissue of the jaw, behind the last deciduous molar. On the inferior aspect of this prolongation, which has no direct connexion with the surface epithelium, adamant organs are formed for the permanent molars, and their further development goes on in the manner described for the other teeth.

The *dates* at which some of the chief events in the development of the teeth occur may be briefly given: The thickening of the epithelium, the first sign of the future teeth, begins about the sixth week of fœtal life, and the dental lamina is completed by the end of the seventh week.

The dental papillæ for the eight front teeth appear and become surrounded by their adamant organs about the tenth week, and the papilla for the first permanent molar about the seventeenth week.

The first traces of calcification, and the formation of the tooth-sacs, take place about the fifth month of fœtal life.

Formation of Adamant and Ivory.—Different opinions are held as to the method in which the **substantia adamantina** is produced by the cells concerned in the process. One view maintains that it is secreted and shed out by the cells (Kölliker). According to the other view, part of the substance of the cells is actually converted or transformed into adamant (Tomes). In connexion with this latter view, which seems to receive more support at present, Tomes has discovered that there projects from the base of each cell, towards or into the most recently formed enamel, a fibrillar process, which has received the name of **Tomes' process,** and he holds that the substantia adamantina is formed by calcification taking place in or around the process.

Similarly, two views are held as to the production of ivory by the odontoblasts: one, that the odontoblasts secrete the matrix ivory, and the other, that their substance is actually converted into the matrix of the ivory. The odontoblasts, when active, are branched columnar-shaped cells, and from their outer ends one or more processes extend towards and into the ivory; between these processes a matrix appears—produced probably by the odontoblasts—and soon this matrix becomes calcified. In this way the ivory is formed, and the process is repeated until its full thickness is attained. The branches of the odontoblasts, encased in ivory, just mentioned, are the Tomes' fibrils already described; the canals in which they lie are the dental canaliculi;

and the fibrils themselves are concerned in the production of the sheaths of Neumann which line the tubes.

The **tooth-sacs**, when fully developed, are large and distinct fibrous bags which lie in the alveoli of the maxilla and mandible, and are continuous above with the tissue of the gum. On the lingual side of the sacs of the deciduous teeth are found the germs of the permanent teeth, surrounded by their own sacs. These latter are at first very small, and are partly embedded in the posterior wall of the deciduous tooth-sacs, but subsequently they come to lie in distinct but incomplete bony cavities of their own. The bone surrounding the tooth-sacs, temporary and permanent, is always wanting over the summit of the sac, and the band of connective tissue by which the sac is connected with the overlying gum tissue, through the deficiency, is known as the **gubernaculum dentis**.

All the points mentioned are easily demonstrated on the mandible of a child at birth, particularly when the tissues have been allowed to soften a little. If, in such a specimen, the gum and periosteum are reflected upwards from the labial and lingual surfaces of the mandible, and freed as far as the superior border of the jaw, the gum, with the tooth-sacs depending from it like small bags, can be pulled away out of the bony groove of the jaw; and if the operation has been successfully performed, the tooth-sacs of the three front permanent teeth may be seen, varying in size from a small pin's-head to a hemp-seed, hanging down behind the superior part of the corresponding deciduous sacs. As already explained, the tooth-sacs are produced simply by a condensation of the connective tissue around the developing tooth, the condensation going on to the formation of a distinct membranous bag.

Eruption of the Teeth.—When the eruption of the deciduous teeth is about to take place, the anterior wall and roof of the alveolus are absorbed; the tooth passes through the sac and appears above the gum, and then the alveolus, which up to this was much too large to give actual support, is re-formed more closely around the tooth. Meanwhile the root, which was only partly formed at the time of the eruption, continues to be added to, possibly for a few years more, and, as it grows, the alveolus is completed around it. When the permanent tooth, or as much of it as is then formed, is about to be erupted, it makes its way from its own bony cell through the posterior wall of the alveolus of its temporary predecessor; the root of the deciduous tooth undergoes absorption at the same time, but quite independently of pressure from the permanent tooth. The alveolus, now occupied by both teeth, is again much enlarged by absorption, particularly in front; what remains of the temporary tooth is shed; the permanent tooth passes onwards through the enlarged alveolus, and, making its way to the surface, appears above the gum. After some time, when the tooth has taken its final position, the alveolus is again re-formed, first around its neck, and later on, as the root is built up, around it also, and thus the tooth is permanently fixed.

What the force is which causes the eruption, is a question that has not been answered satisfactorily. That the growth of the root pushes up the crown was formerly the favourite explanation. For several reasons, unnecessary to detail, this view is now discarded, and a theory which attributes the impelling force to the blood pressure is looked upon with more favour, although even this is not altogether satisfactory. (See Tomes' *Dental Anatomy*, 5th edition, page 211.)

MORPHOLOGY OF THE TEETH.

In most vertebrates below mammals all the teeth are alike in form; such a dentition is said to be **homodont**. In the majority of mammals, on the other hand, the teeth are arranged in groups of different size and form; such a dentition is **heterodont**.

Again, mammals have, neglecting exceptional cases, but two functional sets of teeth; they are consequently said to be **diphyodont**. Most vertebrates below mammals, on the other hand, have a continuous succession of teeth throughout life, and hence are said to be **polyphyodont**.

Seeing that practically all lower vertebrates are provided with simple conical teeth, the evolution of the multi-tuberculate mammalian molar has given rise to much speculation. The jaws of the earliest fossil mammals found are furnished with tri-tubercular teeth, the three tubercles being placed in an antero-posterior line; by a rotation of two of the tubercles to the lingual or labial side, as the case may be (a condition found in certain other fossil skulls), we arrive at a tri-tubercular form, from which the transition to an ordinary mammalian molar is not difficult. As to how the tri-tubercular tooth arose from the simple cone, two different views are advanced: one, that it was formed by the union of several conical teeth as a result of the shortening of the jaw and the crowding of the teeth together; the other, that the single conical tooth developed on its crown two subsidiary tubercles, one in front and the other behind, and that these tubercles growing larger, the tooth assumed the tri-tubercular form.

The complete or **typical mammalian dentition**, in its highest development, as in the horse, is represented by the following formula: i. $\frac{3}{3}$, c. $\frac{1}{1}$, pm. $\frac{4}{4}$, m. $\frac{3}{3}=44$. In the dentition of man, therefore, one incisor and two premolars are wanting. Different views are held as to which teeth have been suppressed—most probably they are the second incisors, and the first and second or first and last premolars.

In general it may be said that the **dentition of the lower races** differs from that of the higher, in that the dental arches are squarer in front, the teeth larger and more regular, the canines stronger, the last molars better developed, and the tubercles on the molars more perfect, in the lower than in the more civilised races. It may be mentioned that the teeth of a savage man, if seen in the mouth of a European, would be looked upon as an "exceedingly perfectly formed set of teeth" (Tomes).

To express the proportion in size of the crowns of the premolars and molars to that of the skull in different races, Flower compared the distance from the front of the first premolar to the back of the last molar, *in situ*, with the distance from the front of the foramen magnum to the naso-frontal suture (basi-nasal length), in the form of a "dental index"—

$$\text{Thus: } \frac{\text{Length of teeth} \times 100}{\text{Basi-nasal length}} = \text{Dental index},$$

and by this means he has divided the various races into **microdont** (index 42 to 43, Europeans, Egyptians, etc.), **mesodont** (index 43 to 44, Chinese, American Indians, Negroes, etc.), and **macrodont** (index 44 and upwards, Australians, Melanesians, etc.).

DEVELOPMENT OF PRIMITIVE PHARYNX AND PHARYNGEAL PORTION OF THE MOUTH.

The anterior blind termination of the foregut in the head region constitutes the primitive pharynx.

Its roof is formed by the tissues covering the under aspect of the mid- and fore-brain, and its floor by the tissues overlying the heart and pericardium. Each side wall is a lamina of tissue extending from the floor to the roof, continuous, in front, with the bucco-pharyngeal membrane, which forms the anterior wall of the pharynx and separates it from the stomatodæum.

In the roof are formed the tissues which form the hinder part of the base of the skull.

In the side wall and in the floor extensive changes occur, connected with the appearance of structures known as the visceral arches and pouches, and with the origin of numerous structures from them and the development of the tongue.

Tongue.—The tongue is formed in two portions, anterior and posterior, in the floor of the pharynx.

The anterior portion, forming the anterior two-thirds of the organ, is formed from the tissues on each side of the tuberculum impar, which grow up and enclose that elevation, and from the tuberculum itself. Evidence of this bilateral origin of the tongue is found in those cases of bifid tongue which occur, though rarely.

The hinder portion, forming the posterior third of the tongue, is formed from the tissues covering the inner ends of the second pair of arches (see p. 51).

These arches, as has been pointed out, meet and fuse in a common mass in front of the furcula, in the floor of the sinus arcuatus.

Between the ridge which they form and the tuberculum impar in front, a slight median depression is found, from which the median thyreoid diverticulum is formed, and which persists as the foramen cæcum of the tongue. On each side of this depression a groove runs obliquely laterally and upwards (the sulcus terminalis) immediately behind the region of the vallate papillæ, and marks the union of the anterior and posterior portions of the tongue.

The tongue mass formed by the union of these different parts increases in size, rises upwards from the floor of the pharynx, and projects forwards.

The tissue forming its interior becomes transformed into the muscular substance of the tongue, and is derived largely from the first branchial region, and not from the musculature of the visceral arches.

The investing epithelium of the anterior two-thirds gives rise to the papillæ and the taste buds, while that covering the posterior portion remains smooth. The papillæ appear about the third month as elevations of the corium, covered with epithelium.

The vallate papillæ are formed by ingrowths of the epithelium in rings, around a central core. The superficial layers of the epithelium desquamate and form the trench surrounding the papilla.

Submaxillary and Sublingual Glands.—These glands are formed in the alveolo-lingual groove in the floor of the primitive pharynx, immediately behind the first arch, by outgrowths somewhat similar to those described in connexion with the parotid (p. 1232).

The submaxillary outgrowths occur about the fifth week, and the sublingual, several in number, on the outer side of it at the ninth week.

Palatine Tonsil.—The glosso-palatine arch arises in the position occupied earlier by the second visceral arch, behind which, in the embryo, lies the pharyngeal portion of the second visceral cleft. The dorsal extremity of that cleft enlarges, and forms a recess termed the sinus tonsillaris. From the lower and greater part of the sinus tonsillaris the palatine tonsil is developed; the upper part of the sinus persists, however, as the supra-tonsillar fossa. The palatine tonsil at first is a smooth depression of the mucous membrane. About the fourth month of fœtal life downgrowths of the epithelium take place, which are afterwards converted into the tonsillar crypts. Subsequently lymph cells accumulate around the downgrowths and form the lymph tissue, which constitutes the mass of the organ. The plica triangularis is formed from a tubercle, which becomes flattened, and forms a fold on the anterior and medial aspect of the inferior part of the palatine tonsil.

DEVELOPMENT OF ŒSOPHAGUS, STOMACH, AND INTESTINES.

1. **Development of the Tissues of the Œsophagus, Stomach, and Intestine.**—The wall of these portions of the intestinal tube consists at first of an internal lining of epithelial entodermal

cells, several layers thick, and of an external investment of mesenchyme. The intra-abdominal portion of the tube has also a partial external covering of flattened cells which form the lining wall of the cœlom.

The epithelial lining gives rise to the entire lining of the adult intestine, whether squamous, as in the œsophagus, columnar as in the stomach and intestine, and to the secreting cells of all the glands of the canal, including the liver and pancreas, as well as to the epithelial lining of the ducts of these and other glands.

The epithelium may be ciliated for a time in the œsophagus, and in the duodenum it may be so thickened as to obliterate for a time the lumen of the tube.

The epithelium shows early very active proliferation, so that ridges and furrows are formed, and the glands arise from downgrowth of the epithelium into, or in the case of the duodenal glands, through the substance of the underlying mesenchyme. In both the large and small intestine, the longitudinal ridges become broken up into isolated, finger-like stalks which form villi, and these are present for some time in the large as well as in the small intestine.

Additional villi are formed later on by a rapid growth of the epithelium in the intervals between the original villi.

The plicæ circulares of the intestine are formed much later, but are well formed at birth.

The **muscular coats** are formed from the mesenchyme by a gradual extension and modification of the cells forming it, by which the multi-nucleated fibrils of non-striped muscle are formed.

The circular coat is the first to originate, and later the longitudinal coat. In the colon this latter coat is formed first at the rectal end and thence spreads headwards, and it is from the first in the form of three separate longitudinal bands, while in the small intestine it is a continuous sheet.

Vessels and Nerves.—The nerves and probably also the vessels, both blood and lymph, grow into the wall of the intestine, the nerves from the neural tube and the vessels from the primitive vascular network connected with the yolk sac. It is, however, possible that both the nerve plexuses and the blood and lymph vessels are formed by a differentiation of the local tissue. The cœliac axis and the superior and inferior mesenteric arteries represent segmented vessels distributed to successive segments of the tube and to the organs derived from these segments. The branches of the vagi and sympathetic nerves grow into the intestinal wall from without.

Formation of Gastric and Intestinal Glands, etc.—The epithelial lining of the intestinal tube is composed, at first, of a single layer of cells, and the inner surface is smooth. In the second month the epithelium increases rapidly, and as a result its surface is thrown into folds and furrows, arranged irregularly. Mesenchymal tissue passes into the interior of the folds, and also blood capillaries. The folds appear first in the stomach, especially in the regions of the curvatures, and later in the duodenum and small intestine, and then in the large intestine, where they are formed first in the rectum and last in the vermiform process. In the stomach the folds are arranged so as to surround small isolated depressions, which afterwards become the foveolæ gastricæ. In the small intestine isolated elevations are found, in place of continuous folds, and at a later stage new elevations are formed between the primary ones. These papillary elevations form the villi. In the large intestine, the arrangement resembles that in the stomach. The glands of the stomach and intestine, viz., the gastric and duodenal glands, and the intestinal glands in the small intestine are formed by an active proliferation of the epithelium at the bottom of the furrows, and at first the cells forming them are everywhere of a similar character, and become differentiated later on. In the stomach the formation of the glands begins about the end of the third month.

The intestinal glands of the large intestine represent merely furrows between adjacent elevations, and are not due to an active proliferation of cells at the base of the furrows, and hence a distinction may be drawn between the two, and be expressed by using the term intestinal glands for the depressions of the small intestine and intestinal follicles for those of the large intestine.

According to v. Nagy, whose description has been followed above, the glandular epithelium of the gastric glands begins to assume its differentiated form in different parts, *i.e.* cardiac and pyloric glands, towards the fifth month of development.

2. **Organ Formation—Œsophagus.**—The lengthening of the thoracic region of the trunk, which occurs with the growth and development of the heart and lungs, causes this portion of the alimentary tube to become greatly lengthened. Vacuoles appear in the epithelial lining, and coalesce to form the wide lumen.

Stomach.—As early as the fourth week, the foregut exhibits a fusiform enlargement in the region of the developing heart, which is the first evidence of the differentiation of the stomach: this enlargement takes the form first of an outgrowth on the dorsal border to form the fundus. Soon, however, as the diaphragm is being formed, the stomach passes into the abdomen, and its dorsal wall—the future greater curvature—begins to grow more rapidly than the ventral wall. As a result the whole organ becomes somewhat curved, and its inferior end is carried forwards from the posterior abdominal wall, giving rise to the curvature of the duodenum. The excessive growth of its posterior wall causes the stomach to turn over on to its right side, which now becomes posterior or dorsal. In this rotation the upper or cardiac portion moves to the left of the median plane, and the whole organ assumes an oblique direction across the abdomen Already, at the fifth or sixth week, the adult form of the stomach is clearly indicated.

This rotation of the stomach around its long axis, which is accompanied by a rotation of the lower end of the œsophagus, explains the asymmetrical position of the two vagi. In the adult the left nerve is found on the front of the stomach, which was originally the left side of the organ; similarly, the right nerve lies on the back, which was originally the right side.

Intestines.—At first there is no separation into large and small intestines; the primitive canal simply forms a slender tube, with a convexity towards the umbilical orifice, through which the vitelline duct passes to the yolk sac. Later, the tube increases in length, and in embryos of 11 or 12 mm. and about five weeks old an outgrowth of the canal appears, which represents the future cæcum, and indicates the separation into large and small intestines. Growing longer, the intestine forms a large loop with the vitelline duct springing from its apex (Fig. 951), and the superior mesenteric artery running down between the layers of its mesentery. This loop passes outside the body of the embryo and lies for some time in the umbilical cord. As the abdominal cavity increases in size it retracts into the abdomen. This primary loop is known as the entero-colic loop, and from it are formed the intestine from the distal end of the duodenum to the left colic flexure. At the root of the loop, where the proximal and distal ends come to lie close to one another, lateral bendings of the intestine appear, the intestine proximal to the upper root bends over and forms a loop convex to the right,—the gastro-duodenal loop, supplied by a branch of the cœliac axis artery, and giving origin to the duodenum. The distal portion of the intestine, supplied by the inferior mesenteric artery, forms a loop on the posterior abdominal wall convex to the left (Fig. 951). There now takes place a change which entirely modifies the position of the parts—this is a rotation of the entero-colic loop, with its mesentery, around the superior mesenteric artery as an axis (Fig. 951). The result of this rotation is that the original right side of the loop of gut and mesentery becomes the left side; and the beginning of the large intestine is carried across the duodenum (Fig. 951), thus explaining the passage of the transverse colon in front of the second part of the duodenum in the adult. At the same time the cæcum comes to lie near the middle of the abdomen below the liver, a position in which it is found during the third month. Subsequently, it passes farther to the right; and finally, descending, comes to occupy its adult position (Fig. 952).

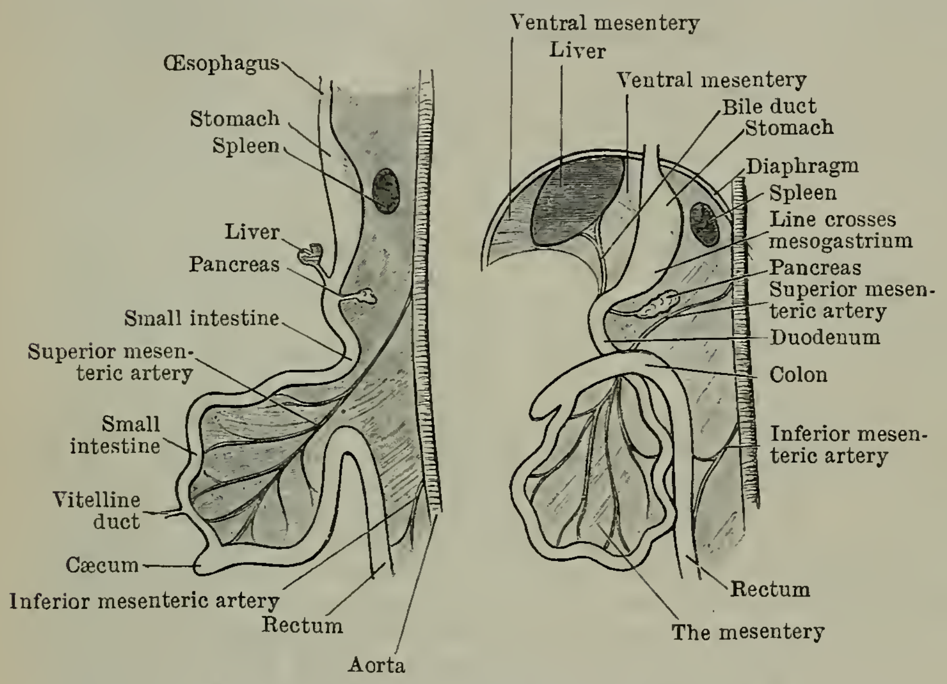


Fig. 951.—Two Diagrams to illustrate the Development of the Intestinal Canal.

The figure to the right shows the rotation of the intestinal loop around the superior mesenteric artery. In both figures the parts are supposed to be viewed from the left side.

The small intestine continues to grow in length, and, as a result, is thrown into coils, which become more and more complex as the length increases, until the adult condition is attained. The terminal portion of the large bowel retains its position on the left side, and passes down to the anus.

Cæcum and Vermiform Process.—The cæcum appears at about the fifth week, as a small outgrowth of the wall of the primitive gut (midgut), not yet differentiated into small and large intestines. The outgrowth is of the same size throughout, and is practically equal to the intestine in diameter. About the eleventh week it increases very considerably in length (being equal to about five times the diameter of the small intestine, and thus being relatively as long as in the adult); but even at this early date the basal portion, for about one-fifth of its length, is quite as wide as the intestine, whilst the remaining four-fifths of the outgrowth—the future vermiform process—is only about one-half or one-third the diameter of the gut. Thus the distal portion of the outgrowth, which subsequently becomes the vermiform process, begins to lag behind even at this early period of its development.

The basal portion continues to expand with the gut; the distal part grows rapidly enough in length, but otherwise enlarges very slowly, so that, towards the end of fœtal life, the cæcum has attained a conical shape, the wider end joining the ascending colon, the narrow end tapering gradually and passing into the vermiform process. This form, known as the infantile type of cæcum, is retained for some time after birth, or even may (in 2 or 3 per cent of cases) persist throughout life.

As early as the sixth or seventh month of fœtal life the wall of the terminal portion of the small intestine adheres to the medial side of the cæcum for some distance below the ileo-cæcal orifice. This connexion, which is rendered more intimate by the passage of two folds of peritoneum, one on the front, the other on the back, between the two parts, profoundly modifies the subsequent growth of the cæcum, and determines very largely its adult form. For, when the cæcum begins to expand, the medial aspect is prevented, by its connexion with the termination of the ileum, from enlarging as freely as the rest of the wall; in consequence of this the lateral part grows and expands much more rapidly, producing the lop-sided appearance already referred to, and soon comes to form the lowest part or fundus of the cæcum, and the greater part of its sac; whilst the original apex, with the vermiform process springing from it, anchored, as it were, to the end of the ileum, is thrust to one side, and finally lies on the medial and posterior aspect of the cæcum, a little way below, and usually posterior to, the end of the ileum.

The position of the cæcum varies at different periods of fœtal life. About the eleventh or twelfth week it lies immediately beneath the liver, and to the left of the median plane; it then gradually travels to the right, crossing the descending part of the duodenum, and is found lying on the right side, just beneath the liver, at the fourth month. From there it descends slowly to its adult position, which it usually approaches towards the end of fœtal life, but it may not actually reach it until some time after birth. An imperfect descent gives rise to the lumbar position of the cæcum, or an excess in this direction to the pelvic position (referred to on p. 1203).

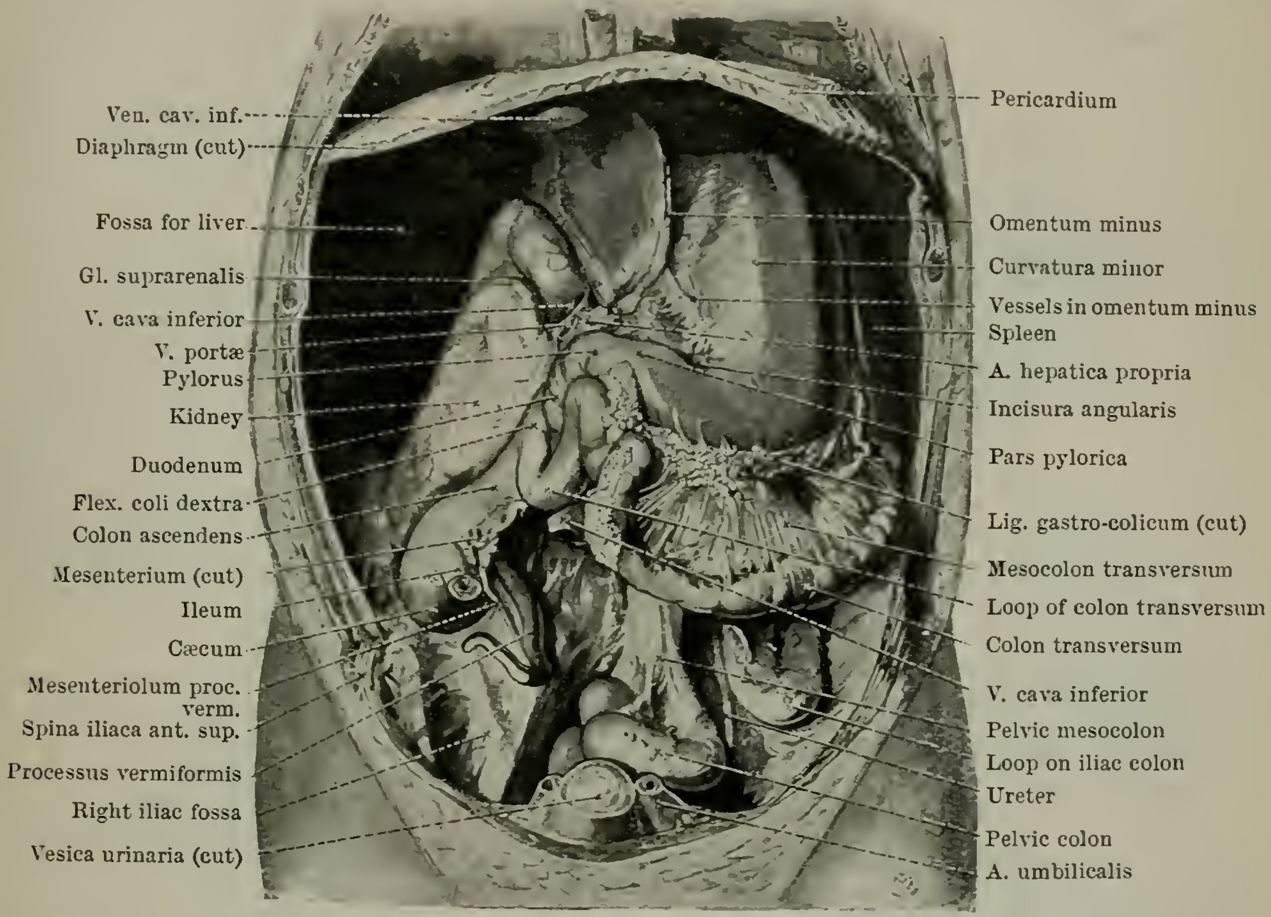


FIG. 952.—THE ABDOMINAL VISCERA IN THE NEWLY-BORN CHILD. The liver and the jejunum and ileum have been removed. The vertical stomach, the large supra-renal gland, the high position of the cæcum, and the whole arrangement of the large intestine are typical of the condition found at birth, and differ, as can be seen, largely from the adult condition.

Rectum.—The rectum and anal canal are formed from the posterior portion of the hindgut, and from the proctodæum.

The primitive closed cloacal portion of the hindgut becomes divided by a vertical septum into ventral and dorsal portions. The ventral, with the allantois growing from it, forms the sinus urogenitalis, the dorsal forms the rectum.

The proctodæum is separated from the rectum by the proctodæal membrane, but that membrane disappears, and thus the rectum comes to open on the surface.

A spindle-shaped enlargement of the terminal portion of the rectum is early formed, and persists until birth, and a smaller temporary enlargement is formed proximal to it. The wall of the distal swelling is thrown into numerous longitudinal ridges and folds from which the rectal columns are formed.

The rectum and anal canal at first form a single continuous straight tube, which passes downwards in front of the comparatively straight anterior surface of the sacrum to the anal orifice.

That is the condition which the parts present at birth. After birth, the bony pelvis undergoes great enlargement. The sacrum and coccyx become curved, and the antero-posterior diameter of the pelvis minor increases very considerably.

The urinary bladder and, in the female, the uterus—both organs at birth lying mainly in the abdomen—descend into the pelvis minor. The anal orifice appears to be moved further forwards in the perineum, through the bending of the sacrum and coccyx, and the rectum is pushed back into the hollow of the sacrum. Hence the "flexura sacralis" is formed.

The "flexura perinealis" is formed by the junction of the curved rectum with the straight vertical or backwardly directed passage formed by the intestine as it passes through the tissues of the pelvic floor.

The increase in the thickness of the pelvic floor gives to the anal canal the length which it attains in the adult.

"Atresia ani" may be persistence of a proctodæal membrane, but in many cases there is imperfect development of all the lower portion of the rectum.

DEVELOPMENT OF THE PERITONEUM.

At first the primitive alimentary canal is suspended from the dorsal wall of the embryo, along the median plane, by a **simple dorsal mesentery**, which extends along the whole length of the tube, and is common to all its divisions—a condition found in the adult stage of many reptiles. There is also present, in the upper part of the cavity, after the stomach and liver descend into the abdomen, a **ventral mesentery** (Fig. 951), which connects the stomach and duodenum to the liver, and, passing on, connects the front of the liver to the anterior abdominal wall and diaphragm. The portion of this ventral mesentery, between the stomach and liver, becomes the lesser omentum; its anterior portion, between the liver and the abdominal wall, forms the falciform ligament (Fig. 951); and, in its inferior margin, the umbilical vein runs from the umbilicus to the liver.

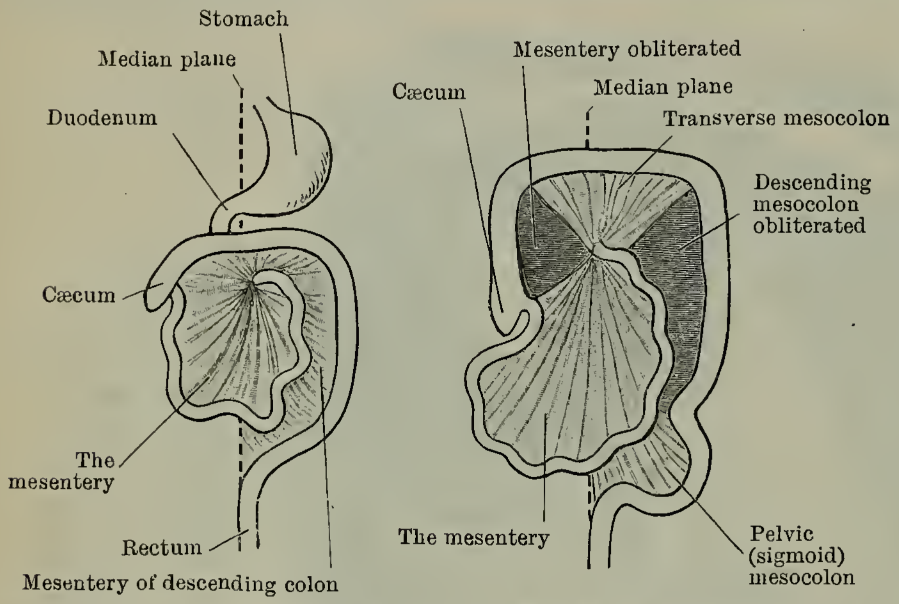


FIG. 953.—TWO DIAGRAMS TO ILLUSTRATE THE DEVELOPMENT OF THE MESENTERIES.

In the first figure the rotation of the intestinal loop and the continuous primitive mesentery is shown. In the second figure (to the right), which shows a more advanced stage, the portions of the primitive mesentery (going to the ascending and descending colons) which disappear, through their adhesion to the posterior abdominal wall, are shaded dark; the portions which persist are lightly shaded.

The portion of the dorsal mesentery lying behind the stomach is known as the **mesogastrium.** At first it is relatively short; but with the growth of the posterior wall of the stomach, and the turning of that organ over on its right side, the mesogastrium becomes elongated, and is folded on itself, forming more or less of a pouch, directed downwards and to the left. The wall of this pouch becomes in part the greater omentum, and the cavity enclosed by it forms the greater part of the omental bursa. In the rotation of the stomach and the accompanying passage of the lesser omentum from an antero-posterior to a more or less transverse direction, a portion of the cavity of the abdomen is, as it were, caught in behind the stomach and lesser omentum. This portion of the cavity becomes the upper part (vestibule) of the omental bursa, and at first it communicates with the general cavity by a wide opening to the right of the lesser omentum; but the growth of the liver, encroaching upon the opening, and other causes, reduce it to a relatively small size, and it forms the **foramen epiploicum** in the adult.

The "recessus superior" of the bursa omentalis has a complicated origin. It represents the right of two pocket-like recesses, a right and a left, which are formed very early in the dorsal wall of the cœlom.

These two recesses are narrow and horizontal slits, which burrow into the dorsal wall, and turn upwards by the side of the œsophagus. They are termed the "pneumato-enteric recesses." The left one disappears entirely. The apex of the right one remains occasionally as the "bursa infra-cardiaca" of the right lung, and is cut off by the diaphragm from the lower portion, which is the origin of the recessus superior.

The **greater omentum** is, as pointed out above, a bag-like growth of the lower part of the mesogastrium, which passes downwards and to the left in front of the transverse colon. As shown in Fig. 954, A and B, it is first entirely unconnected with the transverse colon and mesocolon; but about the third or fourth month it becomes united to both, and the adult condition is established (Fig. 954 C).

It would appear that the growth of the inferior part of the omental bursa, and of the greater omentum, is primarily due to a proliferation of the cells over a limited area of the mesogastrium, and a resulting folding of this layer downwards and to the left.

In the upper part of the mesogastrium the **spleen** is developed, and the portion of this fold which intervenes between the stomach and spleen forms the gastro-lienal ligament, whilst the part behind the spleen becomes the lieno-renal ligament.

Of the primitive mesentery, the portion connected with the stomach—the mesogastrium—becomes modified in the manner just described. The next division—the mesoduodenum—disappears completely, owing to the turning over of the duodenal loop on to its right side, and its subsequent adhesion to the posterior abdominal wall, accompanied by the absorption of its mesentery. The mesenteries of the small and large intestine are continuous at first (Fig. 951). When the rotation of the intestinal loop takes place around the superior mesenteric artery (see above), the beginning of the large intestine, with its mesentery, is carried to the right across the duodenum, and a fan-shaped portion of the general mesentery, lying within the concavity of the loop, is partially cut off; this, later on, forms the mesentery proper in the adult. At first it is continuous by its right border with the mesentery of the ascending colon, a part of the primitive mesentery (which is similarly continued into the mesentery of the transverse, descending, iliac, and pelvic colons). Subsequently, as shown by the darkly shaded parts in Fig. 953, the back of the mesenteries of the ascending, descending, and iliac portions of the colon adheres to the posterior abdominal wall, and these mesenteries become lost; whilst the mesenteries of the transverse and pelvic portions of the colon remain free, and persist in the adult.

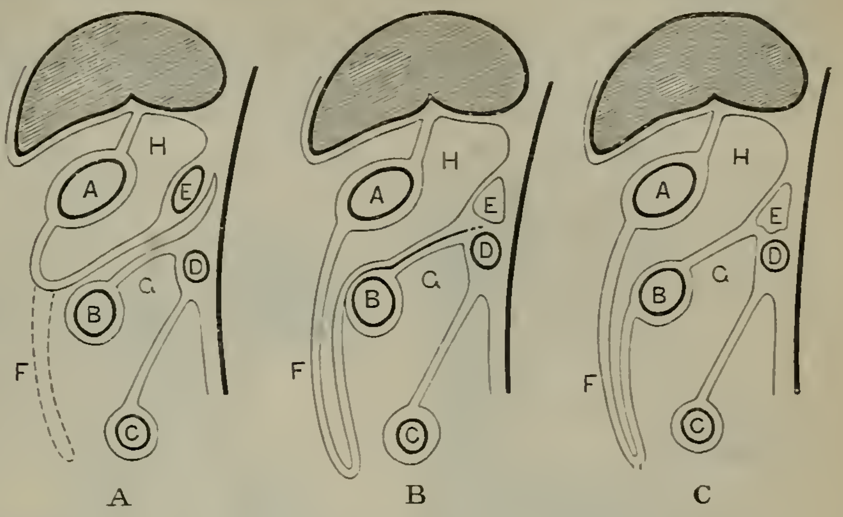


Fig. 954.—Diagrams to illustrate the Development of the Greater Omentum. (After Hertwig.)

A, shows the beginning of the greater omentum and its independence of the transverse mesocolon; in B, the two come in contact; and in C, they have fused along the line of contact. (According to Lockwood, the two layers of the fold shown in A, running in between the greater omentum and transverse mesocolon, instead of fusing, as shown in B, are drawn out—unfolded—producing the condition shown in C.) A, stomach; B, transverse colon; C, small intestine; D, duodenum; E, pancreas; F, greater omentum; G, placed in great sac; H, in omental bursa.

At the same time, the mesentery proper (which was at first attached only at its narrow neck, between the duodenum and transverse colon, and below this was continuous on the right with the ascending mesocolon) now acquires a new attachment to the posterior abdominal wall through the absorption of the ascending mesocolon (Fig. 953), and the adult condition is attained.

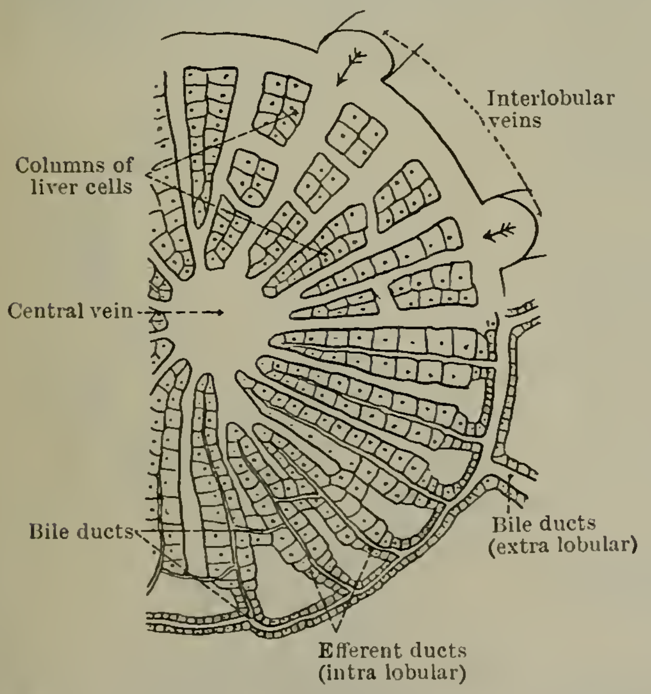


Fig. 955.—Diagram to illustrate the Structure of a Liver Lobule.

Development of the Liver and Pancreas.

The glandular tissue of the liver and pancreas, and the epithelial linings of the ducts of these organs, including the gall-bladder and cystic duct, are formed from protrusions of the endothelial wall of the foregut, below the stomach. The connective tissue framework of the glands is formed from the mesodermic tissue into which the protrusions grow.

The process of formation is as follows:—

1. **Liver.**—A longitudinal groove appears on the interior of the ventral wall of the foregut, close to its union with the midgut, at about the third week. This groove appears on the external surface of the gut as a projection, which rapidly increases in size and grows forwards and upwards towards the lower part of the septum transversum. This septum is a mass of mesodermic tissue which lies in front of the foregut, just below the heart, and which is attached to the anterior and side walls of the trunk. It conveys the umbilical and vitelline veins as they pass to the sinus venosus.

The liver bud grows into the lower (caudal) portion of the septum transversum, and sends out strands of cells termed trabeculæ, which come into contact with the vessels in the septum, and enclose them.

By the growth of capillary vessels, from the vitelline and umbilical veins, and of the trabeculæ, a spongy network is produced, the framework of which is formed by branching and anastomosing trabeculæ, while the spaces of the network represent portions of the lumen of the vessels, and are filled with blood. This form of vascular network is known as a "sinusoidal circulation."

The trabeculæ become hollowed out, and are reduced in size, so that eventually a minute channel is formed in the centre of each of them, surrounded by a single layer of cells. The lumen of the channel forms a bile capillary, and the cells surrounding it form the secreting cells of the liver lobule.

The bile capillaries of adjacent trabeculæ meet and unite, and converging together constitute the bile ducts within the liver. Adjacent trabeculæ become arranged into the form of a lobule, each with a vascular channel in its interior, which communicates with the vascular network in the surface of the lobule by capillary intervals between adjacent trabeculæ.

The central vein becomes a tributary of a hepatic vein, and the capillary network becomes the terminal distribution of branches of the portal vein.

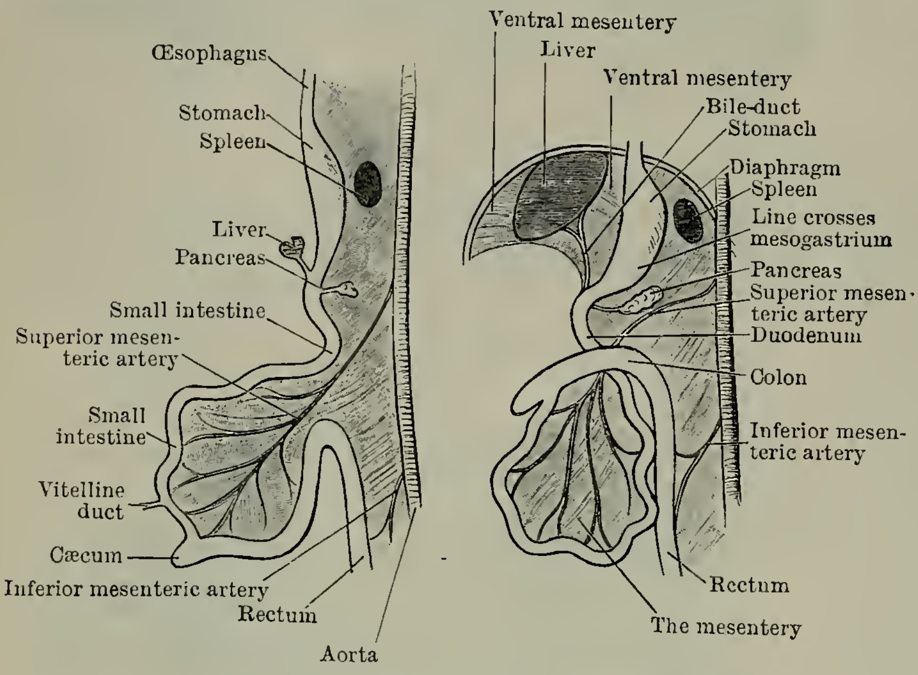


FIG. 956.—TWO DIAGRAMS TO ILLUSTRATE THE DEVELOPMENT OF THE INTESTINAL CANAL.

The figure to the right shows the rotation of the intestinal loop around the superior mesenteric artery. In both figures the parts are supposed to be viewed from the left side.

The proximal portion of the original hollow diverticulum becomes the bile duct, and the gall-bladder and cystic duct are formed by an evagination from it.

As the liver increases in size, it begins to project down from the inferior part of the septum transversum into the ventral mesentery, so that now, instead of being situated within the septum, it looks like an appendage of its inferior surface. In other words, the septum begins to differentiate into two parts—an inferior, the liver, and a superior, which constitutes the greater portion of the diaphragm, both of these having been at first one continuous mass. In the course of development the separation of the two becomes more marked, and finally is complete everywhere except at the coronary and lateral ligaments behind, and at the falciform ligament in front, where they are still connected.

As the liver separates off from the future diaphragm, and descends into the abdomen, it lies between the layers of the **ventral mesentery**—a fold which connects the stomach and duodenum with the anterior abdominal wall. This is divided by the liver into two parts—a lower, stretching from the front (lesser curvature) of the stomach to the liver, which becomes the lesser omentum; and an upper, stretching from the liver to the diaphragm and anterior wall of the abdomen, which forms the falciform ligament.

2. **Pancreas.**—The pancreas is developed at a very early period in man (being present in embryos of 5 mm.) from two outgrowths from the alimentary canal, a dorsal and a ventral.

The dorsal rudiment is an outgrowth from the dorsal aspect of the intestine, anterior to the origin of the hepatic outgrowth. The ventral rudiment grows at a later stage from the root of the hepatic bud in the form of two ventral offshoots, one on either side. That on the left side, however, soon disappears.

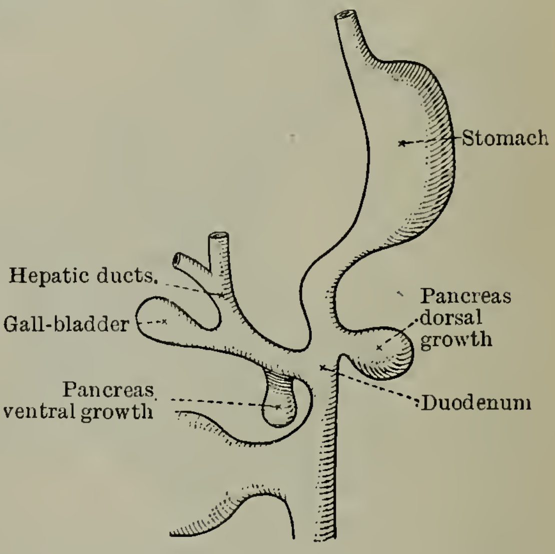


FIG. 957.—DIAGRAM OF THE ORIGIN OF THE LIVER AND PANCREAS.

Through the rotation of the duodenum around its long axis, the dorsal and ventral rudiments approach one another and become fused, and their ducts open on the left side of the duodenum. The connecting stalk between the ventral rudiment and the hepatic bud becomes the main duct of the pancreas, while the connexion of the dorsal outgrowth with the duodenum remains as the accessory pancreatic duct. In embryos of the fifth week, a large dorsal pancreatic rudiment is present, and also a smaller ventral rudiment, which opens into the duodenum in common with the bile duct, and lies on the right of the vena portæ. In the sixth week, these two rudiments meet and unite with one another, forming a long slender glandular mass which passes backwards within the dorsal mesogastrium (mesoduodenum), between the vertebral column and the greater curvature of the stomach. The pancreas, so formed, follows the changes which occur in the position of the stomach and of the dorsal mesogastrium. Consequently its free dorsal extremity comes to be directed to the left, while the right extremity or head is included within the hollow of the curve formed by the duodenum. At first, it possesses a dorsal mesentery, a part of the dorsal mesogastrium, but from the fifth month this disappears, coincidently with the rotation of the gland into the transverse axis of the body.

The lower part of the head, the body and tail of the gland arise from the ventral element, and the upper part of the head arises from the dorsal bud.

The primary diverticula give off buds, lined with cylindrical epithelium, and these in turn give off other buds, and the process goes on until the mass of the gland is formed.

The islets of Langerhans are formed at a very early stage, from the entodermal lining cells of the branching diverticula which form the gland acini.

THE URO-GENITAL SYSTEM.

By A. Francis Dixon.

THE URINARY ORGANS.

The **kidneys**, or glands which secrete the urine, are a pair of almost symmetrically placed organs, situated in the posterior part of the abdominal cavity, one on each side of the lower movable portion of the vertebral column. The fluid, or urine, secreted by the kidneys is received into the upper expanded portions of a pair of long tubes, the **ureters**, and by them it is conducted to the **urinary bladder**, which is placed within the lesser pelvic cavity. From the bladder the urine is passed, during micturition, along a passage called the **urethra** to the exterior. In the male the urethra is a relatively long passage, and traverses the prostate gland and the whole length of the penis; in the female it is a short tube, and opens on the surface just above the vaginal orifice.

THE KIDNEYS (RENES).

The **kidney**, when removed from a fresh subject, presents a bean-shaped contour. It is of a dark brown-red colour, and is surrounded by a thin glistening capsule, the **tunica fibrosa**, which gives to the whole organ a uniformly smooth surface. The kidney is not a solid body, but contains a cavity called the **renal sinus**, the opening into which, termed the **hilum**, is situated on the medial and anterior part of the organ. Each kidney measures about 4½ inches in length, 2 inches in width, and about 1¼ inches in thickness, and is placed so that its long axis is nearly vertical. The weight of the adult kidney is about 4½ ounces. In the freshly removed kidney the superior and inferior ends are smoothly rounded, and the **superior end** is usually a little more bulky than the **inferior end**. The **lateral border**, which is opposite the hilum, is rounded and convex, while the **medial border**, on which the hilum is placed, is concave from above downwards. These two borders separate the **anterior surface** from the **posterior surface** of the kidney.

The *capsule*, which envelops the whole organ, divides in the region of the hilum into two layers, one of which is continued over the lips of the hilum into the interior of the kidney, and lines the walls of the renal sinus. The other layer is prolonged to form a tubular sheath for the vessels and nerves of the kidney before they pass through the hilum to enter the sinus, within which they break up into branches. These branches, piercing the wall of the sinus, enter the substance of the kidney. The upper expanded portion of the ureter leaves the sinus, through the hilum, in company with the blood-vessels and nerves.

Position of the Kidneys.—The precise level of the kidney in the abdominal cavity is subject to a considerable amount of variation, and, further, it is usual to find a difference in the level of the right and left kidney in the same individual. Most frequently the left kidney is on a somewhat higher level than the right, but in many cases the kidneys are found to occupy the same level, or, the more usual condition being reversed, the right kidney is a little higher than the left.

If a line is drawn round the body at the level of the lowest part of the thoracic wall, the whole, or almost the whole, of the left kidney will be found to lie above the level of the subcostal plane so determined. It is, therefore, situated in the subcostal zone of the abdominal cavity. The right kidney, however, although it lies for the most part in the subcostal zone, usually projects at its inferior part somewhat below the subcostal plane, and hence lies to some extent in the umbilical zone. It is often stated that the kidneys are placed on a somewhat lower level in the female than in the male subject.

By far the greater part, usually two-thirds or more, of the kidney lies to the medial side of a line drawn vertically upwards through the middle point of the inguinal ligament.

The posterior aspect of the kidney is closely applied against the muscles attached to the bodies of the last thoracic and upper three lumbar vertebræ, and is placed in front of the last rib and of the transverse processes of the upper three lumbar vertebræ. In some cases, more frequently on the left side of the body, the eleventh rib also lies behind the upper part of the kidney. The relationship of the kidney to the lower two ribs is, however, very inconstant, owing partly to the great variability in size and inclination of those bones.

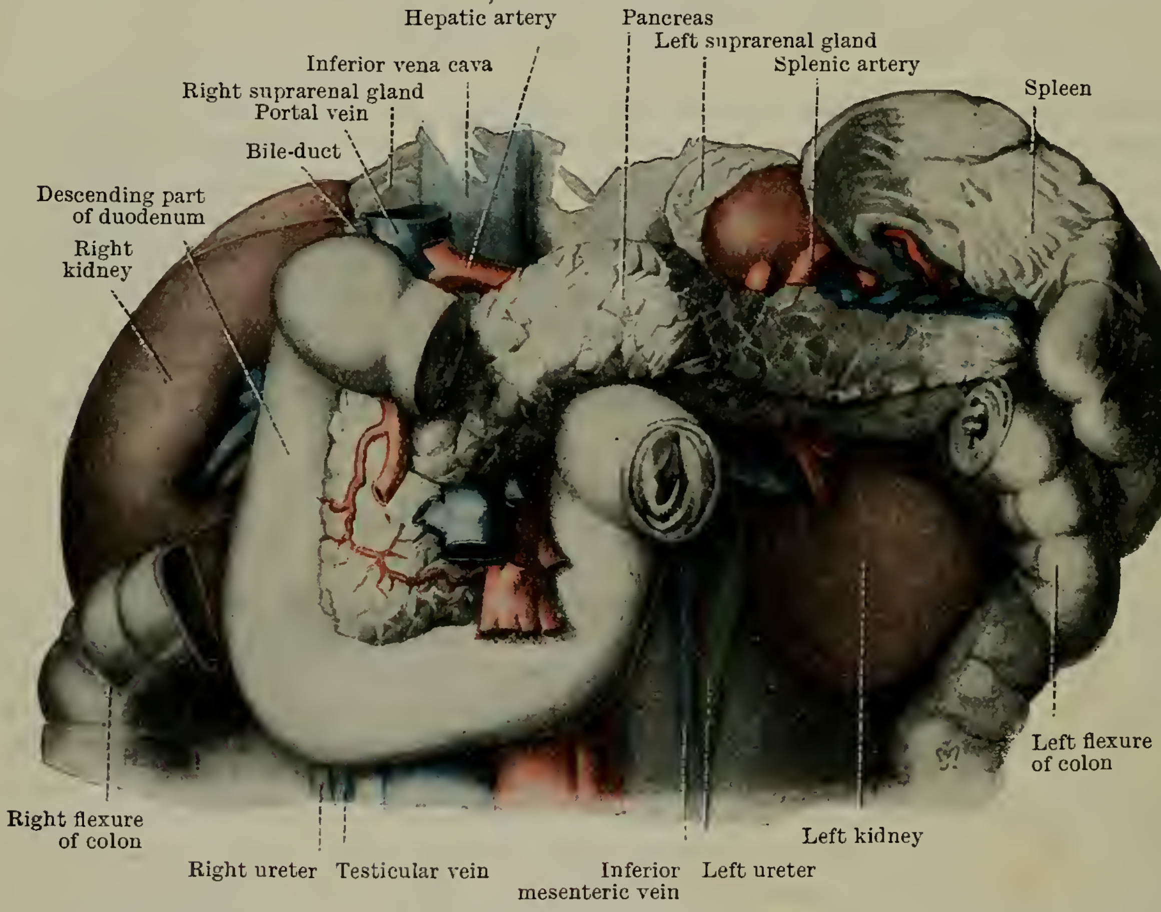


FIG. 958.—DISSECTION TO SHOW THE RELATIONSHIPS OF THE KIDNEYS. The greater part of the stomach has been removed by an incision made close to the pylorus. The transverse colon has been taken away, and the small intestine has been cut across close to the duodeno-jejunal flexure.
A model prepared by the late Professor Birmingham has been made use of in this drawing.

The inferior end of the kidney is usually situated from 1¼ to 2 inches above the highest part of the crest of the ilium; the interval between the kidney and the ilium being usually greater on the left side of the body.

Occasionally the inferior end of the kidney lies on the same level as, or only a short distance above, the iliac crest; this condition is sometimes due to the crest rising to a higher level than usual, the kidney occupying its normal position in relation to the vertebral column. It is important to remember that during life the kidney moves upwards and downwards, following the respiratory movements of the part of the diaphragm against which it rests.

The long axis of each kidney is somewhat oblique, its superior end approaching nearer to the median plane than the inferior. The surface of the kidney which is applied against the muscles forming the posterior wall of the abdomen looks, as a whole, backwards and medially, and that which projects into the abdominal cavity looks forwards and laterally. Hence it happens that the lateral border lies on a more posterior plane than the medial border. The kidney is rotated in this manner on its long axis to such a degree that the medial margin and hilum are scarcely visible from behind, and only a limited view of the lateral border can be obtained from the front (Figs. 958 and 959).

The kidneys are placed behind the peritoneum, and project into the posterior part of the abdominal cavity. Each is surrounded by a considerable amount of loose tissue, often loaded with fat; the fatty tissue, or **capsula adiposa**, being present in greater quantity round the margins of the kidney, and only to a less extent in front of and behind the organ. The renal vessels and nerves lie in this fat before they enter the kidney, and the adipose tissue is continued, along with the vessels, through the hilum into the renal sinus, where it fills up all the space unoccupied by the vessels and nerves.

Embedded in the soft fatty tissue surrounding the kidney is a layer of fibrous tissue to which the term **renal fascia** is applied. This fascia surrounds the kidney and a considerable amount of its fatty capsule in the form of a loose sheath, in which may be distinguished anterior and posterior walls. The sheath is open inferiorly and medially, but closed above and to the lateral side of the kidney by the apposition of its walls. Laterally, the anterior and posterior walls of the sheath come into contact and are connected with the retro-peritoneal tissue. Medially they remain distinct, and the anterior wall is continued across the median plane, in front of the renal vessels and the aorta, to join the corresponding layer of the opposite side, while the posterior wall fuses with the fascia covering the psoas and quadratus lumborum muscles. Inferiorly, below the level of the kidney, the anterior and posterior layers of the renal fascia remain separate, and can be traced downwards into the iliac fossa. Above the level of the kidney and the suprarenal gland the layers of the renal fascia unite and join the fascia covering the diaphragm. The term "perinephric fat" is applied to the loose fatty tissue enclosed along with the kidney within the sheath of renal fascia, and "paranephric fat" is used to denote the tissue outside the renal fascia (Fig. 959). The fibrous capsule of the kidney is joined to the loose sheath formed by the renal fascia by numerous connective tissue strands. These traverse the peri-

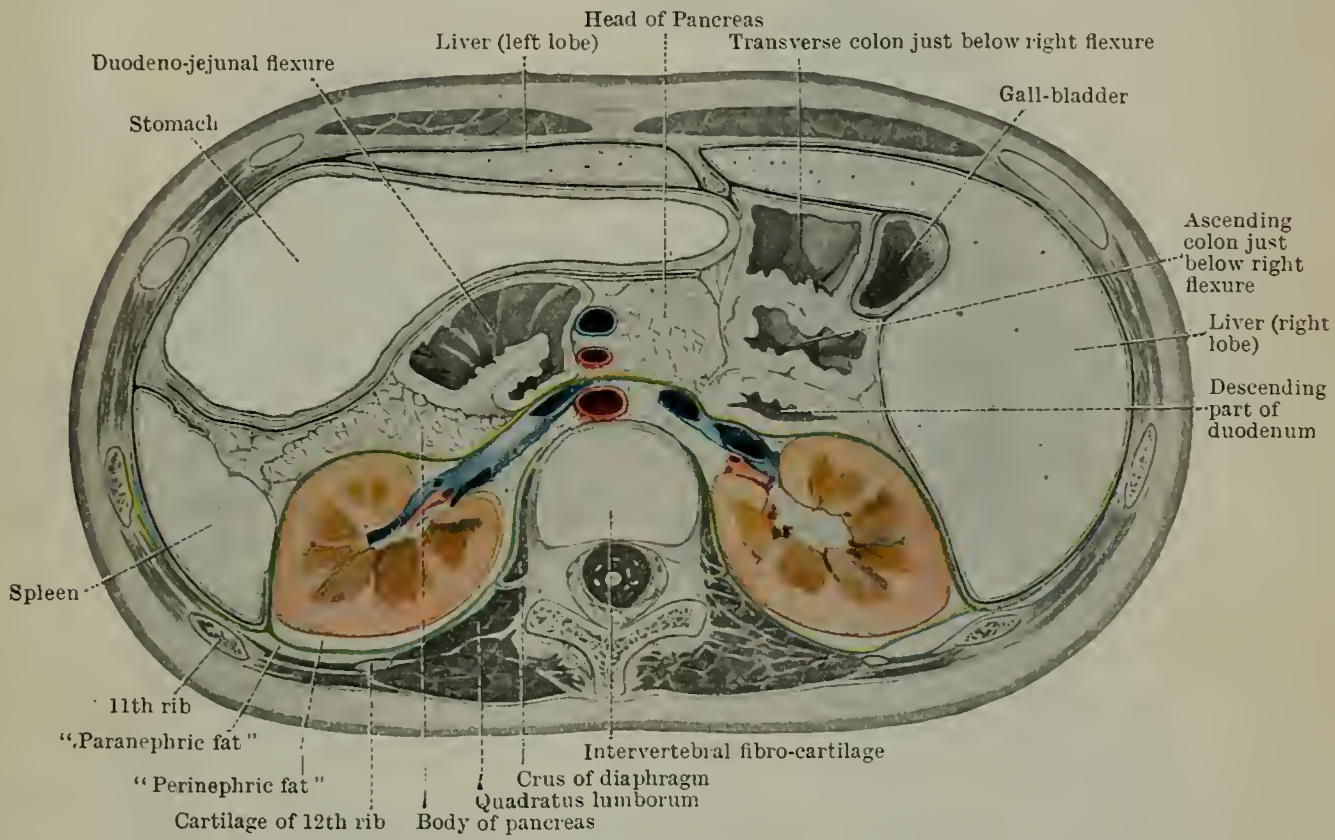


FIG. 959.—TRANSVERSE SECTION THROUGH THE BODY OF A CHILD. The position and relationships of the kidneys are well seen, and the arrangement of the fascia renalis is indicated. The fascia is coloured green.

nephric fat and undoubtedly assist in fixing the kidney in its place. The paranephric fat is present in greatest quantity behind the inferior part of the kidney, and in this position the layer of fibrous tissue, separating the two masses of fat and forming the posterior layer of the sheath of renal fascia, is usually well marked.

Fixation of the Kidney.—The kidney is not held in its place by any distinct ligaments, or special folds of peritoneum, but its fixation depends, to a large extent, on the pressure and counter-pressure which is exerted upon it by neighbouring structures, and on its connexions with the renal fascia above described.

Posterior Relations and the Posterior Surface of the Kidney.—The muscles of the posterior abdominal wall on which the kidney rests are the psoas major, the quadratus lumborum, the diaphragm and the tendon of the transversus abdominis. The abdominal surfaces of these muscles do not lie on the same plane, but slope towards one another, and thus the bed on which the kidney rests is not flat. When but little fat is present, the posterior aspect of the kidney adapts itself to the inequalities of the surface against which it is placed, and so we may find on a kidney which has been carefully fixed and hardened before it has been disturbed, areas marked off for the different planes of these muscles. When such a kidney is in position, slight ridges or elevations separating these areas correspond to the angles along which the different muscular planes meet. These ridges can be observed in the hardened kidney, after its removal from the body, but usually they are not sharply defined, the angles between the muscular planes being very obtuse.

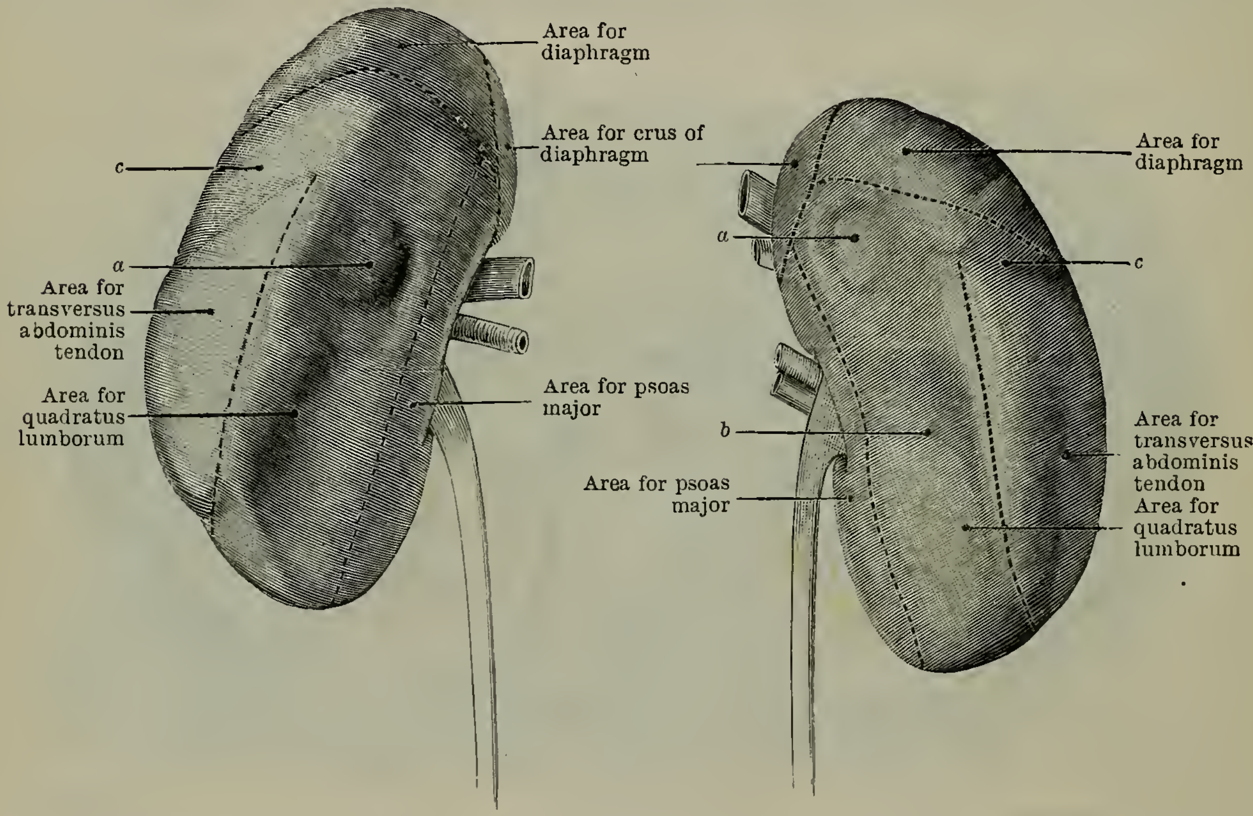

Area for diaphragm
Area for crus of diaphragm
c
a
Area for transversus abdominis tendon
Area for quadratus lumborum
Area for psoas major
Area for diaphragm
a
c
b
Area for psoas major
Area for transversus abdominis tendon
Area for quadratus lumborum

Fig. 960.—The Posterior Aspect of the Kidneys. The dotted lines mark out the areas in contact with the various muscles forming the posterior abdominal wall.

a and *b*. Depressions corresponding to the transverse processes of the first and second lumbar vertebræ.
c. Depression corresponding to the twelfth rib.

A kidney removed from the body after having been hardened *in situ* (Fig. 960) presents an area along the medial part of its posterior surface adapted to the anterior aspect of the psoas major muscle. This part of the posterior surface looks medially and slightly posteriorly. More laterally there is a larger area which rests against the quadratus lumborum and looks more directly backwards. These two areas are separated by a rounded ridge which fits into the angle between the muscles mentioned. Beyond the area in contact with the quadratus lumborum is the thick lateral border of the kidney, which rests for the most part on the tendon of the transversus abdominis and on the diaphragm.

Towards the superior end of the kidney the posterior surface slopes somewhat forwards and rests upon the diaphragm. Indeed the superior part of the kidney is, as a whole, bent slightly forwards, following that part of the arch of the diaphragm on which it rests, and thus a narrow interval is left, in which the pleural cavity passes down behind the superior end of the kidney. This relationship of the pleural cavity to the kidney is of great importance in connexion with surgical operations performed through an incision in the lumbar region. The portions of the diaphragm to which the kidney is applied are the crus and the parts arising from the last rib and lumbo-costal arches.

The anterior divisions of the last thoracic nerve and the ilio-hypogastric and ilio-inguinal branches of the first lumbar nerves pass downwards and laterally in close relationship to the posterior aspect of the kidney.

The posterior relationships of the kidney are well seen in Figs. 959, 842.

In addition to these surfaces, or "facets," for the muscles with which it is in contact, the posterior aspect or lateral border of the kidney often shows a groove for the last rib, another for the lateral lumbo-costal arch, and two or three depressions for the tips of the transverse processes of the upper two or three lumbar vertebræ. In some cases also faint narrow grooves are to be seen for the nerves which pass downwards and laterally between the kidney and quadratus lumborum.

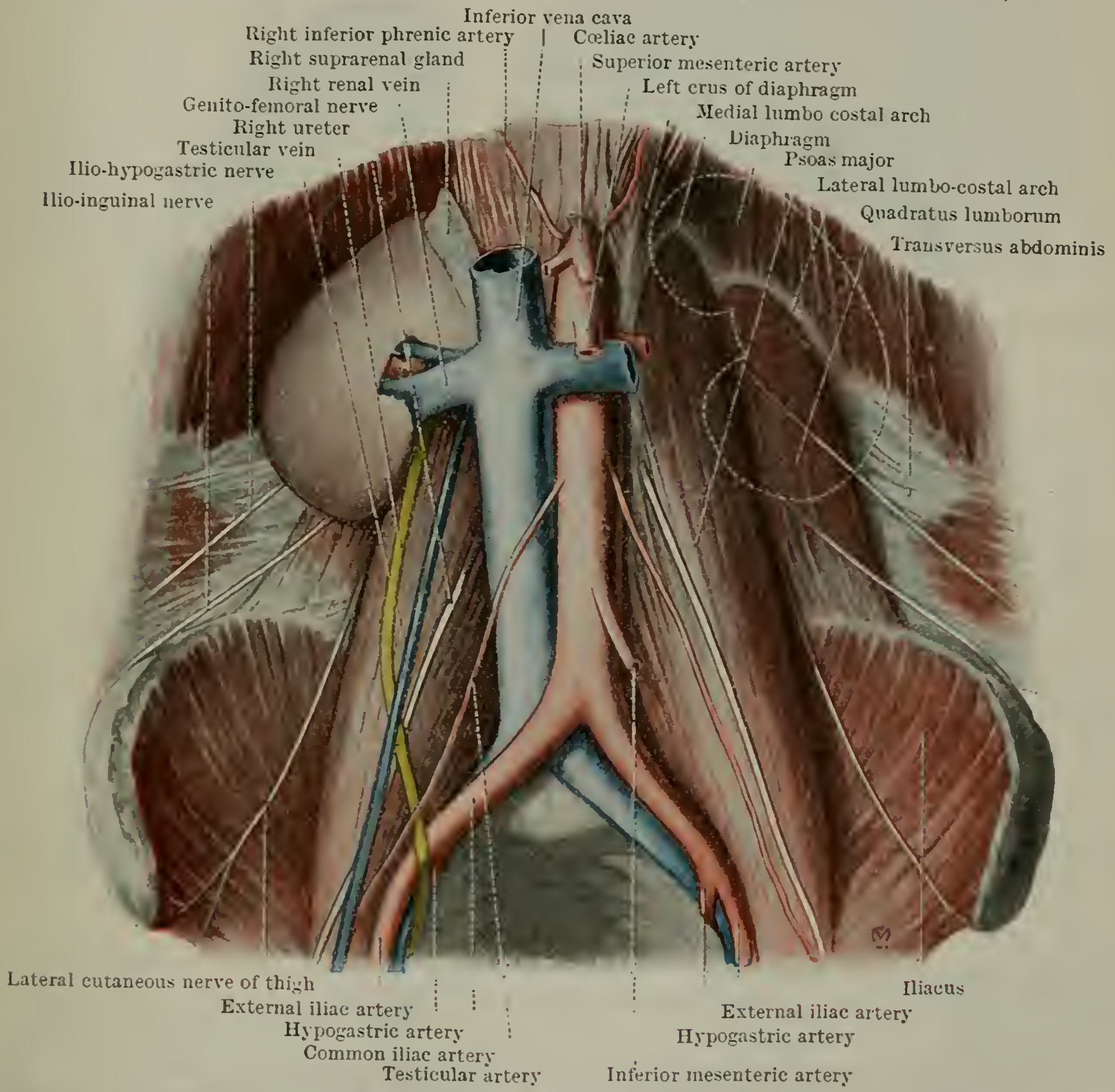


Fig. 961.—Dissection to show the Relationships of the Kidney and of the Ureter to the Posterior Abdominal Wall. The dotted outline indicates the position of the left kidney.

It is probable that some at least of the depressions on the posterior aspect of the kidney are produced after death, and are caused by the weight of the other abdominal organs pressing the kidney backwards against the more resisting structures of the abdominal wall, at a time when the muscles behind the kidney have become flaccid. When much fat is present the posterior aspect of the kidney is more uniformly convex.

The **lateral border** in its middle and inferior part is rather a surface than a border, and looks for the most part directly backwards. It rests on the diaphragm and on the anterior surface of the tendon of the transversus abdominis, to the lateral side of the quadratus lumborum muscle. The lateral border is narrowest above, and widest just below its middle point, corresponding to the greater thickness of the kidney at this level.

In many ways it would be more satisfactory to apply the term **facies muscularis** collectively to the areas above described as "posterior surface" and "lateral border"; in like manner the term **facies visceralis** might be suitably applied to the so-called anterior surface of the organ. The edge separating the visceral from the muscular surface is the actual lateral edge, or border, of the kidney.

Anterior Relations and the Anterior Surface of the Kidney.—The anterior relations of the kidneys not only differ on the two sides of the body, but also many of the structures related to the anterior surface of each kidney undergo frequent changes in position during life. Hence it is not possible to give more than a general account of the anterior relationships of the kidneys.

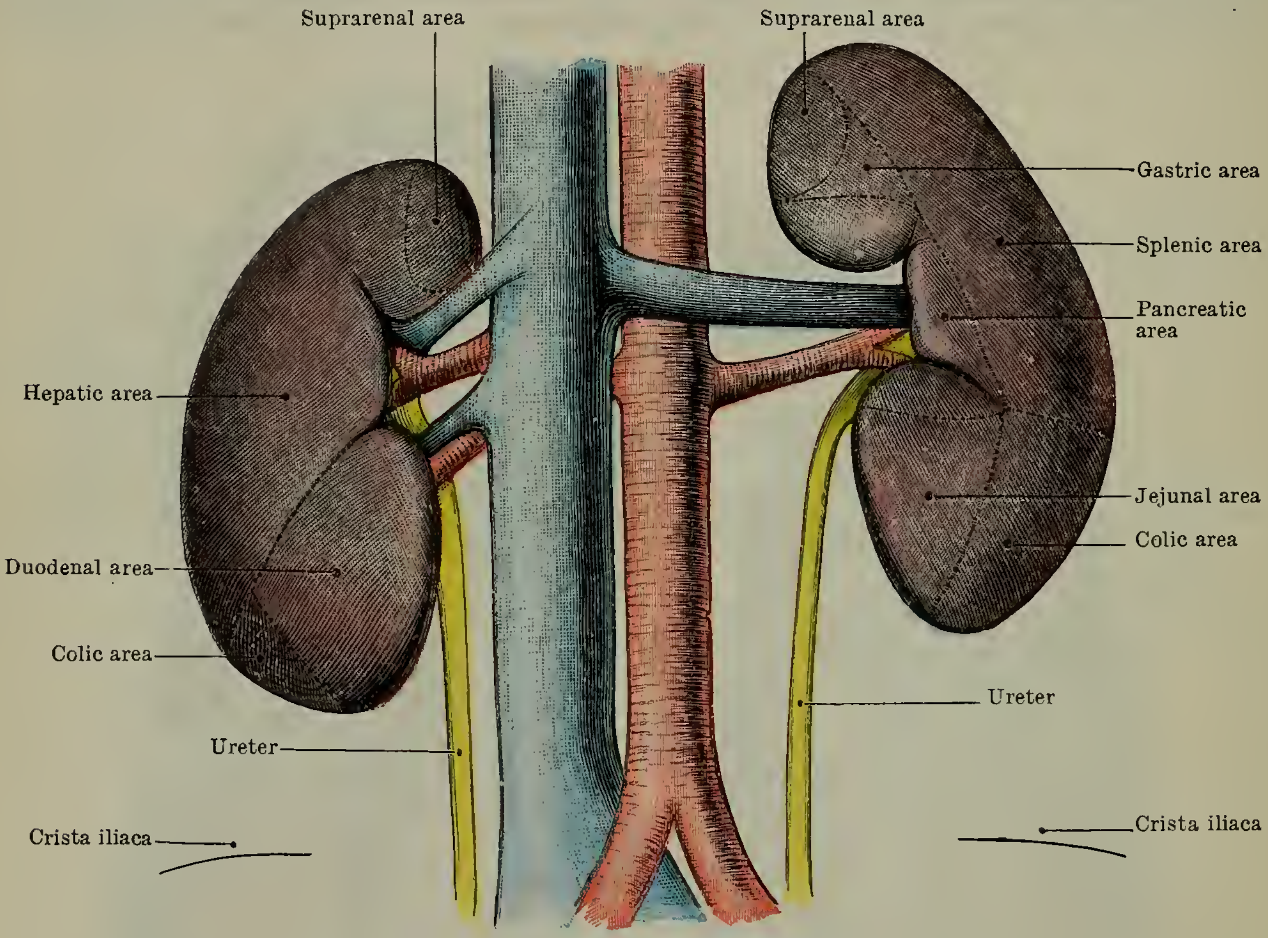


FIG. 962.—ANTERIOR ASPECT OF THE KIDNEYS AND GREAT VESSELS. The drawing was made, before removal of the organs, from a specimen in which the viscera had been hardened *in situ*. The dotted lines mark out the areas which were in contact with the various other abdominal viscera.

Right Kidney.—A small area on the superior part of the anterior surface of the right kidney is in relation to the corresponding suprarenal gland (Fig. 962). The rest of the superior part of the anterior surface is in contact with the visceral surface of the liver, which is often hollowed out to form a fossa for the kidney. The suprarenal gland is bound to the kidney by connective tissue, while the part of the kidney in relation to the liver is, like the liver itself, covered by peritoneum, and thus the two organs, although closely applied, are really separated by a part of the general peritoneal cavity. Immediately anterior to the inferior end of the right kidney are usually found two parts of the alimentary canal—namely, the descending part of the duodenum and the right flexure of the colon, or the commencement of the transverse colon. The part of the kidney related to the duodenum lies to the medial side of the area which touches the colon, but the exact amount of the kidney in contact with each of these two parts of intestine varies much in different subjects. Frequently the colon and the kidney are both covered by peritoneum where they are in contact, but the duodenum is bound down to the kidney by connective tissue. In addition to the structures mentioned, some portion of the ileum, or of the jejunum, is often found in contact with a small part of the right kidney near its inferior end.

In some cases the peritoneal membrane does not cover the whole of the surface in contact with the liver, and then the superior part of the hepatic area of the kidney is, like the anterior aspect of the suprarenal gland, bound by connective tissue to the "uncovered" area on the posterior aspect of the liver.

Left Kidney.—The extreme superior and medial part of the anterior aspect of the left kidney is united by connective tissue to the lower part of the left suprarenal gland, and the area immediately below this is in contact with the stomach and the pancreas. The pancreas, like the suprarenal gland, is bound down to the kidney by connective tissue, but the stomach is separated from the area with which it is in apposition by a portion of the omental bursa. The area in actual contact with the stomach is a small somewhat triangular district situated above the level at which the pancreas is related to the kidney. The superior and lateral part of the anterior aspect of the kidney is related to the spleen, the two organs being separated by a portion of the general peritoneal cavity, except along the area where spleen and kidney are connected by the lieno-renal ligament. The anterior surface of the inferior end of the left kidney is related, towards the medial side, to a part of the jejunum, and, towards the lateral side, to the left flexure of the colon or to a part of the descending portion of the colon. In most cases, however, the colon lies against the posterior abdominal wall to the lateral side rather than on the anterior surface of the left kidney.

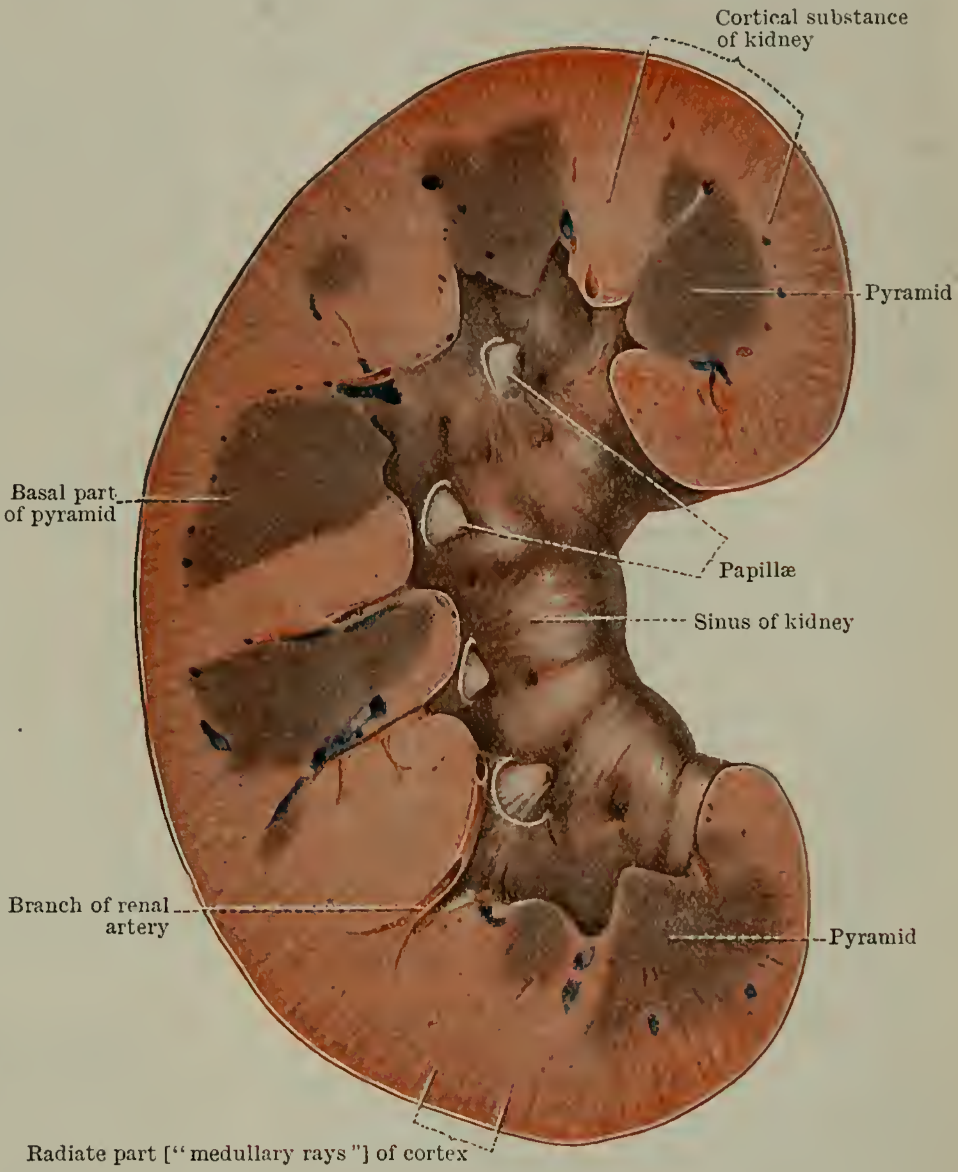


FIG. 963.—LONGITUDINAL SECTION THROUGH THE KIDNEY.

The vessels and fat have been removed to give a view of the wall of the kidney sinus. The points where the vessels enter the kidney substance are seen as holes in the sinus wall.

The right and left colic arteries, or their branches, as they pass laterally to reach the colon, are often related to the anterior aspects of the corresponding kidneys. The splenic vessels pass laterally in front of the left kidney (Fig. 958).

The anterior surface of a kidney which has been hardened *in situ* is, like the posterior surface, not uniformly rounded, but marked by a series of impressions corresponding to the different structures which lie in contact with it. In the case of each kidney, the most prominent region on the anterior surface lies below the level of the middle of the kidney, and corresponds to the thickest part of the organ. From this prominence on the anterior surface a series of more or less flattened planes slope away towards the borders of the kidney. These flattened areas are impressions formed by the viscera which lie against the anterior surface of the kidney.

In the case of the **right kidney**, three areas or impressions can usually be distinguished on the anterior surface. One occupies the whole of the upper part of the organ, and is known as the **hepatic area**; another, the **colic area**, stretches from the most prominent point to the inferior end of the kidney, and is related to the colon; while the third or **duodenal area** extends along the medial margin, below the hilum, and is in contact with the second part of the duodenum (Fig. 962). The relative sizes of these three areas vary much in different specimens.

On the **left kidney**, also, three more or less defined, flattened areas slope towards the borders of the organ from the most prominent part of the anterior surface. One of these, on the superior and lateral part of the kidney, is the **splenic area**; another, extending downwards to the lower end of the kidney, is for the jejunum, or for the jejunum and colon; the third, above and in the region of the hilum, is called the **gastric area**, and corresponds to the position of the overlying stomach. Only a small portion of this area is in direct contact with the stomach, since the pancreas and a part of the suprarenal gland intervene between the stomach and the kidney (Fig. 958).

It is common to find the left kidney thicker and less flattened antero-posteriorly than the right, the impressions, or "facets," upon its surface being at the same time better marked. With this probably is to be associated the fact that *loose* or *floating kidney* is more rarely met with on the left than on the right side of the body.

Extremities of the Kidney.—The kidney, fixed and hardened *in situ*, is usually more pointed at its *inferior* than at its *superior* end. The latter is wider from side to side, and often somewhat flattened from before backwards. The superior end of the kidney is bent somewhat forwards and rests upon the diaphragm, which separates it, as explained above, from the inferior part of the pleural cavity.

Sinus Renalis.—The **sinus of the kidney** (Fig. 963), into which the hilum opens, is a narrow space, having its long axis corresponding to that of the kidney. The thick walls of the sinus cavity are formed by the substance of the kidney, and are lined by a part of the fibrous kidney capsule which enters the sinus over the lips of the hilum. The floor of the sinus is not even, but presents a series of small projecting conical elevations called **renal papillæ**, which vary from six to fifteen in number. Radiating from each papilla are a number of somewhat raised bars, or ridges, of kidney substance, separated by depressed areas. The blood-vessels and nerves enter and leave the kidney by piercing the wall of the sinus where it is formed by these little depressed areas. The summit of each renal papilla is pierced by a number of minute openings called **foramina papillaria**, which are the terminal apertures of the secreting tubules of which the kidney is mainly composed. These openings all lie close together, and give rise to the so-called **area cribrosa** upon the apex of the renal papilla. The urine secreted by the kidney escapes through the foramina papillaria into the subdivisions (calyces) of the ureter or kidney duct.

Kidney in Section.—Sections through the kidney (Figs. 963 and 965) show that it is composed to a large extent of a number of conical masses, known as **renal pyramids**. These together constitute the **medullary substance** of the kidney, and are arranged with their bases directed towards the surface, and their apices projecting into the renal sinus, where they form the renal papillæ already mentioned. The pyramids are more numerous than the papillæ, two or three usually ending in each papilla in the middle part of the kidney, and sometimes as many as six or more in each papilla near the superior and inferior ends of the organ. The bases of the pyramids do not reach the surface of the kidney, but are separated from it by a layer called the **cortical substance** of the kidney. The cortical substance not only covers over the bases of the pyramids, but also sends in prolongations, known as **renal columns**, between the pyramids, towards the sinus. The medullary part of the kidney exhibits in section a striated appearance, while the cortical part is more granular and usually different in colour. The outer, or **basal part**, of each pyramid appears in section to be composed of alternate dark and light streaks, while the inner, or **papillary part**, is often of a lighter colour, and more uniformly and faintly striated.

In sections of the kidney the larger blood-vessels, after they have entered the kidney substance, are seen to lie between the pyramids; and some of their main branches are visible passing across the bases of the pyramids.

In the fœtus and young child, and sometimes, though much less distinctly, in the adult, the surface of the kidney is marked by a number of grooves dividing it into polygonal areas. These represent the **lobes**, or reniculi, of which the kidney is originally composed, and each corresponds to one papilla with its pyramids and surrounding cortical substance.

An examination, with an ordinary pocket lens, of a section through the kidney shows that the lighter striæ of the bases of the pyramids are continued into the cortex. As they pass through the cortex towards the surface of the kidney the striæ become less distinct, and appear, when cut longitudinally, as separate ray-like prolongations carried outward from the bases of the pyramids. These parts of the cortex, which seem, in this way, to be continuations of the medulla, are called "medullary rays" and constitute the **pars radiata** of the cortex. The part of the cortex which intervenes between them forms what is known as the **pars convoluta** or "labyrinth." The appearance presented by the cortex of the kidney in section varies much according to the plane in which the section has been taken. If the section passes through and lies parallel to the axis of a pyramid, the medullary rays will appear as isolated streaks directed from the base of the pyramid towards the surface of the kidney, and separated from one another by narrow strips, or intervals, of the convoluted part or labyrinth. On the other hand, in sections made at right angles to the axis of a pyramid, or cutting this axis obliquely, the convoluted portion of the cortex presents the appearance of a continuous net, the meshes of which are occupied by the radiate parts, and these latter now exhibit circular or oval outlines. In a similar manner sections through the bases of the pyramids differ much in the appearances they afford according to the plane in which they are cut.

Kidney Tubules.—The glandular substance of the kidney is composed of a vast number of minute **renal tubules**, all of which have an exceedingly complicated course. The wall of each tubule consists throughout of a basement membrane and of an epithelial lining, but the lumen of the tubule and the character of the epithelium vary much in its different parts. Every tubule begins in a thin-walled spherical dilatation, known as **capsula glomeruli** or **Bowman's capsule**, in which a complicated loop of capillary blood-vessels or **glomerulus** is contained. The tuft of capillaries is covered by a reflexion of the delicate wall of the capsule, and is, as it were, invaginated into the capsule (Fig. 964). The capsules with their enclosed capillaries are called **kidney corpuscles**, and are all placed in the convoluted portion of the kidney cortex, where they may be recognised as minute red points just visible to the unaided eye and best marked when the renal vessels are congested. The part of the tubule leading from the capsule —*first convoluted tubule*— is very tortuous, and lies within the convoluted part of the cortex. Passing from the convoluted part, the tubule enters a radiate part, in which its course becomes less complicated, and here it receives the name of *spiral tubule*. From the radiate part the tubule enters the basal portion of the pyramid, and, diminishing in diameter, it pursues a straight course towards the apex of the pyramid, forming the so-called *descending limb of Henle's loop*. Within the apical portion of the pyramid the tubule suddenly bends upon itself, forming the *loop of Henle*, and reversing its direction, it passes back again through the base of the pyramid into the radiate part of the cortex as the *ascending limb of Henle's loop*. This ascending limb exhibits a slight spiral twisting. Leaving the radiate part, the tubule once more enters the convoluted part of the cortex, where its outline becomes so uneven that the name *irregular tubule* is applied to it. While still within the convoluted part, its contour having acquired a more uniform appearance, the tubule receives the name of *second convoluted tubule*; this latter finally ends in a short *junctional tubule*, which passes back into a radiate part of the cortex and joins a *collecting tube*. Each collecting tube receives numerous renal tubules, and pursues a straight course through the radiate part of the cortex and the pyramid. Finally, several collecting tubes, uniting together, form an *excretory tube*, which opens on the summit of a renal papilla into a calyx of the ureter by one of the foramina papillaria already described. In microscopic sections the various portions of the kidney tubule may be distinguished by the position which they occupy and by the character of the lining epithelium.

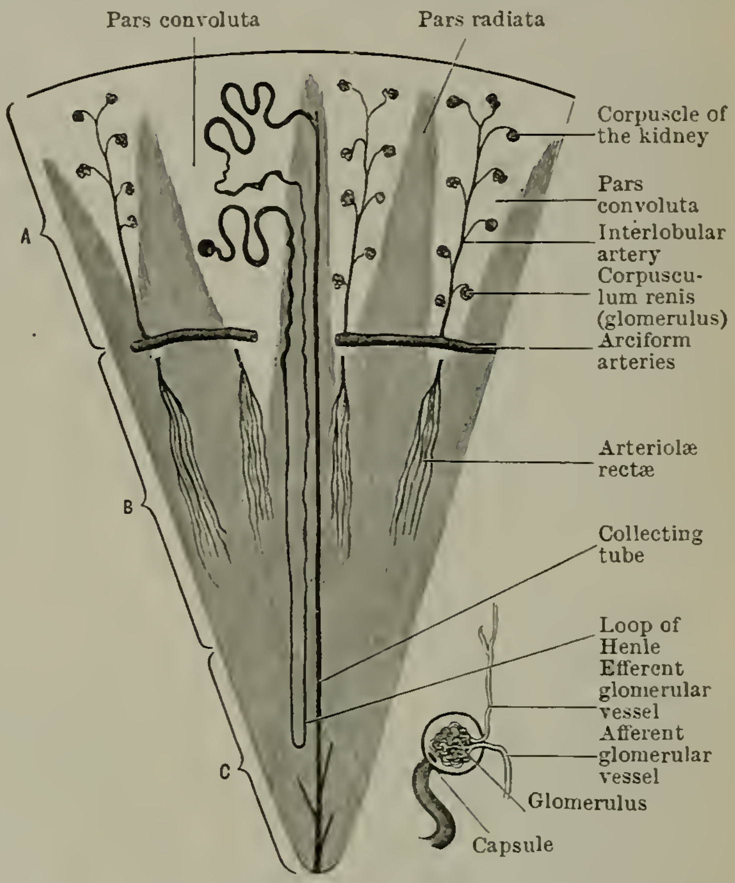


FIG. 964.—DIAGRAMMATIC REPRESENTATION OF THE STRUCTURES FORMING A KIDNEY LOBE.

In the middle part of the figure the course of one of the kidney tubules is indicated, and in the lateral parts the disposition of the larger arteries. A, Cortex; B, Basal portion, and C, Papillary portion of pyramid. The diagram at the right-hand side of the lower part of the figure illustrates the connexions of the structures composing a renal corpuscle.

Connective Tissue of the Kidney.—The tubules and the blood-vessels forming the substance of the kidney are all united together by a very small amount of connective tissue, which completely surrounds each tubule and blood-vessel, and binds it to its neighbours. It has been found possible to obtain an accurate idea of the arrangement of this connective tissue by submitting thin sections of the kidney to the action of certain digestive fluids. When this is done the tubules and blood-vessels are removed, and the connective-tissue stroma is left behind. The connective tissue thus revealed is seen to form a continuous network, the spaces in which faithfully reproduce the outlines and the arrangement of the kidney tubules. The network of the stroma is continuous with the capsule of the kidney.

Vessels of the Kidney.—The renal artery comes directly from the aorta, and is very large in proportion to the size of the organ to which it conveys blood. Its main branches, as they approach the kidney to enter the hilum, lie between the tributaries of the renal vein in front and the ureter behind. Within the sinus of the kidney the branches of the renal artery become arranged in a dorsal and a ventral group, the dorsal vessels lying behind, the ventral ones in front of the subdivisions of the ureter. The ventral group of vessels supplies the part of the kidney which forms the anterior and lateral walls of the sinus; the distribution of the dorsal group is for the most part restricted to the portion of the kidney which lies behind, and to the medial side of the sinus.

Entering the substance of the kidney in the manner described above, the larger arteries lie in the intervals between the pyramids, and are called **interlobar arteries** of the kidney. These vessels dividing, form a series of incomplete arterial arches, the **arteriæ arciformes**, which pass across the bases of the pyramids. Although we speak of arterial arches, it must be understood that no anastomosis between the branches of the interlobar arteries actually takes place, but that each artery which enters the wall of the kidney sinus has an isolated distribution and possesses the characters of an "end artery." Each arterial arch gives off a number of vessels which pass through the convoluted part of the cortex towards the surface of the kidney. These are known as the **interlobular arteries**, and lie at very regular intervals. From them a number of short branches arise, termed **vasa afferentia**, each of which proceeds to the dilated extremity, or capsule, of a kidney tubule. Here the vas afferens breaks up into a much convoluted capillary mass, called a *glomerulus*, which is contained within the invagination of the capsule. The little vein which issues from the glomerulus or **vas efferens**, instead of running directly into a larger vein, breaks up, after the manner of an artery, into capillaries which supply the tubules of the convoluted and radiate parts of the kidney cortex. Hence almost all the blood which supplies the tubules of the cortical part of the kidney passes in the first instance through the glomeruli. The tubules of the bases of the pyramids also receive their blood-supply through vasa efferentia derived from the glomeruli which lie near. The little vessels passing from these latter glomeruli break up into bundles of fine arteries, which give the bases of the pyramids their coarsely striated appearance. They are known as **arteriolæ rectæ**, and, like the interlobular arteries are very conspicuous in injected preparations of the kidney.

The fibrous capsule of the kidney receives minute branches from the interlobular arteries, some of which, piercing the capsule, communicate by capillaries with the vessels of the tunica adiposa.

Veins corresponding to the interlobular arteries and arteriolæ rectæ collect the blood from the capillaries surrounding the tubules, and unite to form a series of complete arches across the bases of the pyramids. From these venous arcades vessels arise, which traverse the intervals between the pyramids and reach the sinus of the kidney, where they unite to form the dorsal and ventral tributaries of the renal vein. Some small veins in the superficial part of the cortex communicate through the fibrous capsule with minute veins in the capsula adiposa. Issuing from the kidney sinus, the renal veins run a direct course to end in the inferior vena cava.

Nerves of the Kidney.—The nerves of the kidney accompany the branches of the artery, and are derived from the renal plexus. Their minute branches form regular net-like plexuses on the walls of the fine arteries and kidney tubules, and the presence of nerve terminations occurring among the epithelial cells lining the tubules has been demonstrated.

From clinical evidence it would appear that the afferent nerve fibres which supply the kidney are connected with the tenth, eleventh, and twelfth thoracic nerves.

The **Lymphatics** of the kidney end in the aortic lymph glands.

Variations.—A marked difference in the size of the two kidneys is sometimes observed, a small kidney on one side of the body being usually compensated for by a large kidney on the opposite side. Cases of complete absence of one or other kidney are recorded.

A few cases are on record in which an extra kidney was found on the right or left side.

Traces of the superficial lobulation of the kidney, present in the fœtus and young child, are often retained in the adult.

Horse-shoe kidney is not an infrequent abnormality. In these cases the two kidneys are united at their inferior ends, across the median plane, by a connecting piece of kidney substance. The amount of fusion between the two kidneys varies much; it is sometimes very complete, while in other cases it is but slight, the connexion being chiefly composed of fibrous tissue.

In very rare cases the kidney appears to be almost entirely surrounded by peritoneum and to be attached to the abdominal wall by a kind of mesentery, enclosing the vessels and nerves passing to the hilum. The condition is believed to be congenital.

Not very infrequently one or both kidneys are found at a much lower level than usual, and occupying a position in the iliac fossa or the pelvic cavity. This condition, when congenital, is associated with an arrest in the normal change in position, relative to surrounding structures, which the kidney experiences during development. In such cases the kidney does not receive its blood-supply from usually placed renal arteries, but from vessels which arise from the lower end of the aorta, or from the iliac, or the middle sacral artery. These congenital abnormally situated kidneys do not usually possess the typical outline of the normal organ, but vary much in shape, and the hilum is often malformed and misplaced.

In some mammalian animals, such as the bear, the kidneys are composed of a number of completely isolated lobes, each of which corresponds to one papilla, its pyramids and surrounding cortex; while in others, such as the horse, the fusion of the lobes is more complete even than in the human kidney, and a single mass represents the united papillæ.

THE DUCT OF THE KIDNEY.

The duct of the kidney is called the **ureter**, and begins above in a thin-walled funnel-shaped expansion called the **renal pelvis**, which is placed partly within and partly outside the sinus of the kidney. Towards the level of the inferior end of the kidney the part of the pelvis which lies outside the sinus diminishes in calibre, and forms a tube-like duct, the **ureter**, which conveys the urine to the bladder.

The Renal Pelvis.—Within the sinus of the kidney the pelvis lies among the larger renal vessels. It is formed by the junction of two, or more rarely three, thin-walled tubes, the **calyces majores**, each of which has a number of branches. These latter, called **calyces minores**, are short, and increase in diameter as they approach the sinus wall, to which they are attached. Their wide, somewhat funnel-like ends enclose the renal papillæ, and receive the urine which enters them through the foramina papillaria. The calyces are usually about eight in number, one calyx sometimes surrounding two or even three papillæ. The portion of the pelvis that lies outside the kidney has in front of it, in addition to the renal vessels, on the *right side*, the descending part of the duodenum, and on the *left side*, a part of the pancreas and sometimes the duodeno-jejunal flexure (Fig. 959).

The Ureter.—The ureter is the vessel which carries the urine from the pelvis of the kidney to the bladder. It is a pale-coloured thick-walled duct with a small lumen. When *in situ* it has a total length of about ten inches, and lies throughout its whole course in the subperitoneal tissue, behind the peritoneum, to which it is closely connected. In its superior part the ureter lies in the abdominal cavity, and in its inferior part in the pelvis minor (Figs. 961 and 966).

The normal ureter, in the flaccid condition, measures after its removal from the body eleven to fourteen inches.

The **abdominal portion** of the ureter, about five or five and a half inches in length, is directed downwards and slightly medially, and lies upon the psoas major muscle (Fig. 958). Certain structures are related to the ureters in a similar manner on both sides of the body; for instance, the abdominal portion of each ureter is crossed very obliquely, on its anterior aspect, by the internal testicular vessels, and behind each ureter the genito-femoral nerve passes downwards and laterally. Other structures are related to the duct of the right or left side alone. On the *right side*, the descending part of the duodenum lies in front of the upper part of the ureter, and the line of attachment of the mesentery crosses it lower down, just before the ureter enters the cavity of the pelvis minor. The right colic and ileo-colic arteries may also be anterior relations. On the *left side* the left colic artery and the line of attachment of the mesentery of the pelvic colon cross the ureter.

Crossing the common iliac, or the external iliac artery, the ureter enters the pelvis minor. The left ureter usually crosses the common iliac artery, and the right ureter, in most cases, lies across the external iliac; but this arrangement is by no means constant.

In X-ray photographs, the shadow cast by the abdominal portion of the ureter when the latter has been rendered opaque, is seen to fall immediately in front of the tips of the transverse processes of the lower lumbar vertebræ.

The **pelvic portion** of the ureter is about four and a half or five inches in length; it passes downwards on the side wall of the pelvis, immediately behind the peritoneum, describing a curve which is convex backwards and laterally (Fig. 966). The most convex portion of this curve lies close to the deepest part of the greater sciatic notch (Fig. 966). As it descends upon the side wall of the pelvis the ureter forms the posterior boundary of the triangular district known as the obturator triangle. The lower limit of this triangle is formed by the ductus deferens, and the upper and anterior boundary by the external iliac vessels and the pelvic brim (Fig. 966).

In its course within the pelvis minor the ureter lies in front of the hypogastric artery, and crosses the medial aspect of the obturator nerve and vessels and of the obliterated umbilical artery. About the level of the ischial spine, the ureter is crossed from before backwards by the ductus deferens, and from this point onwards it is not so intimately related to the peritoneum. It now bends somewhat medially and forwards, to reach the lateral angle of the bladder, and comes into relationship with the upper end of the vesicula seminalis, in front of which it lies (Fig. 940). The ductus deferens having crossed the ureter also turns medially, and as it does so it lies on a posterior plane to the ureter. The inferior end of the ureter is surrounded by a dense plexus of veins which brings the vesical plexus into communication with the hypogastric vein. The great nerve cord which connects the hypogastric plexus with the pelvic plexus, also comes into relationship with the lower part of the pelvic portion of the ureter, in the region where the latter is crossed by the ductus deferens (Fig. 940).

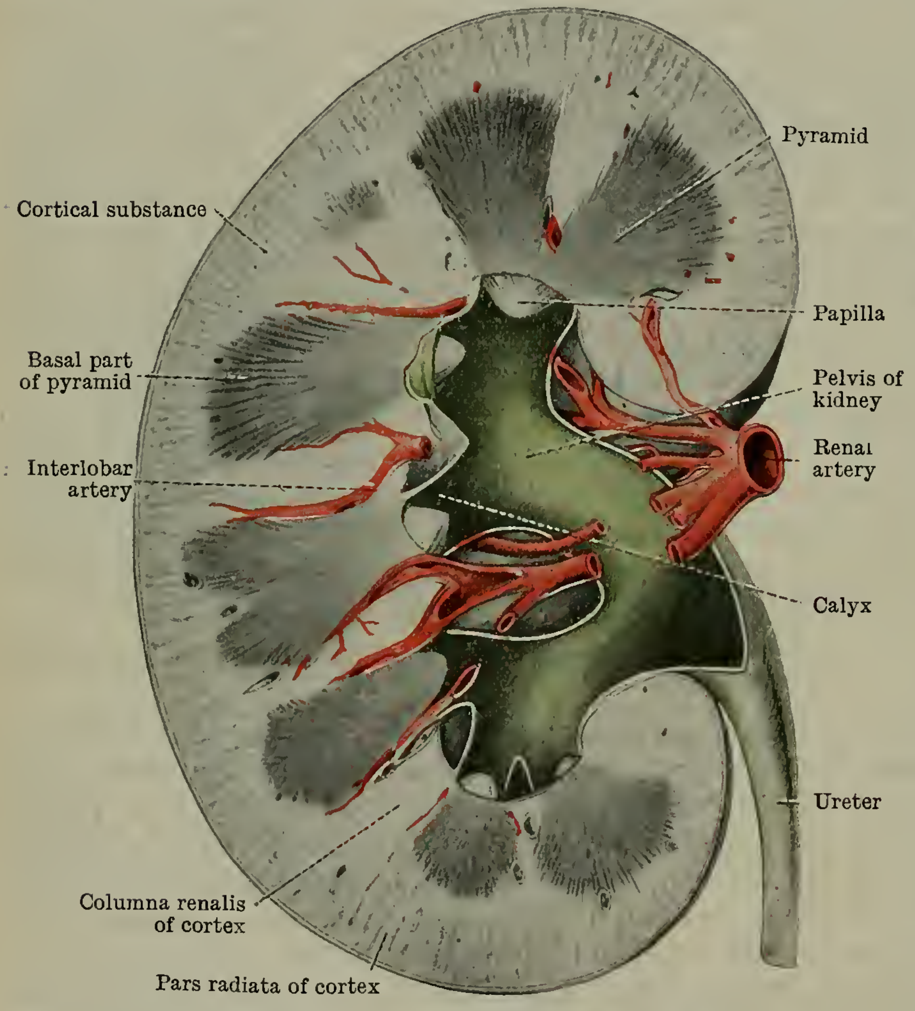


FIG. 965.—LONGITUDINAL SECTION OF THE KIDNEY, OPENING UP THE KIDNEY SINUS.

The pelvis of the kidney and some of its calyces have been laid open as they lie within the sinus.

When the right and left ureters reach the bladder they are a little more than two inches apart. They pierce the bladder wall very obliquely, and are embedded within its muscular tissue for nearly three-quarters of an inch of their length. Finally, they open into the bladder by two small slit-like apertures which are of a valvular nature, and prevent a backward passage of fluid from the bladder. It is probable, however, that an exaggerated idea of the valvular nature of the openings of the ureters into the bladder is obtained by an examination of the parts in the dead subject. When the bladder is empty the openings of the ureters are placed about one inch apart, but when that viscus is distended they are often two inches, or more, distant from one another. As the ureter pierces the bladder wall the muscular fibres of the bladder and ureter remain quite distinct, and so the ureter, remaining a thick-walled tubular structure, appears to pass through a gap in the muscular wall of the bladder. The mucous coat alone of the ureter becomes continuous with that of the bladder.

The lumen of the ureter is not uniform throughout, but is somewhat constricted in certain places, corresponding to the regions where the ureter is most sharply curved or changes its direction. These more constricted parts of the tube are described as occurring one in the middle of the abdominal portion, one at the junction of the abdominal and pelvic portions, and one in the pelvic part of the ureter. Also just before the ureter joins the pelvis of the kidney and just as it reaches the bladder wall its lumen is usually somewhat constricted.

In the female, the ureter, near its termination, passes beneath the lower part of the broad ligament of the uterus, and lies to the lateral side of the cervix uteri and the upper part of the lateral wall of the vagina. It is accompanied in the inferior part of its course by the uterine artery, which crosses it on its anterior aspect not far from its termination. Higher up it lies in the peritoneal ridge which forms the posterior boundary of the fossa ovarica, which, in the female, is a posterior subdivision of the obturator triangle (Fig. 966).

STRUCTURE OF THE URETER.

The wall of the ureter, which is thick and of a whitish colour, is composed of mucous, muscular, and fibrous coats. The **tunica mucosa**, or mucous coat, possesses an epithelium composed of many layers of cells, those nearest the surface being of large size. When the canal is empty the mucous coat is thrown into numerous longitudinal folds, and so its lumen exhibits a stellate outline in transverse section. The submucous tissue varies much in thickness in different parts of the ureter, and contains some elastic fibres. The unstriated muscle fibres which compose the **tunica muscularis**, or muscular coat, are collected into bundles which are separated by a considerable amount of connective tissue, and are arranged, some longitudinally, some circularly. In the upper part of the ureter a relatively large amount of connective tissue is present deep to and among the bundles of muscle fibres, which are arranged in three distinct strata—an inner longitudinal, an intermediate circular, and an outer longitudinal. In the middle part of the vessel the same layers may be recognised, but the circularly disposed bundles of fibres are more numerous than higher up. In the lower part of the ureter the connective tissue is relatively scanty and the inner longitudinal fibres lie close to the lining epithelium; in this region also the longitudinal folds of the mucous coat become fewer and less marked. A short distance above the point where it reaches the bladder, a number of coarse bundles of longitudinally arranged muscle fibres are applied to the outer surface of the muscular coat of the ureter. These form the so-called "sheath of the ureter." In the portion of the ureter which traverses the wall of the bladder nearly all the fibres of the muscular coat are disposed longitudinally.

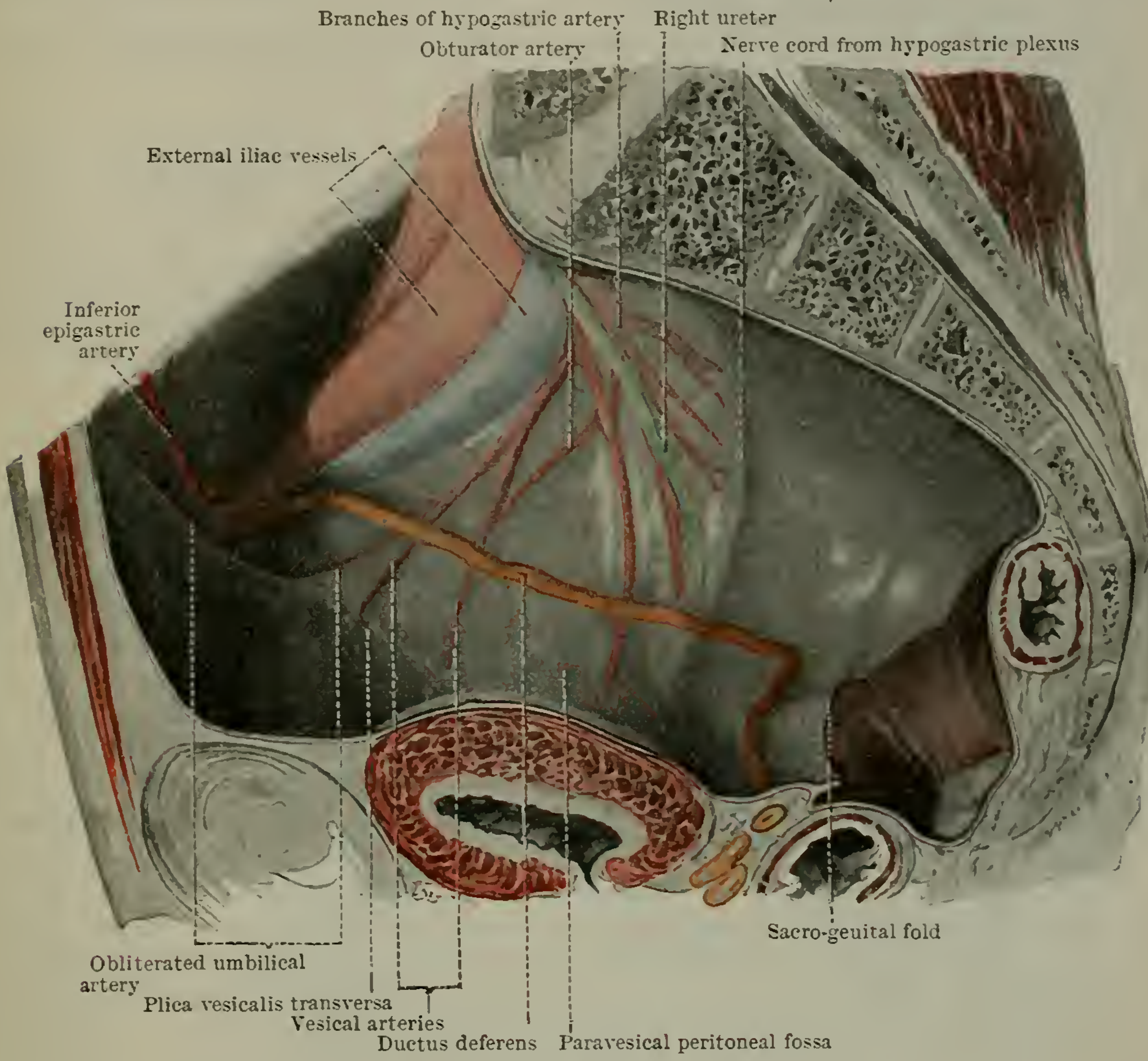

Branches of hypogastric artery
Right ureter
Obturator artery
Nerve cord from hypogastric plexus
External iliac vessels
Inferior epigastric artery
Sacro-genital fold
Obliterated umbilical artery
Plica vesicalis transversa
Vesical arteries
Ductus deferens
Paravesical peritoneal fossa

FIG. 966.—MEDIAN SECTION OF AN ADULT MALE PELVIS.

The coils of the small intestine and of the colon which lay within the pelvis have been lifted out in order to give a view of the side wall of the pelvic cavity.

The muscle fibres lie close beneath the epithelium, and end just where the mucous coats of the bladder and ureter become continuous. The **tunica adventitia**, or outer fibrous coat, of the ureter varies in thickness at different levels, and in its lower part blends with the connective tissue which lies among the muscle fibres forming the sheath of the ureter just mentioned.

The mucous membrane of the calyces and of the pelvis of the kidney possesses an epithelium resembling that of the ureter. Where each renal papilla projects into one of the calyces a deep circular recess, or fornix, is formed between the wall of the calyx and the sloping side of the papilla; at the bottom of this recess the epithelium of the calyx becomes continuous with that covering the papilla. At the foramina papillaria the epithelium joins that of the kidney tubules. The muscular fibres in the wall of the calyces and of the pelvis are collected into loosely arranged bundles separated by wide intervals occupied by fibrous connective tissue. As in the ureter, the outermost and innermost fibres run in a longitudinal, the intermediate ones in a circular direction. The circularly arranged fibres alone form a distinct layer.

Vessels and Nerves of the Ureter.—The abdominal part of the ureter receives its blood-supply from the renal and internal spermatic arteries; the pelvic portion is supplied by the vesical and middle hæmorrhoidal vessels.

The nerves of the ureter are derived from the renal, spermatic, and hypogastric plexuses. The afferent fibres reach the spinal cord through the eleventh and twelfth thoracic, and first lumbar nerves.

Variations.—The ureter is sometimes represented by two tubes in its upper portion. In rarer cases it is double throughout the greater part of its extent, or even in its whole length from the pelvis of the kidney to the bladder. In such cases there may be two openings into the bladder. Asymmetry as regards such abnormalities is very common.

Variations in the form of the pelvis of the kidney are of frequent occurrence. Most usually the pelvis divides into two large subdivisions, one of which passes in the direction of the upper, the other in that of the lower pole of the kidney. In some cases these branches come off directly from the ureter without the intervention of a pelvis, or a marked subdivision may lead to the formation of two pelves.

VESICA URINARIA.

The **urinary bladder** is a hollow muscular organ situated in the anterior part of the pelvic cavity, above and behind the symphysis pubis. It lies in front of the rectum, from which it is separated *in the male* by the seminal vesicles and the terminal portions of the deferent ducts, and *in the female* by the vagina and uterus. The ureters, which convey the fluid secreted by the kidneys, open into the lower part of the bladder about half an inch from the median plane.

The urethra, or canal by which the urine reaches the surface, leads from the bladder, its vesical aperture lying in the median plane, below and anterior to the openings of the ureters. The size and shape of the bladder, the thickness of its wall, and also to a great extent its relations, vary with the amount of distension, or contraction, of the organ. When empty, or only slightly distended, the bladder lies within the pelvis minor; as it becomes filled with urine it rises above the pubis, and crossing the pelvic brim enters the abdominal cavity. These changes affect chiefly the upper part of the bladder, which becomes altered in shape and size, and acquires new connexions and relations; the lower portion varies but slightly with the amount of distension of the organ (see Figs. 967 and 968). The upper part of the bladder is covered with peritoneum, which is reflected on to it from the anterior abdominal wall in front, from the sides of the pelvis laterally, and, *in the male,* across the seminal vesicles and terminal parts of the deferent ducts from the rectum behind. *In the female* the peritoneum passes on to the bladder posteriorly from the anterior surface of the uterus. The peritoneum dips down posteriorly for a certain distance between the bladder and rectum in the male, forming the recto-vesical or recto-genital pouch; in the female a slit-like peritoneal recess, called the utero-vesical pouch, intervenes between the anterior surface of the uterus and the bladder (Fig. 973).

The inferior part of the bladder lies below the peritoneum, and is for the most part directed towards the pelvic floor. Anteriorly in the median plane it is supported by the symphysis pubis and the retro-pubic pad of fat in both sexes. Farther back, *in the male,* it rests upon the prostate and on the lower part of the rectum, from the latter of which it is separated by the vesiculæ seminales and the terminal portions of the deferent ducts. *In the female* it rests upon the anterior wall of the vagina.

Laterally, on each side, the bladder is supported by the levator ani muscle and farther from the median plane by the obturator internus; it is separated from the layer of fascia covering these muscles by loose areolar tissue.

The opening of the urethra, or **internal urethral orifice**, is placed in, or near, the part of the bladder wall which lies lowest in the pelvic cavity. The term neck, or cervix, is often applied to this region, the bladder appearing as if it were suddenly constricted to form the urethra.

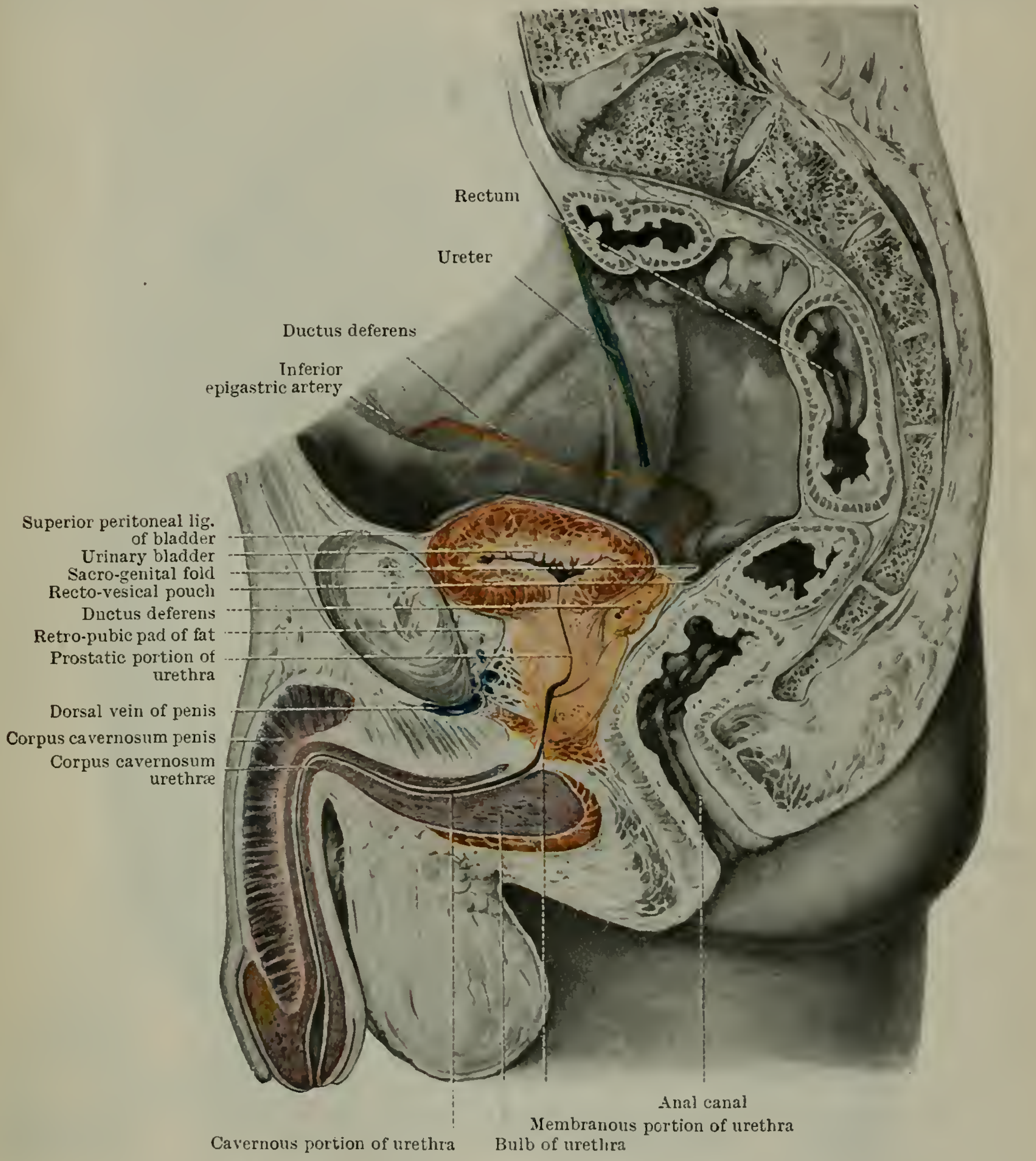


FIG. 967.—MEDIAN SECTION THROUGH THE PELVIS OF AN ADULT MALE SUBJECT.

The urinary bladder is empty and firmly contracted. The coils of small intestine have been removed to afford a view of the side wall of the pelvic cavity.

The portion of the bladder wall posterior to the urethral orifice, which is directed *in the male* towards the anterior wall of the rectum and lies below and in front of the recto-vesical pouch, is called the **fundus vesicæ**; it is closely related to the seminal vesicles and ampullæ of the deferent ducts. The corresponding part of the bladder *in the female* rests against the anterior wall of the vagina.

The term **vertex vesicæ** is applied to the portion of the bladder which lies nearest to the upper border of the symphysis pubis when the organ is empty, and rises high above the pubis into the abdominal cavity when the bladder is distended. Connected with the vertex of the bladder is a fibrous cord, the median umbilical ligament, or **urachus**, which passes upwards, in the median plane, on the posterior aspect of the anterior abdominal wall, and reaches the umbilicus. It represents the passage which in the embryo connects the developing bladder with the allantois.

The part of the bladder connecting the vertex with the base, and not sharply marked off from either, is called the **corpus vesicæ**, or body of the bladder.

Position of the Urethral Orifice.—During the various changes in shape and size which the bladder undergoes, the region of the internal urethral orifice remains

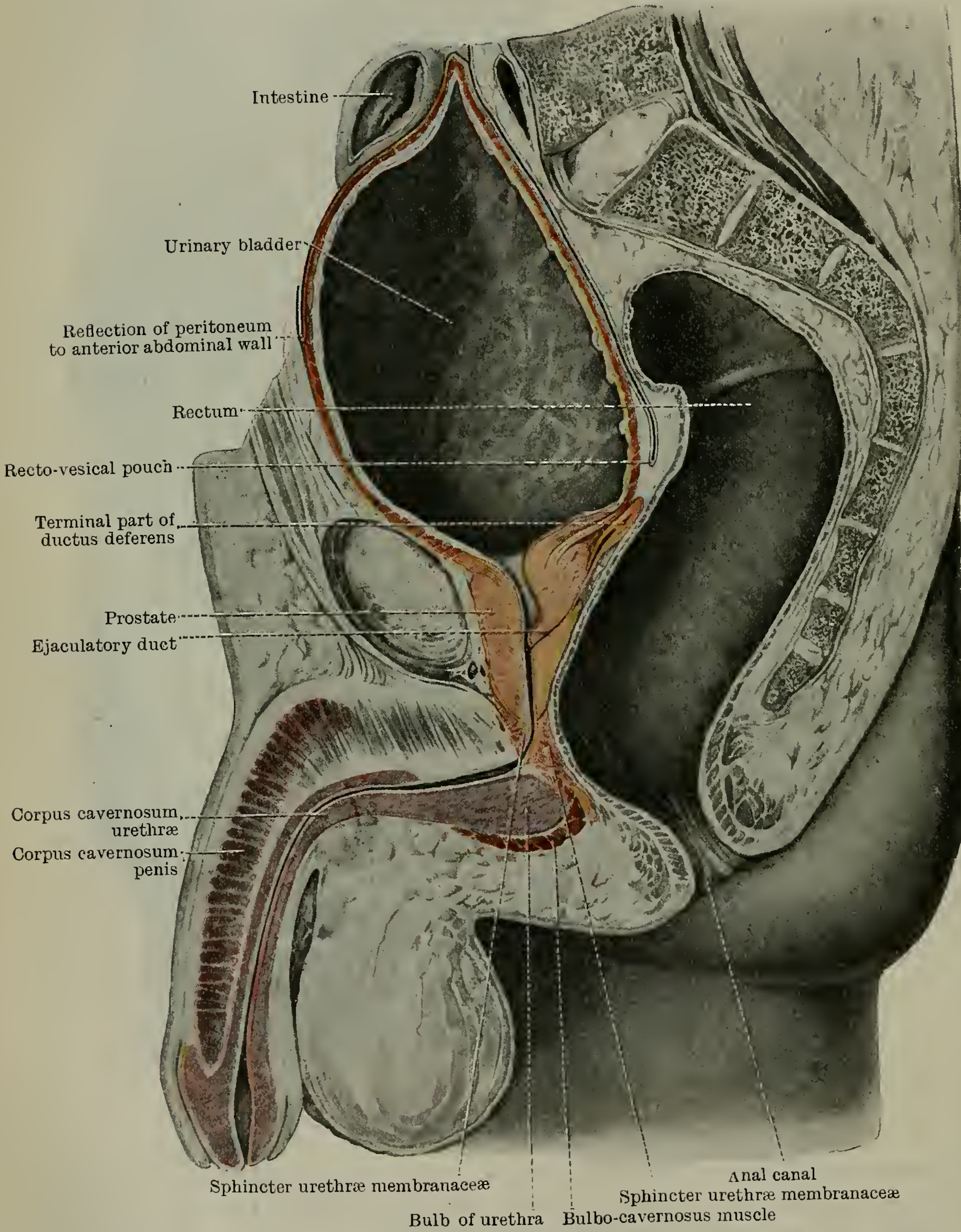

Intestine
Urinary bladder
Reflection of peritoneum to anterior abdominal wall
Rectum
Recto-vesical pouch
Terminal part of ductus deferens
Prostate
Ejaculatory duct
Corpus cavernosum urethræ
Corpus cavernosum penis
Sphincter urethræ membranaceæ
Bulb of urethra
Bulbo-cavernosus muscle
Anal canal
Sphincter urethræ membranaceæ

Fig. 968.—Median Section of the Pelvis of an Adult Male Subject.
The urinary bladder and rectum are both distended.

almost fixed in position. In the male the urethral orifice lies immediately above the prostate, and behind and slightly below the level of the upper margin of the symphysis pubis, from which it is distant about two to two and a half inches. It can be reached by a finger introduced into the bladder through the abdominal wall above the symphysis pubis. It is usually placed half an inch to one inch above the level of a plane passing through the lower margin of the symphysis and the lower end of the sacrum, but in some cases it is found to be somewhat lower. The comparatively slight variations in the level of the internal urethral orifice which do occur, depend partly upon the quantity of fluid contained in the bladder, and partly upon the amount of distension of the lower portion of the rectum. When the bladder is very much distended this region lies at a slightly lower level in the pelvis than when the organ is empty. On the other hand, distension of the lower part of the rectum raises, to some extent, the level of the urethral orifice. Since the position of the internal urethral orifice varies, in the manner just described—with the condition of the rectum and of the bladder—it follows that it lies at its lowest limit when the bladder is full and the rectum empty, and at its highest level when the bladder is empty and the rectum distended. In the female the internal urethral orifice normally occupies a lower level than in the male (compare Figs. 968 and 973).

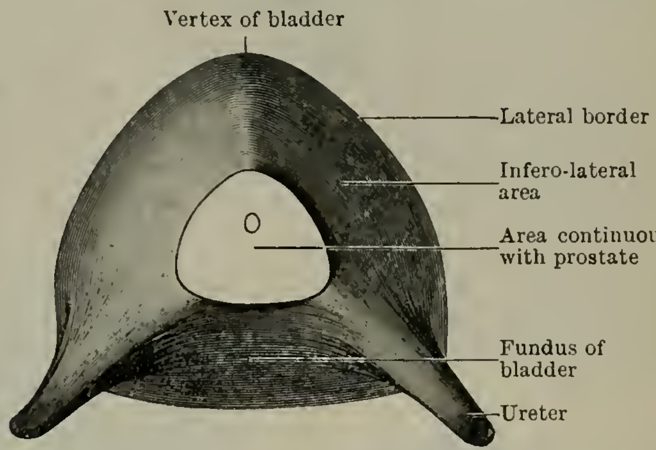


Fig. 969.—Inferior Aspect of the empty Male Urinary Bladder. From a subject in which the viscera had been hardened *in situ.*

The prostate has been severed from the bladder, and the white area in the drawing indicates the position where the two structures were continuous.

Inferior Aspect of the Bladder.—The lower part of the bladder, which is directed towards the pelvic floor, changes, as we have seen, but slightly with the varying amount of distension of the viscus. When the organ has been hardened before its removal from the body, it is possible to map out on its inferior aspect three convex triangular areas, which may be distinguished from one another by the directions in which they look. The three areas approach one another in the region of the urethral orifice, where, in the male, a portion of the inferior aspect of the bladder wall is structurally continuous with the upper part of the prostate. Posterior to the urethral orifice is a triangular district, directed downwards and backwards, and related, *in the male,* to the seminal vesicles and the terminal portions of the deferent ducts, which, together with the recto-vesical fascia, intervene in this position between the bladder and the rectum. This triangular area corresponds to the **fundus** of the bladder, and *in the female* it is directed against the anterior wall of the vagina. The rest of the inferior aspect of the bladder is formed by two **infero-lateral areas,** or surfaces, which meet in the median plane in front of the urethral orifice, and are directed for the most part downwards and laterally (see Fig. 971). Each of these areas extends backwards to join the fundus along a rounded border which lies between the point where the ureter reaches the bladder and the urethral orifice. The infero-lateral area of the bladder wall rests on the areolar tissue covering the fascia of the levator ani and the obturator internus muscles, and, nearer the median plane, upon the os pubis and the retro-pubic pad of fat.

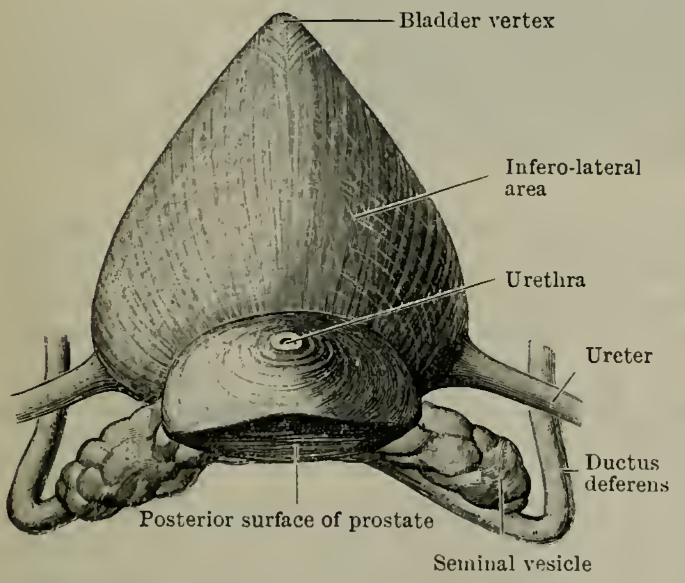


Fig. 970.—The Urinary Bladder, Prostate, and Seminal Vesicles, viewed from below.

Taken from a subject in which the viscera were hardened *in situ.* Same specimen as Fig. 971, A. The bladder contained but a small amount of fluid.

The three rounded borders which mark off the three triangular areas on the inferior aspect of the bladder, just described, extend from the region of the urethral orifice to the vertex of the bladder, and to the points where the ureters reach the bladder wall (Figs. 969, 970).

Shape and Relations of the Empty Bladder.—When the bladder is empty, or nearly so, it has, roughly speaking, the shape of an inverted tetrahedron, the apex of which corresponds to the point where the urethra leaves the organ, while the base of the tetrahedron is formed by the superior surface of the bladder. The three basal angles of the tetrahedron correspond to the bladder vertex and to the two **lateral angles** of the bladder, or points where the ureters join the organ. The three surfaces, which meet inferiorly at the urethral orifice, are only marked off from one another by rounded borders, but as long as the organ is empty, or nearly so, they are separated by distinct borders from the superior surface. These three areas have been already described as the infero-lateral surfaces and the fundus of the bladder (Fig. 969). Their relations have also been indicated. The **superior surface** of the empty bladder looks upwards into the pelvic cavity; it is convex when the organ is contracted, concave when relaxed. This surface is covered by peritoneum, and its outline, which is approximately triangular, is determined by lateral and posterior borders. The **lateral borders** of the empty bladder are sharply marked, and extend from the bladder vertex to the lateral angles of the bladder, or points where the ureters join the organ. They separate the superior surface from the infero-lateral portions of the inferior aspect of the bladder wall (Fig. 971, A). The **posterior border** stretches across between the lateral angles of the bladder, and separates the superior surface from the fundus. The superior surface is related *in the male* to coils of intestine; *in the female* it is related also to the anterior surface of the uterus. The lateral border of the empty bladder lies against the lining fascia of the pelvis just above, or at the level of, the arcus tendineus. The ductus deferens crosses the side wall of the pelvis parallel to it, but at a considerably higher level (Fig. 967).

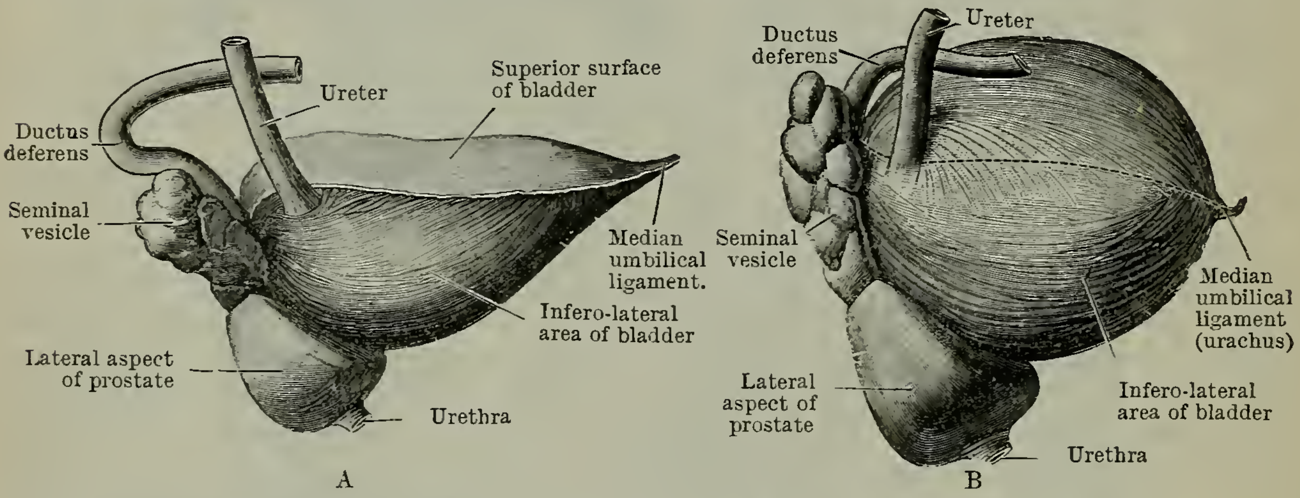

Ductus deferens
Ureter
Superior surface of bladder
Seminal vesicle
Median umbilical ligament.
Infero-lateral area of bladder
Lateral aspect of prostate
Urethra
A
Ductus deferens
Ureter
Seminal vesicle
Median umbilical ligament (urachus)
Lateral aspect of prostate
Infero-lateral area of bladder
Urethra
B

FIG. 971.—THE URINARY BLADDER, PROSTATE, AND VESICULA SEMINALIS, VIEWED FROM THE LATERAL ASPECT.

Drawn from specimens in which the viscera were hardened before removal from the body. In A the bladder contained but a very small quantity of fluid; in B the quantity was somewhat greater. In A the peritoneum is shown covering the superior surface of the bladder, and its cut edge is seen where it is reflected along the lateral border of the organ. In B the level of the peritoneal reflexion is indicated by a dotted line.

In median section the cavity of the empty and relaxed bladder often presents the appearance of a Y-shaped chink, the stem of the Y being represented by the urethra as it leaves the organ, and the two limbs by the narrow intervals between the superior surface and the under parts of the bladder wall which lie in front of and behind the urethral orifice. This relaxed form is sometimes described as the diastolic condition of the empty bladder, and is found associated with a bladder wall of but little thickness, and with a concave upper surface. The condition is usually the result of an escape of fluid after death, when the bladder wall has lost the power of contracting. It does not represent a normal condition of the organ in the living. The normal empty bladder is strongly contracted, and its wall is thick and firm. A distinctly Y-shaped appearance is not presented by its cavity in median section, but the interior of the organ is seen as a simple narrow interval continuous with the canal of the urethra.

Distended Bladder.—As the bladder fills with fluid the superior wall is raised upwards from the fundus and infero-lateral walls. At the same time, the borders separating the superior from the other surfaces of the bladder become at first more rounded and then nearly obliterated (Fig. 971). The lateral borders of the bladder becoming in this manner opened out, give rise to so-called **lateral surfaces** in the distended organ. These surfaces, however, are not sharply marked off, and are directly continuous with the superior surface. During distension, the angles present in the empty condition of the organ become rounded as the entire bladder wall becomes more uniformly convex. The general shape of the bladder becomes altered; the tetrahedral form of the empty organ is lost, and the bladder as it becomes filled assumes first a somewhat spherical, then an oval contour. The enlarging bladder comes to occupy more and more of the pelvic cavity, displacing upwards the portions of the colon and small intestine which may lie in the pelvis when the organ is empty. Until all the available pelvic space has been filled, the form of the distended bladder is spherical, or oval with the larger end directed downwards and backwards. When the pelvic wall prevents further expansion of this portion, the outline of the organ may become an oval, with the larger end directed upwards and forwards into the abdominal cavity. The highest part of the distended bladder does not correspond to the attachment of the urachus at the apex, but to a point farther back. As the superior wall of the bladder is raised up during distension it carries with it the peritoneum, and thus the reflexion of that membrane, from the anterior abdominal wall on to the vertex of the bladder, comes to lie one and a half inches, or even more, above the upper margin of the symphysis pubis (Fig. 973). It is, therefore, possible to puncture, or open into the distended bladder, through the anterior abdominal wall above the symphysis pubis, without at the same time opening into the peritoneal cavity. In a similar manner the line of reflexion of the peritoneum, from the side wall of the pelvis on to the lateral aspect of the bladder, is raised higher during distension, and may come to correspond, in part, to the level of the ductus deferens, or to that of the obliterated umbilical artery. On the other hand, the level of the reflexion of the peritoneum from the rectum towards the basal aspect of the bladder does not vary much with the distension, or contraction, of the organ (compare Figs. 967 and 968), and thus the fossa between the bladder and rectum

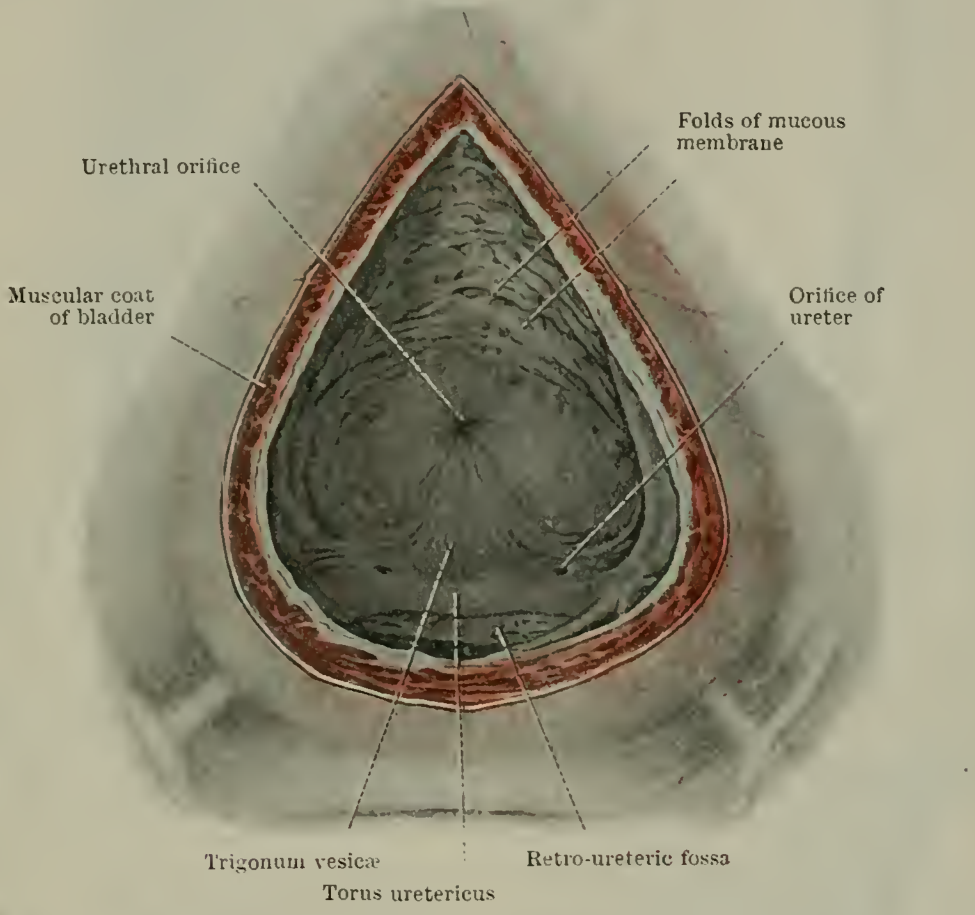


FIG. 972.—EMPTY AND CONTRACTED URINARY BLADDER, OPENED UP BY THE REMOVAL OF ITS UPPER WALL. The peritoneum is seen spreading out from the lateral and posterior borders of the organ. Compare with Fig. 967.

becomes relatively very deep when the bladder is full. The bladder in normal distension may contain nearly one pint, but in most cases the organ is emptied when its contents reach from six to ten ounces. Under abnormal or pathological conditions the bladder capacity may be very much increased.

Varying Relationships, according to the degree of Distension of the Bladder.—The lateral aspect of the distended bladder may be related to the obliterated umbilical artery as it passes forwards on the side wall of the pelvis. When the bladder is empty its lateral border lies about one and a quarter inches below this artery. The ductus deferens, during a part of its course, is in contact with the lateral wall of the distended bladder, but lies above and parallel to the lateral border when the organ is empty. The side wall of the distended bladder is closely related to the obturator vessels and nerve.

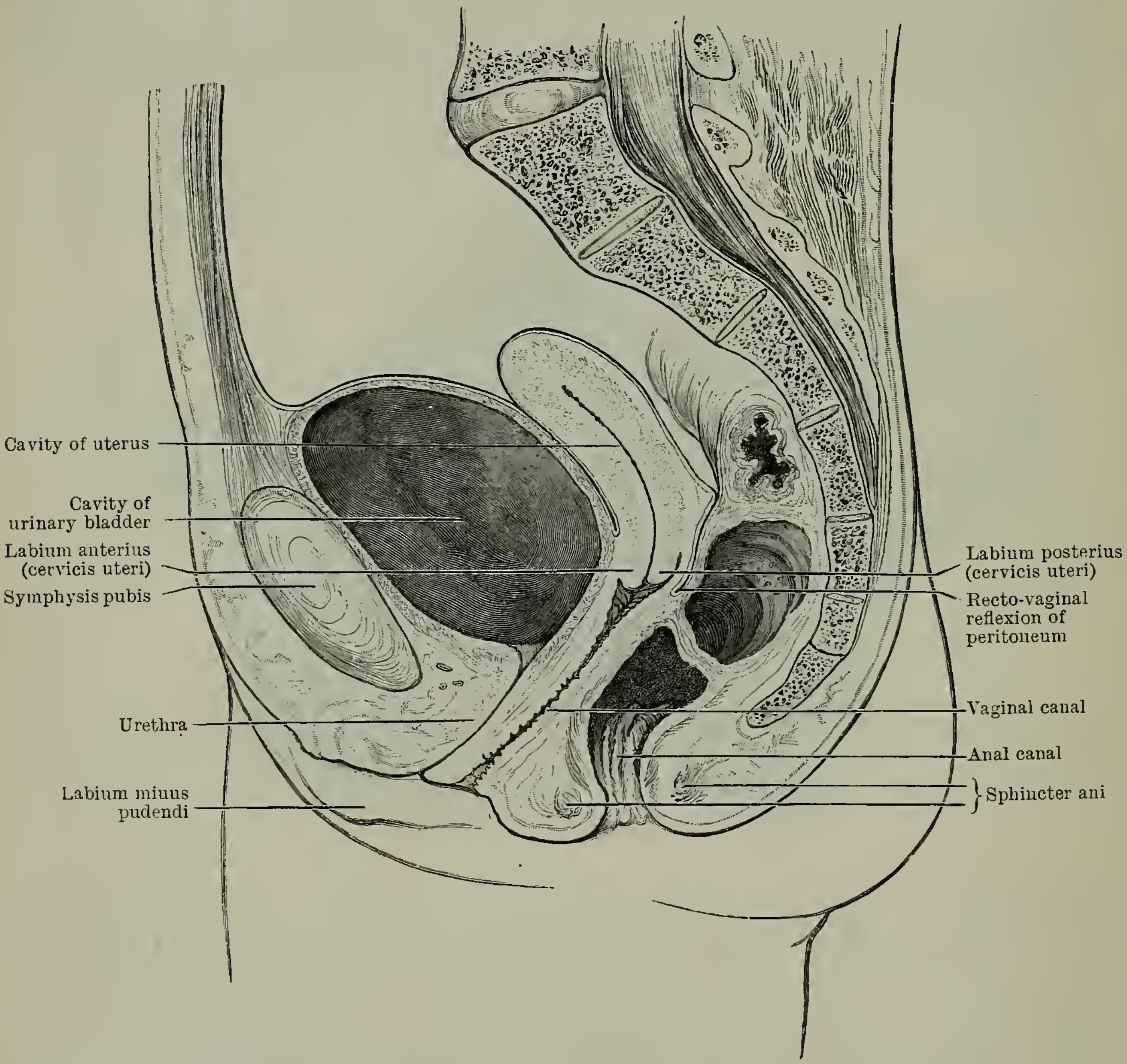

Cavity of uterus
Cavity of urinary bladder
Labium anterius (cervicis uteri)
Symphysis pubis
Urethra
Labium minus pudendi
Labium posterius (cervicis uteri)
Recto-vaginal reflexion of peritoneum
Vaginal canal
Anal canal
Sphincter ani

FIG. 973.—MEDIAN SECTION OF THE PELVIS IN AN ADULT FEMALE.
The cavity of the uterus is indicated diagrammatically.

Interior of the Bladder.—The mucous membrane lining the bladder is loosely connected to the muscular coat, and when the bladder is contracted the mucous lining is thrown into a number of prominent wrinkles or folds (Fig. 972). At one place only the mucous membrane is firmly connected to the subjacent muscular coat, and the inner surface of this part of the bladder wall is smooth and free from wrinkles. This smooth area corresponds to a triangular surface behind the urethral orifice, called the **trigonum vesicæ**, and to the part of the bladder wall which immediately surrounds the opening. The apex of the triangle lies at the beginning of the urethra, and the base is formed by a line drawn between the openings of the ureters into the bladder. Just behind the urethral opening the bladder wall sometimes bulges slightly into the cavity, owing to the presence of the middle lobe of the prostate, which lies beneath the mucous coat in this position. When well marked, as it often is in old people, this bulging is termed the **uvula vesicæ**. Stretching across between the openings of the ureters there is usually to be seen a smooth ridge, due to the presence of a bundle of transversely disposed muscle fibres, which lies within this part of the bladder wall, beneath the mucous membrane. This ridge has been called the "**torus uretericus**" (Fig. 972). It may be deficient near the median plane, and it is curved so as to be convex forwards. The lateral portions of the ridge which lie lateral to the openings of the ureters are called the **plicæ uretericæ**, and are produced by the terminal parts of the ureters as they traverse the bladder wall and lie beneath the mucous coat of the bladder. In old people the region behind the trigonum is often depressed and forms a shallow *retro-ureteric fossa.* A less distinct depression may sometimes be observed on each side of the trigonum. Round the urethral orifice are a number of minute radially disposed folds which, disappearing into the urethra, become continuous with the longitudinal folds of the mucous membrane of the first part of that canal. The ureter pierces the bladder wall very obliquely, and so the minute ureteral orifice has an elliptical outline. The lateral boundary of each opening is formed by a thin, crescentic fold, which, when the bladder is artificially distended in the dead subject, acts as a valve in preventing water or air from entering the ureter. Hence the term "valvula ureteris" is sometimes used to designate the fold. In the empty bladder the urethral orifice and the openings of the two ureters lie at the angles of an approximately equilateral triangle, the sides of which are about one inch in length. When the bladder is distended the distance between the openings may be increased to one and a half inches or more.

Bladder in the Female.—In the female the bladder is related posteriorly to the uterus and upper part of the vagina. The anterior surface of the uterus in its upper part is separated from the upper surface of the bladder by the shallow utero-vesical pouch of peritoneum, but the two organs are nevertheless normally in apposition. So close is this relationship that the upper surface of the bladder very often shows a slight concavity, due to contact with the convex anterior wall of the uterus. The lower part of the uterus and upper part of the vagina are not separated by peritoneum from the fundus of the bladder, but are united to it by areolar connective tissue (Fig. 973). Thus, below the level of the utero-vesical pouch, the female bladder is related in much the same manner to the uterus and anterior wall of the vagina as the male bladder is related to the seminal vesicles and deferent ducts. The vertex of the bladder, where the urachus is attached, often lies on a lower level than in the male, so that the organ, even when distended, rises less freely into the abdomen. The bladder as a whole is placed deeper in the pelvis than in the male, and the internal urethral orifice lies just above, or just below, a line drawn from the lower margin of the symphysis to the lower end of the sacrum (p. 1260). The lower level of the internal urethral orifice is probably correlated with the absence of a distinct prostate in the female. It is probable that as regards capacity no difference exists between the bladder in the male and in the female; the conflicting results arrived at by different observers are probably due to the faulty methods which have been employed in estimating the capacity of the organ.

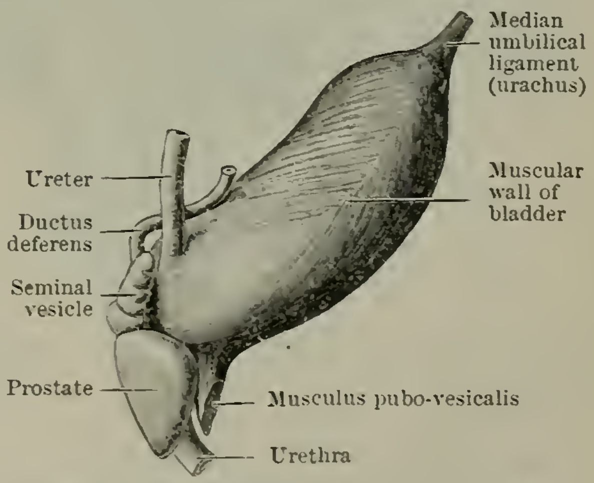


FIG. 974.—THE URINARY BLADDER OF A NEWLY-BORN MALE CHILD, viewed from the side.
The drawing is from a specimen which had been hardened *in situ.*

Bladder in the Newly-born Infant and in the Child.—At birth the empty bladder is spindle- or torpedo-shaped, and its long axis, which extends from the point of attachment of the urachus to the internal urethral orifice, is directed downwards and backwards (Fig. 974). The lateral and posterior borders seen in the adult organ cannot be recognised at birth, nor is there any part of the bladder wall directed downwards and backwards, as is the fundus of the adult organ. In the fœtus and young child the bladder occupies relatively a much higher level than it does in the adult, and, even when empty, it extends upwards into the abdominal cavity. Its anterior aspect is in contact with the posterior surface of the anterior abdominal wall. At birth the peritoneum forming the recto-vesical pouch covers the whole of the posterior aspect of the bladder, and reaches as low as the upper limit of the prostate. The internal urethral orifice is placed at a high level, and sinks gradually after birth (Fig. 975). In the newly-born child this opening lies on a level with the upper margin of the symphysis pubis, and the openings of the ureters lie almost on a level with the plane of the pelvic brim. The obliterated umbilical arteries are more intimately related to the bladder in the child than in the adult, and lie close against its sides as they pass upwards on the posterior aspect of the anterior abdominal wall towards the umbilicus (Fig. 988).

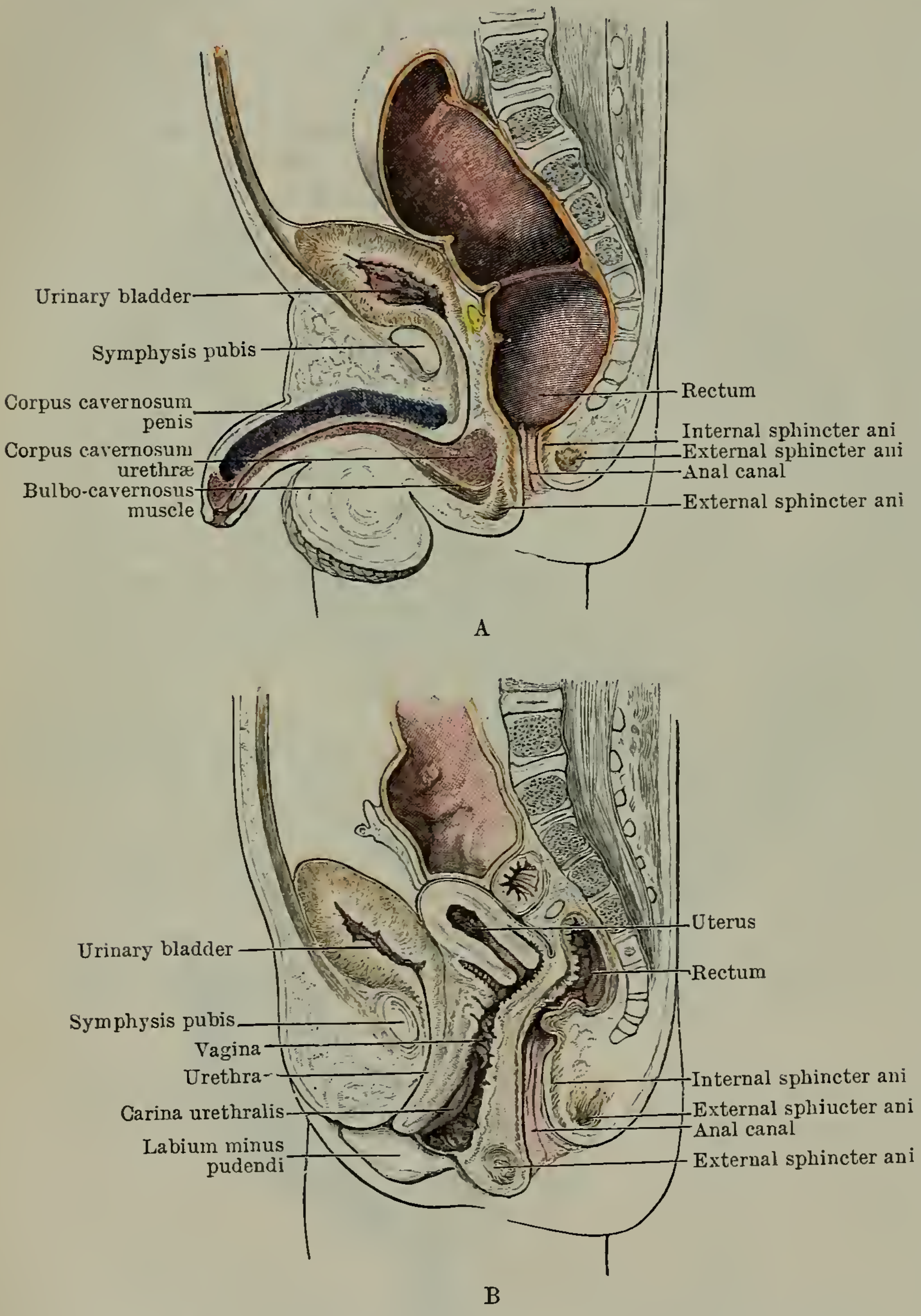


Fig. 975.—Median Section through the Pelvis of newly-born Child.
A, Male, and B, Female.

Peritoneal Relations and Connexions of the Bladder.—We have already seen that the superior surface of the empty bladder is covered by peritoneum, which leaves it along the lateral border on each side to reach the pelvic wall about the level of the arcus tendineus of the levator ani muscle. To this peritoneal reflexion the term **lateral peritoneal ligament** is often applied. The lateral peritoneal ligaments of opposite sides are continuous in front, at the bladder vertex, where the peritoneum is conducted over the fibrous cord of the urachus to reach the anterior abdominal wall, forming the so-called **superior peritoneal ligament.** When the bladder is empty the level of this anterior reflexion lies just behind, or just below, the upper margin of the symphysis pubis. When the bladder becomes filled the level of the peritoneal reflexion forming the superior peritoneal ligament is raised upwards, and may reach a point one and a half inches, or more, above the upper margin of the symphysis pubis. Similarly, the line along which the lateral peritoneal ligament reaches the pelvic wall is also carried upwards in distension of the bladder, and may reach the level of the ductus deferens and of the obliterated umbilical artery.

When the bladder is empty the peritoneum is carried downwards upon the side wall of the pelvis as low as the lateral border of the organ, and lines a shallow depression which receives the name of **paravesical fossa** (Figs. 976, 941). This peritoneal fossa lies below the level of the obturator triangle (p. 1255), from which it is separated by the ductus deferens. As the bladder fills, the peritoneum is raised off this part of the pelvic wall, and certain structures, such as the obturator vessels and nerve and the ductus deferens, which lie on the lateral wall of the pelvis, come into direct relationship with the lateral aspect of the distended bladder.

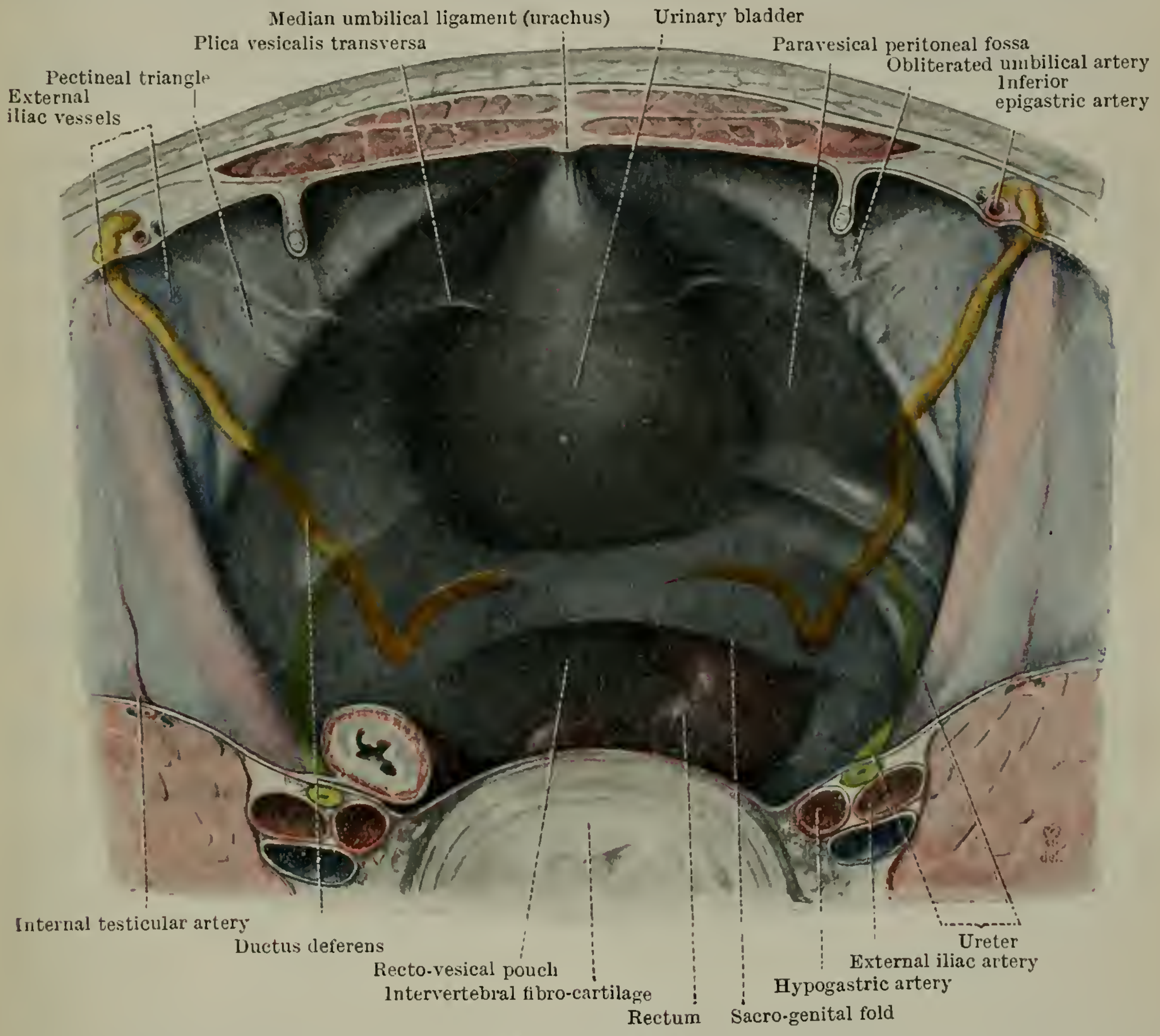

Median umbilical ligament (urachus)
Urinary bladder
Plica vesicalis transversa
Paravesical peritoneal fossa
Obliterated umbilical artery
Pectineal triangle
External iliac vessels
Inferior epigastric artery
Internal testicular artery
Ductus deferens
Recto-vesical pouch
Intervertebral fibro-cartilage
Rectum
Ureter
External iliac artery
Hypogastric artery
Sacro-genital fold

FIG. 976.—VIEW LOOKING INTO THE MALE PELVIS FROM ABOVE AND SOMEWHAT BEHIND.

From a specimen in which the bladder was firmly contracted and contained but a small amount of fluid. The paravesical fossa is seen on each side of the bladder. The peritoneal pouch in front of the rectum is bounded on each side by the crescentic sacro-genital folds or "posterior peritoneal ligaments of the bladder," which meet together in the median plane some distance behind the posterior border of the bladder.

Posteriorly the peritoneum leaves the superior surface of the empty bladder at its posterior border, and is carried backwards, forming a kind of horizontal shelf, or fold, for a distance of about half an inch, giving at the same time a partial covering to the deferent ducts and superior ends of the seminal vesicles. The peritoneum then suddenly dips downwards to reach the bottom of the recto-vesical, or recto-genital, pouch, where it is reflected on to the anterior surface of the rectum

(Figs. 944, 967). As a rule, no part of the fundus of the contracted and empty bladder receives a covering from the peritoneum, since the seminal vesicles and terminal portions of the deferent ducts intervene as they lie in the anterior wall of the recto-vesical or recto-genital pouch. When the bladder is distended the posterior border, separating the upper surface and fundus, is rounded out, and the peritoneum forming the horizontal shelf, just described, is taken up (compare Fig. 968). It is to be specially noted that the level of the peritoneal reflexion, forming the bottom of the recto-vesical pouch, does not vary much, as regards its relationship to the prostate, during distension and contraction of the bladder (Figs. 967 and 968).

An examination of median sections of the pelvis shows the great danger run by the ampullæ of the deferent ducts in any operation for reaching the bladder through the anterior wall of the rectum, and the difficulty in avoiding injury to the peritoneum.

The term "**posterior peritoneal ligament**" is sometimes applied to the somewhat variable crescentic fold of peritoneum which bounds, on each side, the entrance to the recto-vesical or recto-genital pouch, and which often unites with the fold of the opposite side across the median plane, behind the posterior border of the bladder and the ductus deferentes (Figs. 966 and 976). These folds represent the recto-uterine folds found in the female, and are to be regarded as connexions of the deferent ducts rather than of the bladder; hence the name **sacro-genital folds** is applicable to these structures in both sexes.

The peritoneum covering the upper surface of the empty or partly distended bladder often exhibits a transversely disposed fold or wrinkle, known as the **plica vesicalis transversa.** This fold, when well developed, can be traced on to the side wall of the pelvis, where it traverses the paravesical fossa, and in some cases it is found to cross the pelvic brim and to be directed towards the abdominal inguinal ring (Fig. 976).

In the female the peritoneum is reflected posteriorly from the upper surface of the bladder on to the anterior aspect of the uterus and forms the **utero-vesical peritoneal ligament.**

Fixation of the Bladder.—When the **medial umbilical ligament**, or fibrous cord of the urachus, which binds the bladder vertex to the anterior abdominal wall, and the peritoneal connexions, already described, are severed, the bladder is easily moved about, except in its lower part. Except in the region of the fundus and of the internal urethral orifice the bladder wall is connected to the pubis and lining fascia of the pelvis by loose areolar tissue and thus free movement is permitted during expansion and contraction of the organ.

The lower fixed part of the bladder is held in place chiefly by its firm connexion with the prostate, with which indeed it is structurally continuous. The prostate is surrounded by a dense fibrous sheath from which strong fascial connexions pass anteriorly to the back of the pubis and on each side to the lining fascia of the pelvis. These fibrous connexions are known as the pubo-prostatic and lateral ligaments of the prostate, and by fixing the prostate they maintain the lower part of the bladder in position.

In the female similar fibrous connexions exist for the upper part of the urethra, and in both sexes the region of the internal urethral orifice is the most fixed part of the bladder wall.

The pubo-prostatic ligaments contain bundles of smooth muscle fibres continuous with those forming the muscular coat of the bladder, and these are known as the **pubo-vesical muscle.**

Behind the urethral orifice the region of the fundus receives fixation and support from the dense fibrous tissue and strands of unstriped muscle which surround the seminal vesicles and the terminal portions of the ureters and deferent ducts. On each side many of the fibrous and muscular strands forming this support are continued into the fascia surrounding the branches of the hypogastric artery.

In the female the fundus of the bladder wall is supported and held in place by its connexion with the anterior wall of the vagina.

Structure of the Bladder Wall.—The wall of the bladder from without inwards is composed of a serous, a muscular, a submucous, and a mucous coat. The **serous coat** formed by peritoneum is incomplete, and covers only the upper and posterior parts of the distended bladder (Fig. 968).

A considerable amount of loose connective tissue surrounds the **muscular coat**, and penetrating it, divides it into numerous coarse bundles of muscle fibres. All the muscle fibres are of the unstriped variety, and the bundles which they form are arranged in three very imperfectly separated strata called external, middle, and internal. The **external stratum** is for the most part made up of fibres which are directed longitudinally, and it is best marked near the median plane on the upper and under aspects of the bladder. Farther from the median plane, on the sides of the bladder, the fibres composing the external stratum run more obliquely, and their directions frequently cross one another. In the male, many of the fibres of the external stratum pass both anteriorly and posteriorly into the prostate, and in the female the corresponding fibres join the dense tissue which in this sex forms the upper part of the wall of the urethra. Other fibres of this stratum on each side of the middle line join the lower part of the symphysis pubis and constitute the **musculus pubovesicalis**, which follows the course of the pubo-prostatic ligament. Lastly, some fibres of the external stratum blend posteriorly with the anterior aspect of the rectum and receive the name of **musculus rectovesicalis.** The **middle stratum** is composed of fibres which for the most part run circularly, and form the greater part of the thickness of the muscular coat. In the region of, and behind, the urethral orifice the bundles of fibres are finer and more densely arranged, and surround the opening in a plane which is directed obliquely downwards and forwards. This part of the middle stratum is often spoken of as the "sphincter vesicæ." Inferiorly the fibres of the sphincter vesicæ are continuous with the muscular tissue of the prostate in the male, and with the muscular wall of the urethra in the female. In other parts of the bladder the bundles of the middle stratum are coarser and separated by intervals filled by connective tissue. The **internal stratum** is composed of a thin layer of muscle fibres directed for the most part longitudinally.

The **submucous coat** is composed of areolar tissue, but contains numerous fine elastic fibres.

The **mucous coat** is loosely attached, by means of the submucous layer, to the subjacent muscular coat, except in the region of the trigonum vesicæ. Here the muscular fibres lie close beneath, and are firmly adherent to the mucous membrane. Over the trigonum the mucous coat is always smooth and flat; elsewhere it is thrown into folds when the bladder is empty. The mucous membrane of the bladder is continuous with that of the ureters and urethra. The epithelium, covering it, varies much in appearance in different conditions of the organ, and is of the variety known as transitional stratified epithelium. The appearance of the mucous coat is described on p. 1264.

When as a result of urethral obstruction the muscular coat of the bladder becomes hypertrophied, strong strands of muscular tissue become raised up and project into the cavity of the bladder. The resulting net-like arrangement of ridges resembles the trabeculæ carneæ of the heart ventricle.

Vessels and Nerves of the Bladder.—The bladder receives its blood supply on each side from the **superior** and **inferior vesical** branches of the hypogastric artery. The largest **veins** are found just above the prostate, and in the region where the ureter reaches the bladder. They form a dense plexus which pours its blood into tributaries of the hypogastric vein, and communicates below with the pudendal venous plexus.

The **lymph-vessels** from the bladder join the iliac group of lymph-glands.

The **nerve** supply of the bladder is derived on each side from the **vesical plexus**, the fibres of which come from two sources, namely (1) from the **upper lumbar nerves** through the hypogastric plexus, and (2) from the **third** and **fourth sacral nerves.** The fibres from the latter sources join the vesical plexus directly.

THE URETHRA.

The **urethra** is the channel which serves to convey the urine from the bladder to the exterior. In the *male* it consists of two portions, a proximal part, less than one inch in length, extending from the bladder to the points where the ducts of the reproductive glands join the canal, and a much longer distal portion which serves as a common passage for the secretion of the kidneys and for the generative products. An account of the male urethra follows the description of the male reproductive glands and passages (see p. 1289). In the *female* the urethra is more simple in its arrangement, and represents only the proximal part of the male canal. It is a short passage leading from the bladder to the external urethral orifice—an aperture placed within the pudendal or uro-genital cleft, immediately above and in front of the opening of the vagina.

Urethra Muliebris.—The **female urethra** is a canal of about one to one and a half inches in length which follows a slightly curved direction downwards and forwards, below and behind the lower border of the symphysis pubis. As it leaves the pelvis the urethra pierces the uro-genital diaphragm. The part of the passage which lies between the superior and inferior layers of the uro-genital diaphragm is surrounded by the fibres of the sphincter urethræ membranaceæ muscle. Except during the passage of fluid the canal is closed by the apposition of its anterior and posterior walls. The **external urethral orifice** is placed between the labia minora, immediately in front of the opening of the vagina, and lies about one inch below and behind the clitoris (Fig. 1007). The opening is slit-like, and is bounded by slightly marked lateral lips. The posterior wall of the urethra, except in its upper part, is very intimately connected with the anterior wall of the vagina. As it approaches the external urethral orifice the urethra is practically embedded in the anterior vaginal wall. The mucous lining of the canal is raised into a number of slightly marked longitudinal folds, one of which, more distinct than the others, and placed upon the posterior wall of the passage, receives the name of **crista urethralis**.

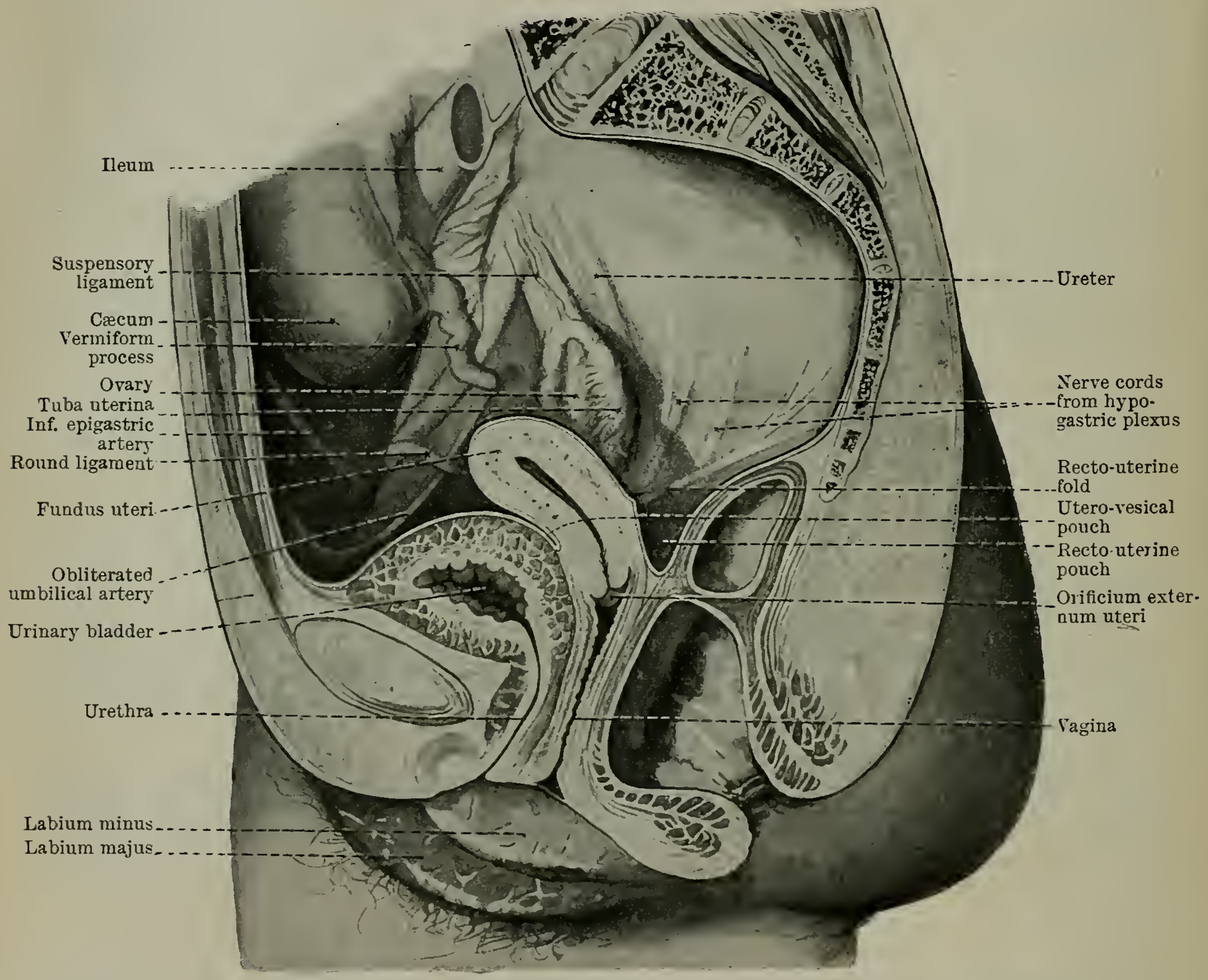


FIG. 977.—MEDIAN SECTION THROUGH THE FEMALE PELVIS. Drawn for the most part from a model of a dissection by Professor Edward H. Taylor.

Structure.—The wall of the female urethra is thick and contains much fibrous tissue which passes without any sharp line of demarcation into the surrounding mass of connective tissue. The thick **muscular coat** of the urethra is continuous above with that of the bladder, and is composed of layers of circularly disposed smooth muscle fibres, together with a few bundles which are longitudinally directed. Within the muscular coat the wall of the urethra is very vascular, and the canal itself is lined by a pale mucous membrane which is thrown into longitudinally directed folds, one of which is the crista urethralis mentioned above. The epithelium of the canal, in its upper part, is of the transitional variety, like that of the bladder; in its lower part it becomes scaly. Numerous minute **urethral glands** and pit-like **urethral lacunæ** open into the urethra. One group of these glands on each side possesses a minute common duct known as the **para-urethral duct**, which opens into the uro-genital cleft by the side of the external urethral orifice. These latter glands represent the prostatic glands of the male subject. The vascular layer which lies between the muscular coat and the mucous membrane contains elastic fibres, and in appearance resembles erectile tissue. Striped muscle fibres are present on the outer aspect of the muscular coat of the urethra. In the upper part of the canal these fibres form a complete ring-like sphincter, but in the middle and lower parts the striped muscle fibres, though present in front, are absent on the posterior wall of the urethra, as at this level they pass backwards on the outer aspect of the vagina, and enclose this latter passage together with the urethra in a single loop of muscle tissue. The lower fibres, therefore, form a uro-genital sphincter.

THE MALE REPRODUCTIVE ORGANS.

We have here to describe (1) the testes or essential reproductive glands of the male, together with their (2) coverings and (3) ducts, (4) the prostate, (5) the bulbo-urethral glands, (6) the external genital organs, and (7) the male urethra.

The reproductive glands of the male, or **testes**, are a pair of nearly symmetrical oval-shaped bodies situated in the scrotum. The duct of each gland, at first much twisted and intertwined, forms a structure known as the **epididymis**, which is applied against the posterior and lateral part of the testis. From the epididymis the excretory duct, or **ductus deferens**, passes upwards towards the inferior part of the anterior abdominal wall, which it pierces very obliquely, to enter the abdominal cavity. Here each ductus deferens is covered by the peritoneum, and, crossing the pelvic brim, almost at once enters the pelvis minor. The duct now runs on the side wall of the pelvis towards the base of the bladder, where it comes into relation with a branched tubular structure termed the **vesicula seminalis**. Joined by the duct of the vesicula seminalis, the ductus deferens forms a short canal called the **ejaculatory duct**, which terminates by opening into the prostatic part of the **urethra**. The **prostate**, a partly glandular, partly muscular structure, surrounding the first part of the urethra, and also the **bulbo-urethral glands**, are accessory organs connected with the male reproductive system. The ducts of the bulbo-urethral glands and those of the prostate, like the ejaculatory ducts, open into the urethra, which thus serves not only as a passage for urine, but also for the generative products. The external genitals are the **penis** and **scrotum**.

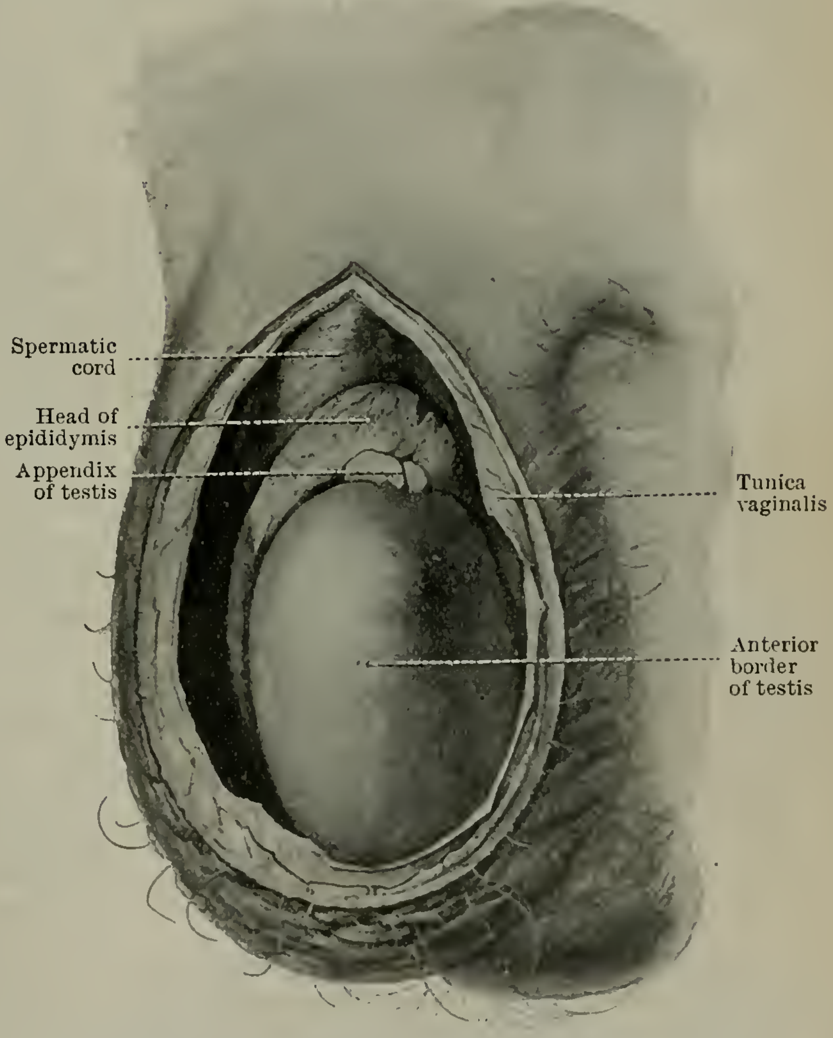


Fig. 978.—Right Testis and Epididymis, exposed by the Removal of the Anterior Wall of the Scrotum.

THE TESTIS.

The male reproductive glands, the **testes**, are a pair of somewhat oval, slightly flattened bodies of a whitish colour, measuring about an inch and a half in length, one inch from before backwards, and rather less in thickness. Each testis is placed within the cavity of the scrotum in such a manner that its long axis is directed upwards, slightly forwards, and laterally. Usually the left gland occupies a lower level than the right. The testis (Fig. 979) has two somewhat flattened surfaces; a *lateral surface* which looks backwards as well as laterally, and a *medial surface*, which looks forwards as well as medially, and is usually the more flattened. The two surfaces are separated by two rounded borders, one of which, the *anterior border*, is the more convex and free; while the other, the *posterior border*, is less rounded. By the posterior border the testis is suspended within the scrotum. The **epididymis** and the lowest portion of the **funiculus spermaticus**, or *spermatic cord*, are attached to the posterior border of the testis. Each border ends above in the *superior extremity*, and below in the *inferior extremity* of the testis. Owing to an obliquity of the long axis of the gland, the superior extremity of the testis lies on a more anterior and lateral plane than the inferior extremity.

Epididymis.—The epididymis is a somewhat crescentic structure, which is curved round the posterior border of the testis and overlaps to some extent the posterior part of the lateral surface of that organ. The superior, somewhat swollen part is called the **head of the epididymis**, and overhangs the superior end of the testis, to which it is directly connected by numerous emerging ducts, by connective tissue, and by the serous covering of the organ. The inferior and smaller end is termed the **tail of the epididymis**, and is attached by loose areolar tissue and by the serous covering to the inferior end of the testis. The intermediate part, or **body of the epididymis**, is applied against, but is separated from, the posterior part of the lateral surface of the testis by an involution of the serous covering of the organ, which forms an intervening pocket termed the **sinus of the epididymis**.

The main mass of the epididymis is composed of an irregularly twisted canal, the **duct of the epididymis**, which forms the first part of the duct of the testis.

Minute sessile, or pedunculated, bodies are often found attached to the head of the epididymis or to the superior end of the testis. These are called appendices of the epididymis and testis, and have a developmental interest. The minute body which lies on the superior end of the testis represents the free end of Müller's duct in the embryo and the fimbriated end of the uterine tube of the female; it is usually sessile. Above the head of the epididymis, and in front of the lower part of the spermatic cord, there may also be present a small vestigial body called the **paradidymis**. This is rarely seen in the adult, and is best marked in young children.

Tunica Vaginalis.—The cavity within which the testis and epididymis are placed is lined by a smooth serous membrane—the **tunica vaginalis**—which resembles in appearance and structure the peritoneum, from which it is originally derived. The cavity is considerably larger than the contained structures, and extends not only down to a lower level than the testis, but also reaches upwards to a higher level than the gland. The sac, or cavity, tapers as it is traced upwards, and above the level of the testis the spermatic cord bulges forwards into its posterior part. The tunica vaginalis is reflected from the posterior wall of the scrotal chamber over the testis and epididymis, giving a covering to each. The part of the membrane lining the cavity is called the **parietal lamina** of the tunica vaginalis, while the part clothing the testis and epididymis is termed the **visceral lamina.** Between the lateral surface of the testis and the body of the epididymis, the visceral lamina of the tunica vaginalis dips in and lines a narrow interval called the **sinus of the epididymis.** The entrance to the sinus is limited above and below by short crescentic folds of the tunica vaginalis, which pass from the testis to the head and tail of the epididymis. These folds are spoken of as the *superior* and *inferior ligaments* of the epididymis. In three positions the surface of the testis receives no covering from the tunica vaginalis—superiorly where the head is attached, inferiorly where the cauda epididymidis is in contact, and posteriorly where the blood-vessels and nerves enter the organ from the funiculus spermaticus or spermatic cord.

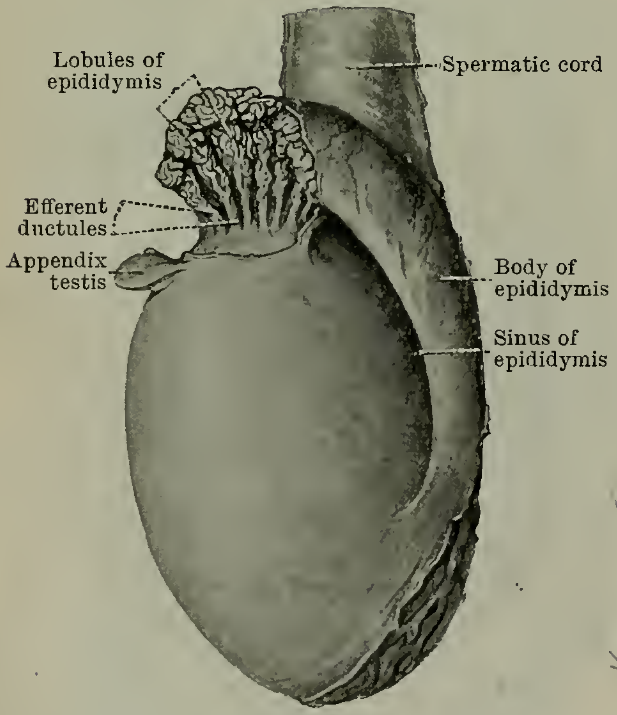


Fig. 979.—Left Testis and Epididymis.

A part of the tunica vaginalis has been removed in order to show the ductuli efferentes and lobuli epididymidis.

Structure of the Testis.—Beneath the serous tunica vaginalis the testis is invested by an external coat, composed of dense white inelastic fibrous tissue called the **tunica albuginea**, from the deep surface of which a number of slender fibrous bands, or septa, dip into the gland. These—the **septula testis**—imperfectly divide the organ into a number of wedge-shaped parts called **lobuli testis** (Fig. 980). All the septa end posteriorly in a mass of fibrous tissue which is directly continuous with the tunica albuginea, and which projects forwards into the testis along its posterior border. This structure receives the name of **mediastinum testis**, and is traversed by an exceedingly complicated network of fine canals, into which the minute tubules which compose the substance proper of the testis open. The mediastinum is also pierced by the arteries, veins, and lymph vessels of the testis. These vessels enter the posterior border of the organ, and traversing the mediastinum, spread out on the fibrous septa which radiate towards all parts of the deep surface of the tunica albuginea. In this way a delicate network of vessels (tunica vasculosa) is formed on the deep surface of the tunica albuginea and on the sides of the septula.

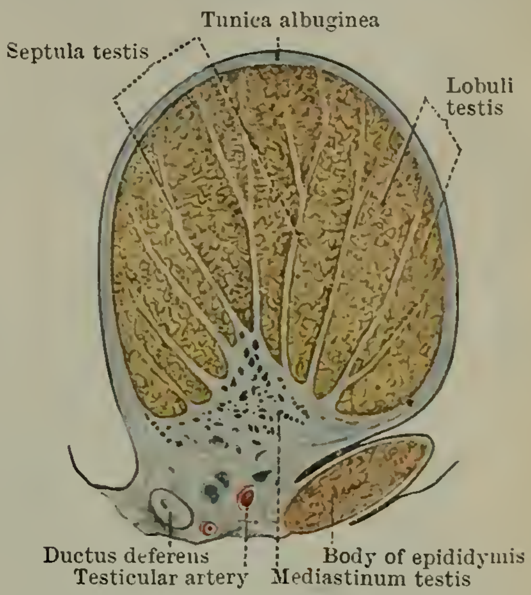


Fig. 980.—Transverse Section of the Testis and Epididymis.

The mediastinum, the septula, and the tunica albuginea form a framework enclosing a number of imperfectly isolated spaces which are filled by a loosely packed substance of a light brown colour called the **parenchyma testis**.

The parenchyma is composed of enormous numbers of much-convoluted seminiferous tubules, called **tubuli seminiferi contorti**, and completely fills up the intervals between the septula. The minute tubules look like fine threads to the unaided eye, and are but loosely held together by a small amount of connective tissue. Usually two or four tubules are found in each lobule of the gland, and the total number in the testis has been estimated at about 600. The seminiferous tubules pass towards the mediastinum testis and unite at acute angles, to form a smaller number of slender tubes which run a straight course. These latter are called **tubuli seminiferi recti**, and open into a complicated network of fine canals situated in the substance of the mediastinum, called the **rete testis**. The tubules are much more twisted and convoluted in the cortical part of the gland, near the tunica vaginalis, than in the region of the mediastinum. According to some observers, they give off side branches which may effect anastomoses between the tubules. Recent observations lead to the conclusion that each convoluted tubule is to be regarded as an arched canal opening by both its ends into a straight tubule.

Microscopic sections show that the walls of the seminiferous tubules are composed of a basement membrane and of an epithelial lining, formed of several layers of cells. Certain cells of this epithelium are, in the adult, constantly undergoing transformation into **spermatozoa**, and the appearance of the tubules in section varies much, according to age and to the greater or less activity of the epithelial cells.

Structure of the Epididymis.—The secretion of the contorted seminiferous tubules is carried through the tubuli seminiferi recti into the rete testis, and leaves the latter, to reach the canal of the epididymis, through from fifteen to twenty minute tubules called **ductuli efferentes testis**. These efferent ductules pierce the tunica albuginea and enter the head of the epididymidis where it is in direct contact with the superior extremity of the testis. Each ductule is at first straight, but soon becomes much convoluted, and forms a little conical mass of twisted tubule, called a **lobule of the epididymis**, or conus vasculosus. Within the head of the epididymis the little twisted canals finally open into the single much-convoluted tube which constitutes the chief bulk of the epididymis, and is called the **duct of the epididymis**. This canal, which is not less than 19 or 20 feet in length, may be said to begin in the head of the epididymis, and to end, after an extraordinarily tortuous course, at the tail by becoming the **ductus deferens** (Fig. 981).

In most cases one or more slender convoluted diverticula from the duct of the epididymis may be found near its lower end. These receive the name of **ductuli aberrantes**, and one of them which is very constantly present often measures a foot or more in length.

The duct of the epididymis and the efferent ductules are lined by a ciliated epithelium, the cilia of which maintain a constant current towards the ductus deferens. The duct possesses a muscular coat composed of an inner stratum of circularly and an outer stratum of longitudinally directed fibres. The wall, at first thin, becomes much thicker as the duct approaches the ductus deferens.

Vessels and Nerves of the Testis.—The testis is supplied by the **testicular artery**, a branch of the aorta. This slender vessel, after a long course, reaches the posterior border of the testis, where it breaks up into branches which enter the mediastinum testis, and are distributed along the septula and on the deep surface of the tunica albuginea.

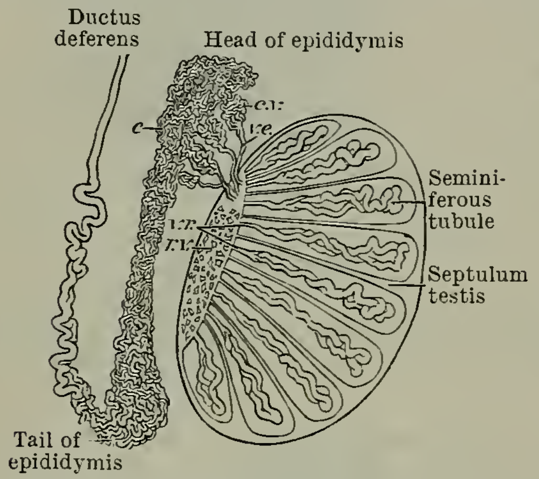


FIG. 981.

DIAGRAM to illustrate the structure of the testis and epididymis.

c. Duct of epididymis. v.e. Ductuli efferentes testis.
c.v. Lobuli of epididymis. v.r. Tubuli seminiferi recti.
r.v. Rete testis.

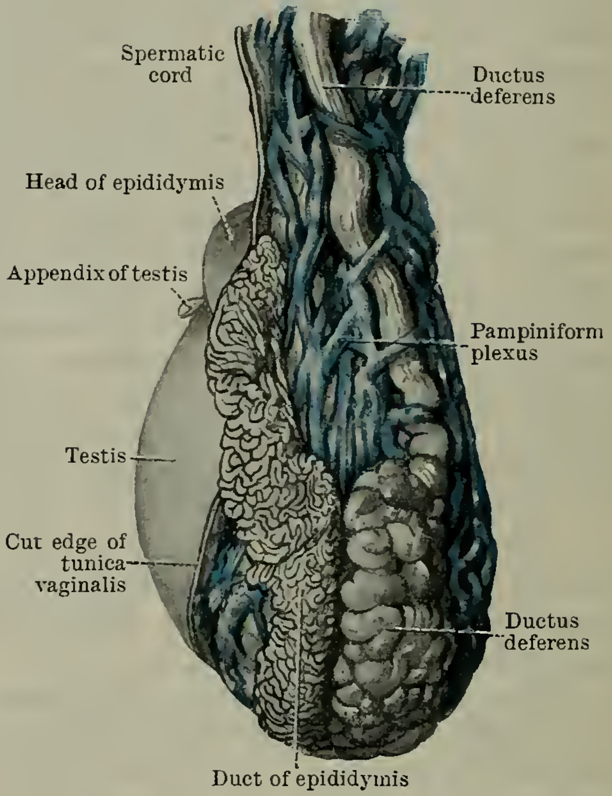


FIG. 982.—LEFT TESTIS AND EPIDIDYMIS VIEWED FROM BEHIND, showing the ductus epididymidis and the first part of the ductus deferens.

The **veins** issuing from the posterior border of the testis form a dense plexus, called the **pampiniform plexus**, which finally pours its blood through the testicular vein, *on the right side*, into the inferior vena cava, and *on the left side*, into the left renal vein.

The **nerves** for the testis accompany the artery, and are derived through the **aortic** and **renal plexuses** from the tenth thoracic segment of the spinal cord. The afferent fibres from the epididymis appear to reach the spinal cord through the posterior roots of the eleventh and twelfth thoracic and first lumbar nerves. The arteries and nerves of the testis communicate with those on the lower part of the ductus deferens, namely, with the artery of the ductus deferens and with twigs from the hypogastric plexus.

The **lymph-vessels** of the testis pass upwards in the spermatic cord, and end in the lumbar lymph-glands.

DUCTUS DEFERENS.

The **ductus deferens** is the direct continuation of the duct of the epididymis. Beginning at the inferior extremity of the epididymis, it ends, after a course of nearly 18 inches, by opening as the **ejaculatory duct** into the prostatic, or first, part of the urethra. The duct in parts of its course is somewhat convoluted, and the actual distance traversed by it is not more than 12 inches. Placed in the first instance outside the abdominal cavity, the deferent duct ascends within the scrotum towards the lower part of the anterior abdominal wall, which it reaches not far from the median plane. During this part of its course the duct, together with the vessels and nerves of the testis, is surrounded by a number of loose coverings derived from certain layers of the abdominal wall, and the cord-like structure so formed is termed the **funiculus spermaticus** or spermatic cord. The deferent duct, together with the accompanying vessels and nerves, now passes through the abdominal wall in an oblique passage, to which the name **inguinal canal** is applied. Within the abdomen the duct lies immediately beneath the peritoneum, and soon crossing over the pelvic brim, it enters the pelvis minor, on the side wall of which it proceeds backwards towards the fundus of the bladder. Here, near the median plane, the deferent duct is joined by the duct of the corresponding **seminal vesicle** and the ejaculatory duct, thus formed, having traversed the prostate, opens into the urethra.

At first the ductus deferens, like the canal from which it takes its origin, is very tortuous, but soon increasing in thickness, it becomes less twisted, and passes upwards along the medial side of the epididymis, behind the testis, to enter the spermatic cord (Fig. 980). Its course is now almost vertically upwards towards the pubic tubercle, near which, crossing the medial end of the inguinal ligament, the duct enters the inguinal canal by the subcutaneous inguinal ring (Fig. 991). Of the structures composing the spermatic cord the duct is the most posterior, and it can be distinguished readily, even in the undissected subject, by its hard firm feel, when it is taken between the finger and thumb. In the inguinal canal the ductus deferens is directed laterally, upwards and a little backwards to the abdominal inguinal ring, where, at a point half an inch above the inguinal ligament, and midway between the symphysis pubis and the anterior superior iliac spine, it enters the abdomen. The distance between the point where the cord enters the inguinal canal to the point where it leaves it, to enter the abdomen, is about one and a half inches. While passing from the subcutaneous to the abdominal inguinal ring the ductus deferens, together with the other

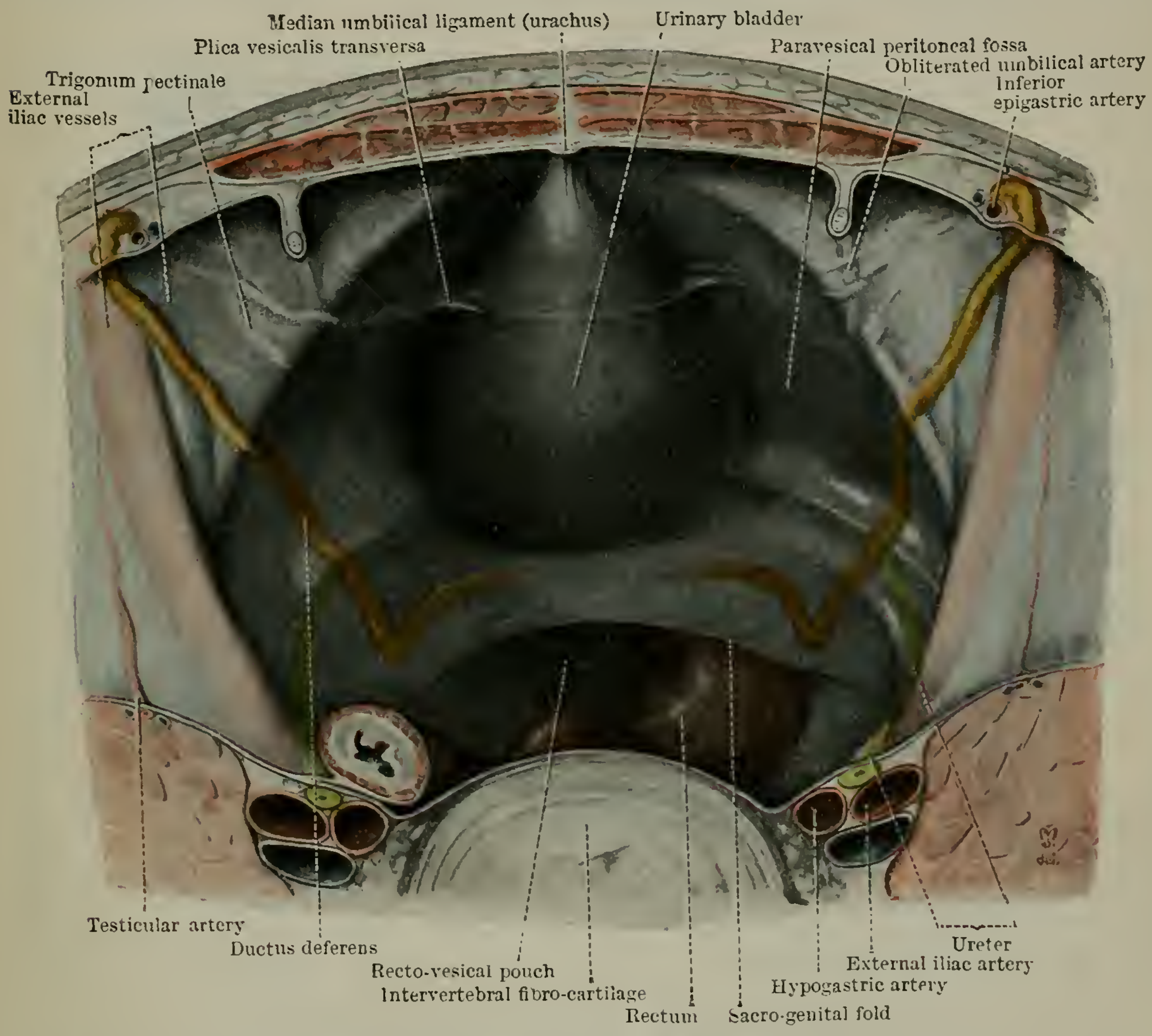


FIG. 983.—VIEW OF THE MALE PELVIS SEEN FROM ABOVE AND BEHIND.
The course of the ductus deferens is well seen.

structures of the spermatic cord, rests upon the upper grooved surface of the inguinal ligament, and is placed behind the aponeurosis of the external oblique and some of the lower fibres of the internal oblique muscle. From before backwards the duct rests, in the first instance, upon the falx aponeurotica, or conjoined tendon of the internal oblique and transversus abdominis muscles, and more laterally upon the fascia transversalis. Above are some arching fibres of the internal oblique muscle which enter the falx. As the deferent duct leaves the inguinal canal by the abdominal inguinal ring, it turns round the inferior epigastric artery on its lateral and posterior aspect (Fig. 983). Completely changing the direction of its course, the duct now runs for a short distance backwards, medially, and upwards, beneath the peritoneum, to a point one and a half to two inches from the pubic tubercle, where it crosses the pecten of the pubis and enters the pelvis minor.

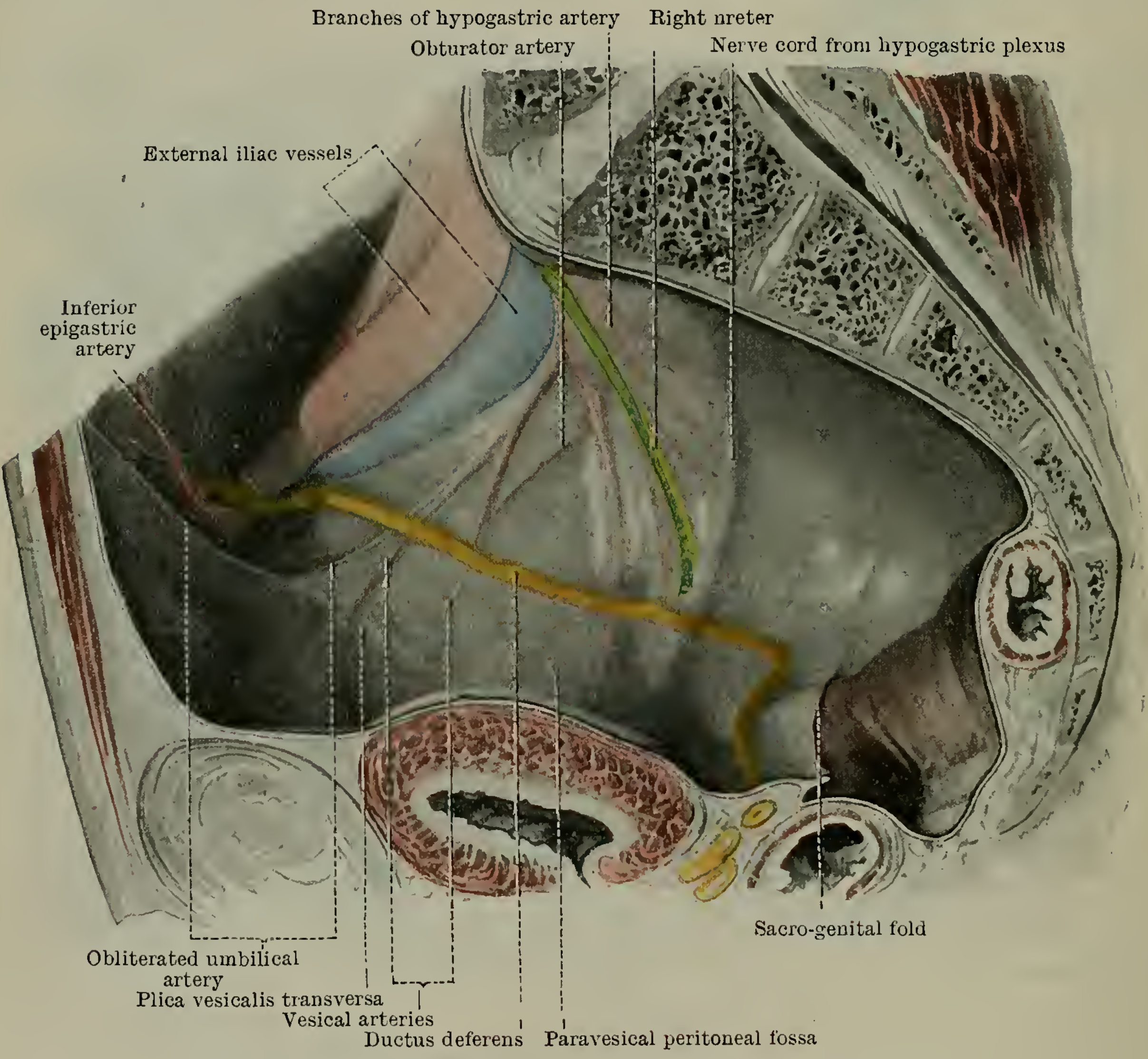

Branches of hypogastric artery
Right ureter
Obturator artery
Nerve cord from hypogastric plexus
External iliac vessels
Inferior epigastric artery
Sacro-genital fold
Obliterated umbilical artery
Plica vesicalis transversa
Vesical arteries
Ductus deferens
Paravesical peritoneal fossa

FIG. 984.—MEDIAN SECTION OF THE PELVIS IN AN ADULT MALE.

The coils of small intestine and colon which lay within the pelvis have been lifted out in order to give a view of the side wall of the pelvic cavity.

In this part of its course the duct usually lies at first in front of the external iliac vessels, and then in the floor of a little triangular fossa, the *trigonum pectinale* between these vessels and the pelvic brim (Fig. 983). On the side wall of the pelvis minor the deferent duct is continued backwards, and a little downwards and medially, in the direction of the ischial spine, and lies immediately external to the peritoneum, through which it can usually be seen shining. In the pelvic part of its course the duct crosses on the medial side of (1) the obliterated part of the umbilical artery, (2) the obturator nerve and vessels, (3) the vesical vessels, and (4) the ureter (Fig. 984).

Beyond the ureter the duct takes a somewhat sudden bend, and passes downwards and medially towards the median plane, beneath the peritoneum of the pelvic floor. Reaching the interval between the fundus of the bladder in front and the rectum behind, the ducts of opposite sides occupy the angle formed between the right and left seminal vesicles (Fig. 987). As they approach one another each duct becomes somewhat tortuous, sacculated and dilated, and assumes a general resemblance in structure to a portion of the seminal vesicle. This dilated part of the deferent duct is termed the **ampulla**. As it turns medially the duct lies a short distance behind the ureter, and immediately in front of the free edge of the (sacro-genital) peritoneal fold which bounds the recto-vesical or (recto-genital) pouch of the peritoneum. Just above the base of the prostate the ductus deferens becomes once more a narrow canal and is joined by the duct of the corresponding seminal vesicle to form the **ejaculatory duct**, which, after a short course downwards, forwards and medially through the prostate, opens into the urethra.

In some cases the ductus deferens crosses the obliterated umbilical artery before it enters the cavity of the pelvis minor; it normally does so in the fœtus (Fig. 988).

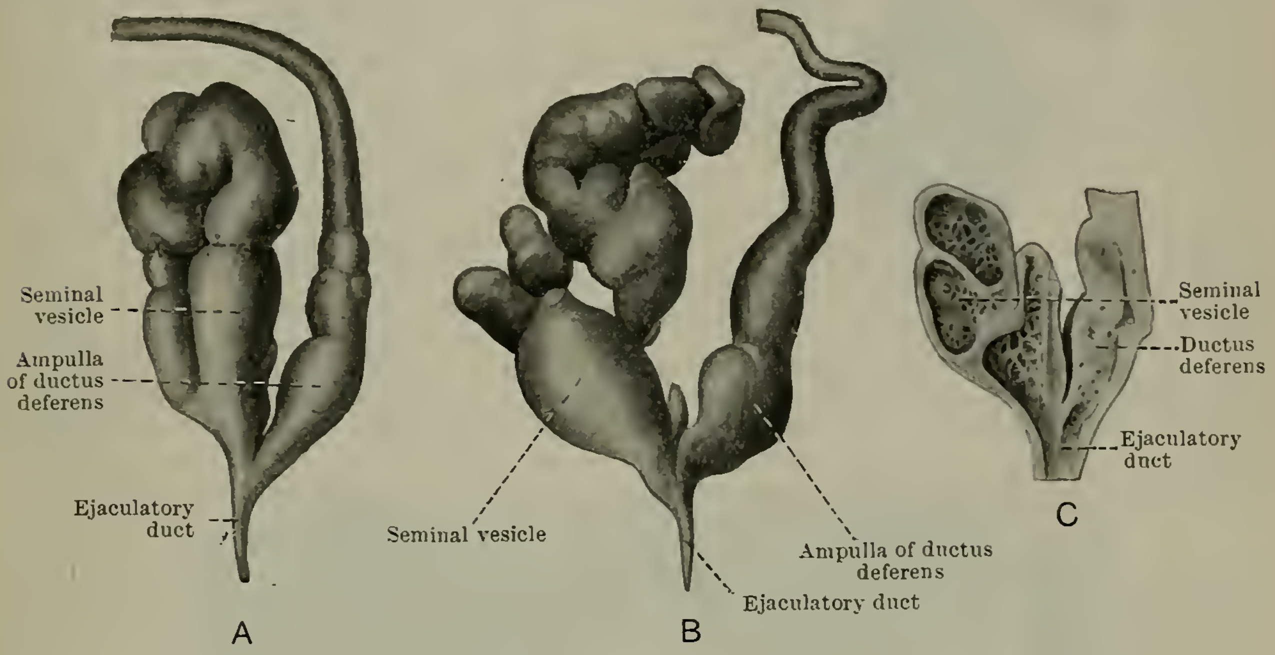


FIG. 985.

A and B. Drawings illustrating the seminal vesicle and the ampulla of the ductus deferens taken from two different subjects.
C. The seminal vesicle and ductus deferens have been cut into to show the pitted structure of their walls.

Ductus Ejaculatorius.—The **ejaculatory duct** is a very slender canal, formed by the union of the ductus deferens with the duct of the corresponding seminal vesicle (Fig. 985). It is less than one inch in length, and lies very close to its fellow of the opposite side as it passes through the prostate behind its median lobe. The ducts open by slit-like apertures into the first part of the urethra, one on each side of the **prostatic utricule**. They are well seen in sections through the upper part of the prostate (Figs. 986 and 997).

The mucous membrane of the duct is thrown into numerous complicated folds, and in connexion with it are a number of remarkable minute diverticula, which are enclosed within the muscular coat of the duct.

VESICULÆ SEMINALES.

The **seminal vesicles** are a pair of hollow sacculated structures placed in front of the rectum and behind the bladder (Fig. 986). Each vesicle is usually about two inches in length, and has its long axis directed downwards, medially, and somewhat forwards. The superior extremity of the vesicle, which is partly covered by peritoneum, is large and rounded, and lies at a considerable distance from the median plane, behind the inferior end of the ureter. It is separated from the rectum by the peritoneum of the recto-vesical or recto-genital pouch. Below the level of the peritoneal cavity the seminal vesicle and rectum are more intimately related. The vesicle tapers towards its inferior end, which is placed close to the median plane immediately above the prostate. In this position the vesicle becomes constricted to form a short duct, which joins the lateral side of the corresponding ductus deferens at an acute angle. The common duct thus formed is known as the ejaculatory duct. The medial side of each vesicle is related to the ductus deferens, and the lateral side, when the bladder is empty, lies close to the sloping pelvic floor. The seminal vesicles are more intimately related to the wall of the bladder than to that of the rectum. Their superior extremities are, as we have seen, separated from the rectum by a portion of the recto-vesical pouch of peritoneum, and lower down the septum of fascia which intervenes between the seminal vesicles and the rectum is denser than that which separates them from the bladder.

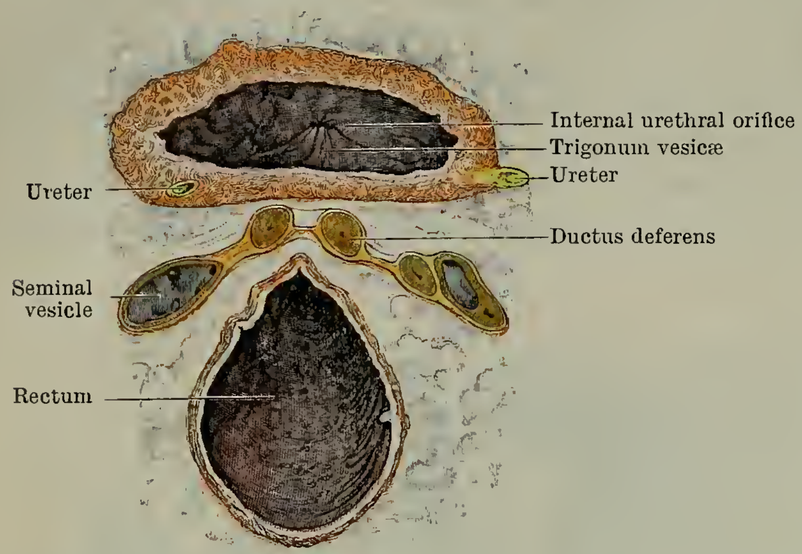


Fig. 986. — Horizontal Section through the Rectum and Urinary Bladder at the Level at which the Ureters pierce the Bladder Wall.

From a specimen in the Surgical Museum, Trinity College, Dublin.

The seminal vesicle often assumes a more vertical position when the bladder is distended; a more horizontal direction when the bladder is empty. Its superior extremity is sometimes found to be curved backwards

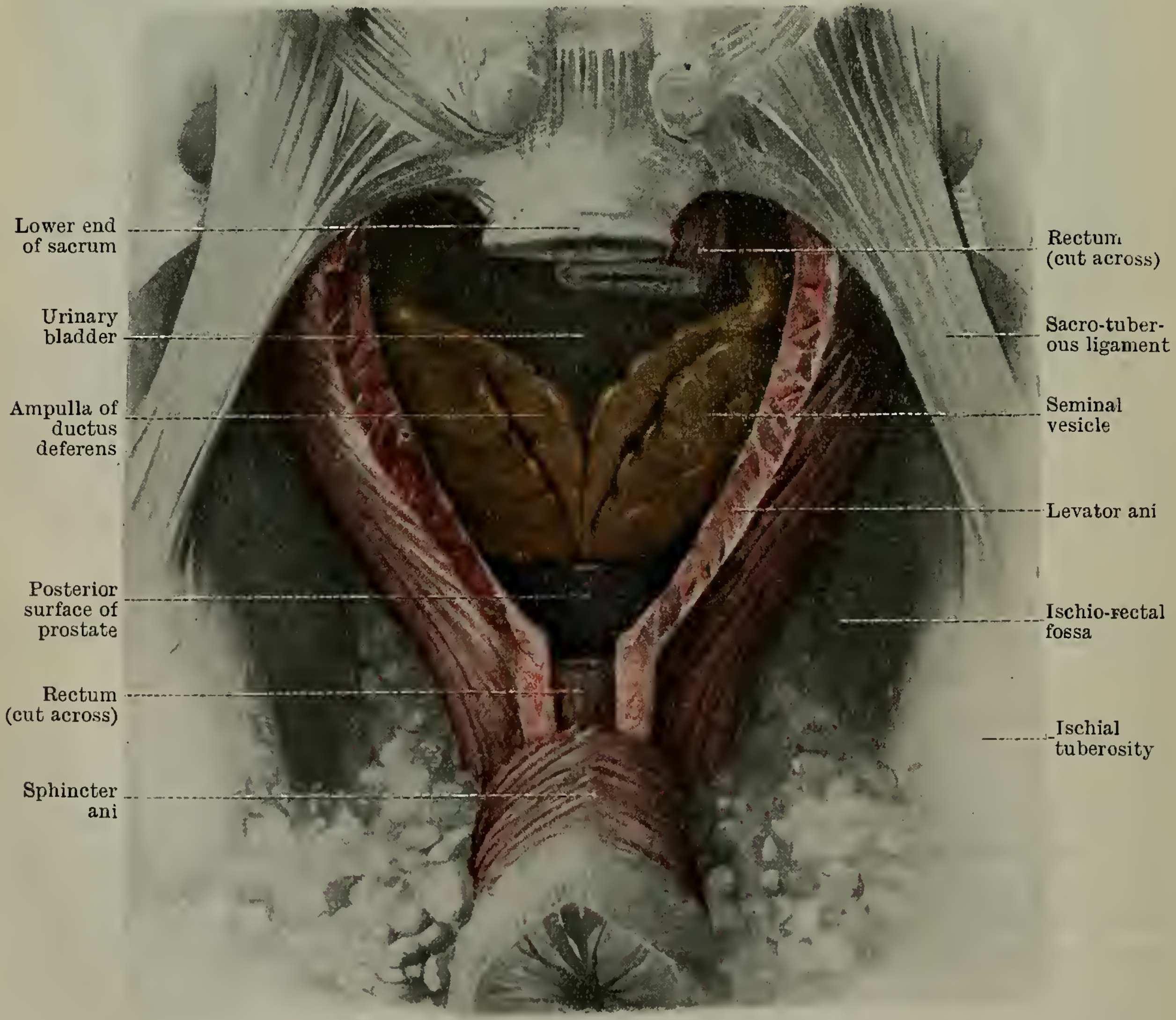


Fig. 987.—Dissection to display the Posterior Aspect of the Vesiculæ Seminales, the Ampullæ of the Ductus Deferentes, and the Prostate. The coccyx and portions of the levatores ani have been removed, also a considerable portion of the rectum.

against the side of the rectum. In some cases the seminal vesicles are much smaller than usual, and may be less than one inch in length. Frequently they are asymmetrical as regards size and shape.

Each seminal vesicle is in reality a tube bent in a tortuous manner on itself, and if the dense connective tissue which envelops it is taken away, the length of the tube when untwisted may be found to be as much as five inches. The tube is closed above, and a variable number of short tortuous branches come off it at different levels. The blind end of the tube usually lies at the superior and lateral extremity of the seminal vesicle, but in some cases the tubular structure is so bent upon itself that the blind terminal part lies against the side of the issuing duct. Their mode of development shows that the seminal vesicles are to be regarded as diverticula of the deferent ducts, from which they originally arise as small pouched outgrowths.

The seminal vesicles are not present in all mammals, and in those in which they do occur their relative size and form vary much. Among the carnivora and marsupials, for instance, the seminal vesicles do not occur; in some other animals, as in the hedgehog, they are relatively of enormous size.

The dense tissue in which the seminal vesicles are embedded contains much unstriped muscle tissue, which sweeps round in the side wall of the recto-vesical pouch. Inferiorly this tissue is attached to the capsule of the prostate. The large veins coming from the prostatic and vesical plexuses are closely related to the seminal vesicles.

Structure of the Ductus Deferens and of the Vesicula Seminalis.—Except near its termination, where it is dilated to form the ampulla, the ductus deferens is a thick-walled tube with relatively a very small lumen. The hard cord-like sensation which it conveys to the touch is due to the thickness and toughness of its wall. Microscopical examination shows that the wall of the ductus deferens is composed of three layers—an outer **adventitious coat** of fibrous connective tissue, an intermediate **muscular coat** and an inner **mucous coat**. The thickness of the wall is due to the great development of the middle or muscular coat, which is composed of an intermediate stratum of circularly and an inner and outer stratum of longitudinally directed unstriped muscular fibres. Of these strata the intermediate is by far the thickest, and forms the chief part of the thickness of the wall of the ductus deferens. The mucous membrane of the duct exhibits a number of slight longitudinal folds and possesses a ciliated epithelium. The ampulla, or terminal part, possesses a much thinner wall, and, as the surface of its mucous membrane has a number of ridges separating depressed areas, the lining of this part of the tube presents a pitted or honeycombed appearance. The wall of the vesicula seminalis resembles that of the ampulla in being thin, and in having a mucous lining with uneven honeycomb-like ridges and depressions. In it the same coats are to be recognised as in the ductus deferens, but the muscular layer is much thinner, and the strata composing it less regularly arranged.

Vessels and Nerves of the Ductus Deferens and of the Vesicula Seminalis.—The deferent duct receives its main arterial supply from the superior or inferior **vesical artery**. The artery to the duct accompanies that structure, supplying it as far as the testis, where it ends by anastomosing with branches of the testicular artery. The seminal vesicle is supplied by the **inferior vesical artery**. The **nerves** of the ductus deferens and vesicula seminalis are derived from the hypogastric plexus. In lower animals the nerves for the seminal vesicles are derived from the nerve roots of the second, third, and fourth lumbar nerves.

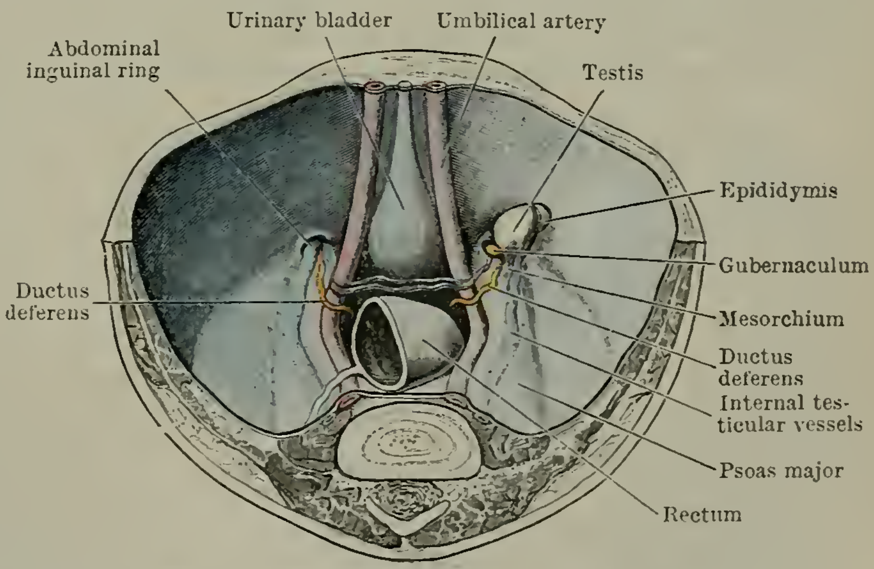


Fig. 988.—View looking from above into the Pelvis and Lower Part of the Abdominal Cavity in a Fœtus of about the Seventh Month.

On the left side, which represents a slightly more advanced condition than the right, the testis has entered the inguinal canal; on the right side the testis is still within the abdominal cavity.

Descent of the Testis.

The peculiar course pursued by the ductus deferens in the adult, and the manner in which it is related to the anterior abdominal wall, are rendered clear by a study of the arrangement of the parts in the fœtus. The testes until nearly the end of intra-uterine life are placed in the abdominal cavity. Lying at first on the posterior wall of the abdomen at the level of the upper lumbar vertebræ, and just below the level assumed at this time by the permanent kidney, the testis is held in place by a fold of peritoneum or mesentery, called the **mesorchium**. As growth goes on the testis is found to occupy a lower level in the abdominal cavity; in the third month it lies in the iliac fossa, and in the seventh it is situated near the abdominal inguinal ring. Meanwhile a blind pouch or diverticulum of the peritoneal membrane, termed the **processus vaginalis**, has grown downwards and medially through the anterior abdominal wall towards the scrotum, deriving as it goes a covering from each of the layers of the abdominal wall through which it passes. The testis with its mesorchium enters the processus vaginalis and descends within it until the scrotum is reached. At a later stage, the connexion between the part of the processus vaginalis that lies in the scrotum and the peritoneal lining of the abdomen becomes lost by the obliteration of the upper part of the pouch. Thus the part of the processus vaginalis that persists in the scrotum becomes the parietal lamina of the tunica vaginalis; while the visceral lamina of that membrane is the primitive peritoneal covering of the testis and epididymis (Figs. 978, 989).

Often a small fibrous band—the "ligamentum vaginale"—may be found in the adult passing through the inguinal canal and joining the peritoneum superiorly in the region of the abdominal inguinal ring. Sometimes this band is connected below with the tunica vaginalis, but more often it cannot be traced so far downwards. When present it represents the obliterated portion of the processus vaginalis, and is therefore known as the **rudimentum processus vaginalis.**

In rare cases the processus vaginalis may persist after birth as a channel freely open to the abdominal cavity above, or the passage, becoming closed at intervals, may give rise to one or more cysts within the coverings of the spermatic cord.

It sometimes happens that the descent of the testis is arrested, and then, either failing to enter the processus vaginalis, the testis remains within the abdominal cavity, or entering the processus vaginalis, it fails to reach the scrotum, and lies in the inguinal canal. The term "cryptorchism" is frequently applied to such cases.

In connexion with the descent of the testis a remarkable cord-like structure—the **gubernaculum testis** [Hunteri]—must be mentioned. The gubernaculum arises for the most part within a peritoneal fold which, at an early time in the development of the fœtus, may be seen stretching from the inguinal region to the Wolffian duct (future duct of the testis) and inferior end of the mesonephros or primitive kidney. This peritoneal fold, termed the *plica inguinalis* (or plica inguino-mesonephrica), is joined from above by a less marked fold (the plica testis inferior) which extends downwards from the inferior end of the testis, which, at this time, is situated in the abdomen close to the medial aspect of the mesonephros. Within both these folds smooth muscular and fibrous tissue arise and give origin to a continuous band, or ligament—the gubernaculum testis. The gubernaculum is therefore to be regarded as originally composed of two portions—a lower part developed within the plica inguinalis, and an upper part formed within the plica testis inferior. It is interesting to note that in the female the representatives of these two parts of the gubernaculum remain separate throughout life, and constitute the round ligament of the uterus and the ligament of the ovary. The gubernaculum, when it is at its greatest development (about the sixth month), is rounded and cord-like, and is attached above to the lower end of the testis, while inferiorly it is fixed near the inguinal region. In the lower part of its course it is closely related to, and is partly covered by, the peritoneum of the processus vaginalis. Striped muscular fibres are present in the lower part of the gubernaculum, and have their origin from the muscles of the inguinal part of the anterior abdominal wall. As the testis enters the processus vaginalis the gubernaculum atrophies, but at birth a short part of the gubernaculum may still be found passing downwards towards the inferior part of the scrotum and lying below the level of the tunica vaginalis. It is considered by some anatomists that the movement downwards of the testis may be partly due to a pull caused by the shrinking of the gubernaculum as it atrophies.

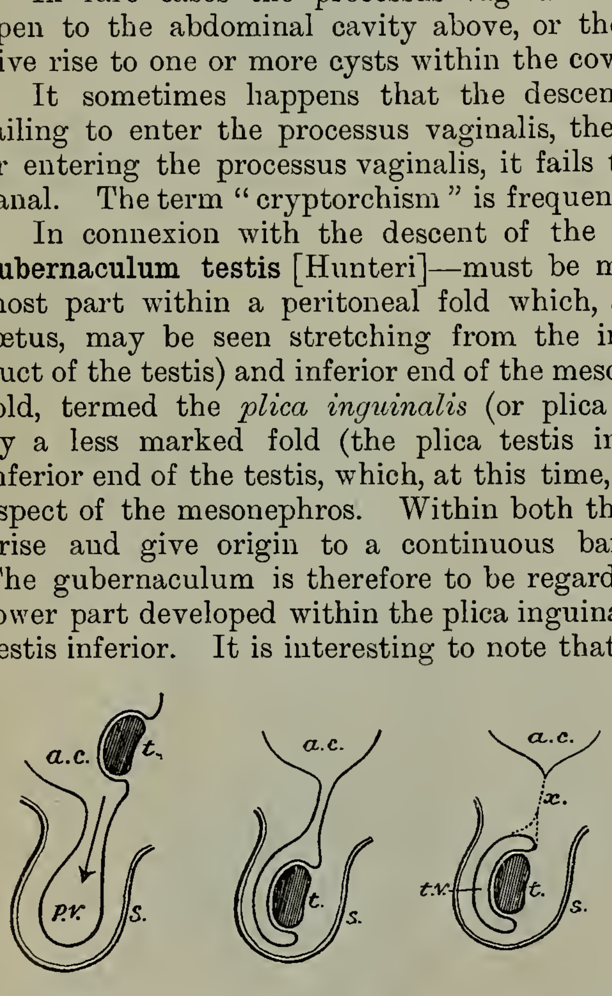


FIG. 989.—DIAGRAM to illustrate the descent of the testis and the manner in which the tunica vaginalis is derived.

a.c. Abdominal cavity.	*s.* Scrotum.
p.v. Processus vaginalis.	*t.v.* Tunica vaginalis.
t. Testis.	*x.* Rudimentum processus vaginalis.

In some mammals, such as the elephant, the testes remain permanently within the abdominal cavity; while in others, such as the rabbit and the hedgehog, the peritoneal pouches remain widely open throughout life, and the testes are periodically withdrawn into the abdomen.

Funiculus Spermaticus (Spermatic Cord).

The testis in its course downwards through the abdominal wall into the scrotum takes with it its duct, its blood and lymph vessels and nerves. All these lie together in the inguinal canal as they traverse the abdominal wall, and when they leave the canal by the subcutaneous inguinal ring they extend downwards to the posterior border of the testis. The deferent duct, the testicular vessels, and the nerves and lymphatics of the testis loosely connected together, form the **funiculus spermaticus**, or spermatic cord. At the abdominal inguinal ring its constituent parts separate from one another, and the cord may therefore be considered to extend from the abdominal inguinal ring to the posterior border of the testis. The structures which form the spermatic cord are enclosed within a number of coverings derived from the layers of the anterior abdominal wall, and these, when the constituents of the cord reach the posterior border of the testis, surround the tunica vaginalis, and so form a part of the wall of the scrotum. The sheaths or coverings of the cord derived from the abdominal wall are three in number, and are named external spermatic fascia, cremasteric fascia, and internal spermatic fascia. The *external spermatic fascia* is the most superficial of the three sheaths, and is derived from the aponeurosis of the external oblique muscle, with which it is continuous round the margins of the subcutaneous inguinal ring. The *cremasteric fascia* consists partly of muscular fibres derived from the lower part of the internal oblique muscle, and partly of delicate connective tissue. The muscular fibres constitute the **cremaster** muscle and, passing down over the funiculus, form a series of loops round the testis and tunica vaginalis. The *internal spermatic fascia* is derived from the fascia transversalis of the abdomen. It passes downwards as a continuous sheath over the cord, and encloses its various structures, together with a certain amount of areolar tissue derived from the subperitoneal tissue of the abdominal wall and some smooth muscle fibres.

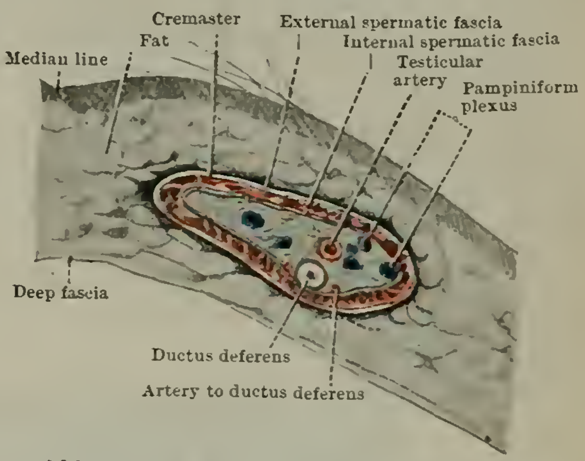


Fig. 990.—Transverse Section of the Funiculus Spermaticus, or Spermatic Cord, just below the Subcutaneous Inguinal Ring.

A section through the spermatic cord as it leaves the superficial inguinal ring shows the coverings loosely surrounding the constituents of the cord, namely the ductus deferens, the testicular artery, the pampiniform plexus of veins, the nerves and lymphatics of the testis. In addition to these structures, the artery to the ductus deferens, the external spermatic branch of the inferior epigastric artery, and a branch of the genito-femoral nerve are included in the structures forming the spermatic cord.

Scrotum.

The **scrotum**, in which the testes are placed, varies much in appearance in different subjects, and even in the same individual at different times. As the result of cold or of exercise, the wall of the scrotum becomes contracted and firm, and the skin covering it wrinkled; at other times the wall may be relaxed and flaccid, the scrotum then assuming the appearance of a pendulous bag. The left side of the scrotum reaches to a lower level than the right, in correspondence with the lower level of the testis on that side of the body. The skin covering the scrotum is of a darker colour than the general skin of the body, and is covered with hair. It is marked in the median plane by the **raphe scroti**, which is continued backwards towards the anus, and forwards on to the urethral surface of the penis. The difference in the appearance of the scrotum at different times is due to the amount of contraction or relaxation of a layer of muscular fibres, constituting the **dartos tunic**, situated in the superficial fascia. When this muscular layer is contracted, the scrotum becomes smaller and somewhat globular, and the skin is thrown into folds or wrinkles called rugæ; when it is relaxed, the scrotum is flaccid and pendulous, and the skin becomes more smooth and even. The layer of fascia which contains the smooth muscle fibres can be shown to be continuous superiorly with the superficial fascia of the penis, and with the deep layer of the superficial fascia of the abdomen, and to be attached laterally to the bones forming the pubic arch. The muscle fibres are arranged in a thick layer of interlacing bundles, and many of the deeper fibres are continued into the **septum scroti**, which divides the scrotum into two cavities, one for each testis. The wall of each of these cavities is formed by the corresponding tunica vaginalis, internal spermatic fascia, cremasteric fascia, and external spermatic fascia; while the skin, the superficial fascia, and the superficial part of the dartos muscle form coverings which are common to the whole scrotum, and enclose both cavities. The layer of tissue immediately beneath the dartos tunic is made up of exceedingly loose and easily stretched areolar connective tissue, and in it, as throughout in the superficial fascia of the scrotum, there is an entire absence of fat.

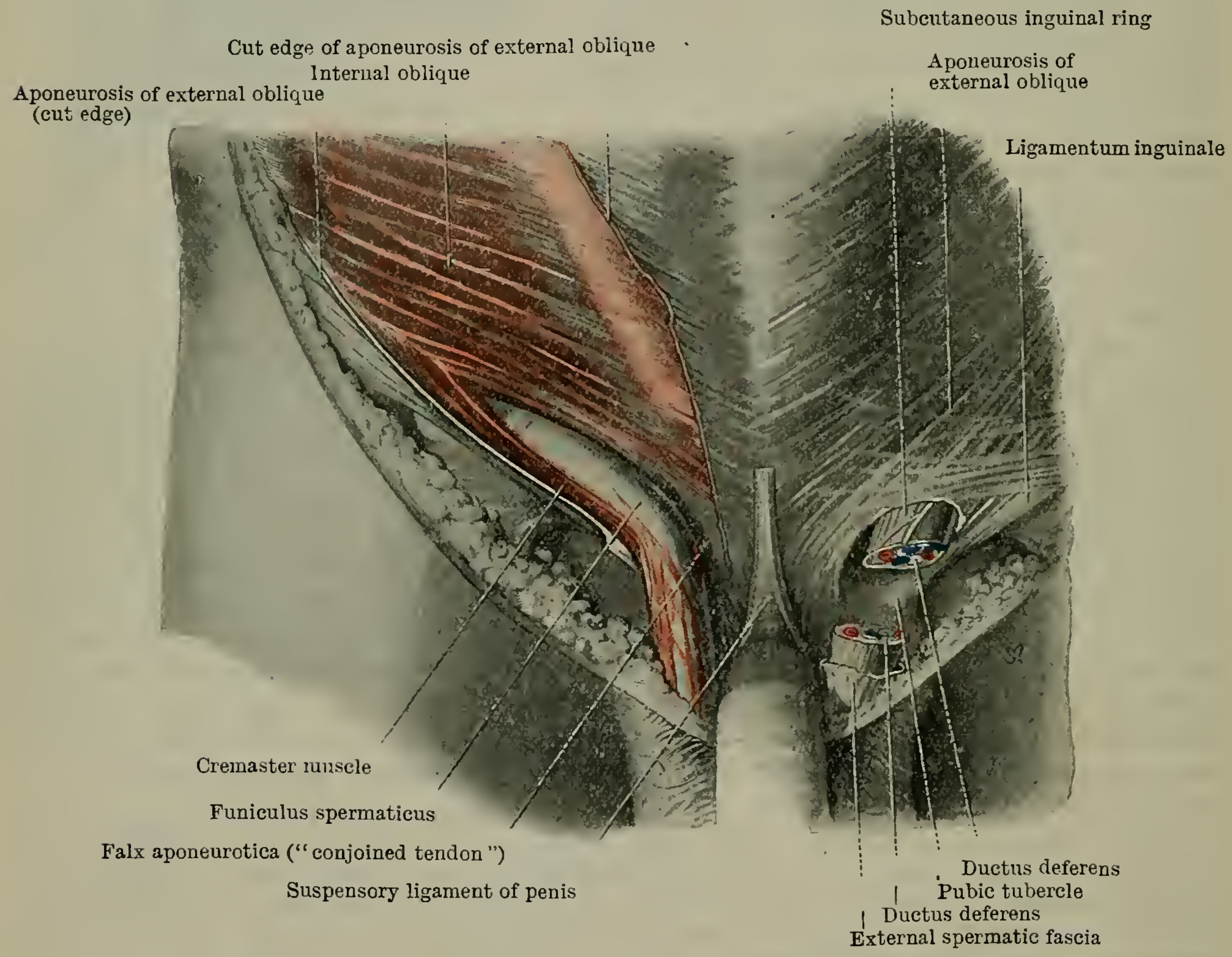

Subcutaneous inguinal ring
Cut edge of aponeurosis of external oblique
Internal oblique
Aponeurosis of external oblique
Aponeurosis of external oblique (cut edge)
Ligamentum inguinale
Cremaster muscle
Funiculus spermaticus
Falx aponeurotica ("conjoined tendon")
Suspensory ligament of penis
Ductus deferens
Pubic tubercle
Ductus deferens
External spermatic fascia

FIG. 991.—DISSECTION TO SHOW THE FUNICULUS SPERMATICUS AS IT ISSUES FROM THE SUBCUTANEOUS INGUINAL RING. On the right-hand side of the figure the funiculus has been cut across, and the structures composing it are seen in section. On the left-hand side of the figure the external oblique muscle has been removed (A. M. Patterson).

The scrotum in the fœtus contains no cavity, but, like the labia majora in the female, it is composed entirely of vascular connective tissue.

The scrotum receives its **vascular supply** on each side from the posterior scrotal branches of the internal pudendal artery, which reach it from behind, and from the external pudendal branches of the femoral artery, which reach its upper and anterior part.

The **nerves** of the scrotum are derived on each side from the posterior scrotal branches of the pudendal nerve, from the perineal branch of the posterior cutaneous nerve of the thigh, and from the ilio-inguinal nerve. The branches from the pudendal and posterior cutaneous nerves reach the scrotum from behind, while the ilio-inguinal supplies its upper and anterior part. The nerve fibres for the dartos muscle fibres are believed to have their origin from the hypogastric plexus.

PENIS.

The **penis** is composed chiefly of erectile tissue, and is traversed by the canal of the urethra. The surface nearest to which the canal of the urethra lies is called the **urethral surface**; the opposite and more extensive aspect is the **dorsum penis**. The erectile tissue is for the most part disposed in three longitudinal columns, which in the body of the organ are placed side by side, while at the root of the penis they separate from one another, and become attached to the inferior fascia of the uro-genital diaphragm and to the pubic arch. Two of these masses of erectile tissue, placed one on each side of the median plane, and forming the dorsum and sides of the penis, are called the **corpora cavernosa penis**, while the third, which is situated in the median plane near the urethral surface, is called the **corpus cavernosum urethræ**. The corpus cavernosum urethræ is the part of the penis which is traversed by the urethra, and it is considerably smaller than the corpora cavernosa penis, which form the chief bulk of the organ (Fig. 992).

In the **body of the penis**, each corpus cavernosum penis is placed close to the median plane, and presents a rounded surface, except where it is flattened by contact with its fellow of the opposite side. The corpora cavernosa penis are separated on the dorsal surface by a shallow groove, and on the urethral aspect by a deeper and wider furrow, in which lies the corpus cavernosum urethræ (Fig. 993). Towards the distal end of the penis the corpus cavernosum urethræ appears to expand, and, spreading towards the dorsal surface of the organ, it forms a kind of conical cap, the **glans penis**, which covers over the blunt rounded termination of the corpora cavernosa penis. The prominent margin of the glans, called the **corona glandis**, projects dorsally and laterally beyond the extremities of the corpora cavernosa penis. The glans is traversed by the terminal part of the urethra, which ends near the summit of the glans in a slit-like opening, the **external urethral orifice**. The united corpora cavernosa penis end in a blunt conical extremity, the apex of which is received into a hollow in the base of the glans. The skin covering the body of the penis is thin, delicate, and freely movable, and, except near the root of the organ, is free from hairs; on the urethral aspect of the penis the skin is marked by a median raphe, continuous with the raphe of the scrotum. Traced towards the base of the glans, the skin forms a free fold called the **præputium**, or prepuce, which overlaps the glans to a variable extent. From the deep surface of the prepuce the skin is reflected on to the terminal part of the penis, along a line just proximal to the corona glandis, and is continued over the entire glans to the external urethral orifice. A small median fold, the **frenulum præputii**, passes to the deep surface of the prepuce from a point immediately below the external urethral orifice. The skin covering the glans is firmly attached to the underlying erectile tissue, and here, as well as on the deep surface of the prepuce, it presents some resemblance to mucous membrane.

The secretion, known as the **smegma præputii**, which tends to collect beneath the prepuce has its source in the desquamated and broken-down epithelial cells derived from the surface of the glans and prepuce.

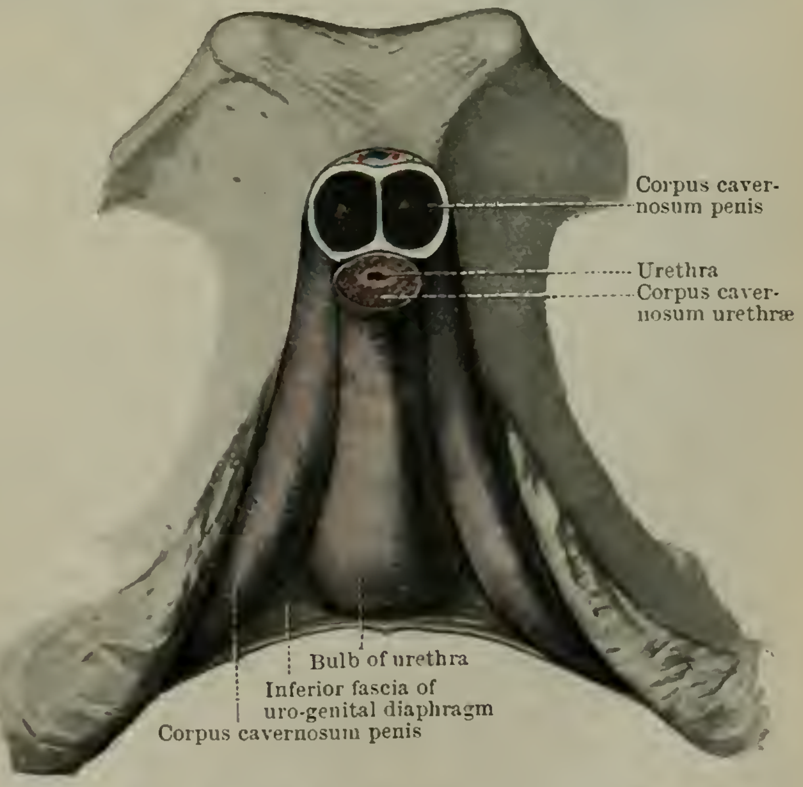


Fig. 992.—Structures composing the Radix Penis.
The corpus penis is seen in section.

At the **root of the penis** the three component parts of the organ separate from one another (Fig. 992). The corpora cavernosa penis, diverging laterally, at first become somewhat swollen, and then, gradually tapering, gain a firm, fibrous attachment to the periosteum on the medial surface of the pubic arch. These diverging parts of the corpora cavernosa are called the **crura penis**, and each is covered by the corresponding ischio-cavernosus muscle. The corpus cavernosum urethræ lying between the crura becomes enlarged, and forms a somewhat spherical mass which receives the name **bulbus urethræ**. The bulb varies much in size in different individuals, and is attached to the under surface of the inferior fascia of the uro-genital diaphragm, against which it rests. The posterior part and under surface of the bulb usually show a median notch or groove—an indication that the bulb is originally composed of two symmetrical portions, which during development have become fused in the median plane. These two portions are best seen in subjects whose tissues have been hardened by intravascular injection. A slightly marked median septum, situated within the bulb tissue, indicates on a deeper plane the line along which fusion has taken place. The canal of the urethra, piercing the inferior fascia of the uro-genital diaphragm, enters the bulb obliquely a short distance in front of its posterior extremity (Fig. 995). Covering the superficial surface of the bulb is the bulbo-cavernosus muscle.

A somewhat triangular band of strong fibrous tissue, called the **suspensory ligament of the penis**, is attached to the front of the symphysis pubis, and extends to the fibrous capsule of the penis, with which it becomes continuous (Fig. 991).

Structure of the Penis.—Each corpus cavernosum penis is enclosed by a dense white fibrous coat—**tunica albuginea**, which, fusing with the corresponding coat of the opposite side, forms the median **septum** of the penis. The septum is very incomplete, especially near the terminal part of the penis, where it is interrupted by a number of nearly parallel slit-like perforations; hence the term "septum pectiniforme" is often applied to it (Figs. 993 and 994). Through these openings the erectile tissue of the corpora cavernosa of opposite sides is continuous.

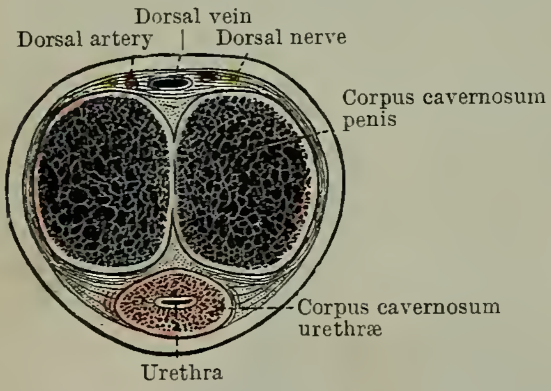


FIG. 993.—TRANSVERSE SECTION THROUGH THE BODY OF THE PENIS.

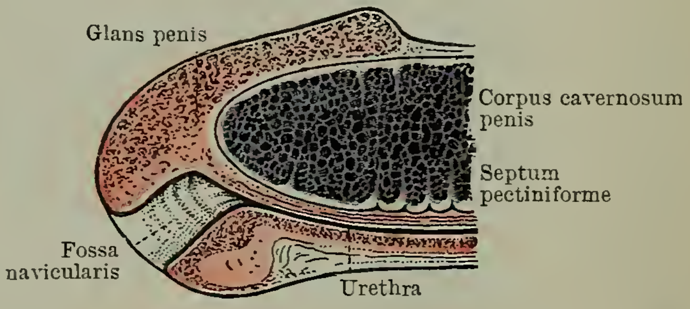


FIG. 994.—A LONGITUDINAL SECTION OF THE TERMINAL PORTION OF THE PENIS.

The fibrous coat contains some elastic fibres, and may be divided into an outer layer of longitudinally directed fibres and an inner layer of circular fibres, some of which latter are continued into the septum. Numerous fibrous strands, called **trabeculæ**, proceed from the deep surface of the tunica albuginea, and stretching across the interior of the corpus cavernosum, form a fine sponge-like framework whose interspaces communicate freely with one another, and are filled with blood. These blood-containing spaces lead directly into the veins of the penis, and, like the veins, have a lining of flat endothelial cells. The size of the penis varies with the amount of blood in this cavernous tissue. The structure of the corpus cavernosum urethræ resembles that of the corpora cavernosa penis, but the fibrous coat is much thinner and more elastic, and the trabeculæ are finer (Fig. 993).

The glans penis is also composed of cavernous tissue which communicates by a rich venous plexus with the corpus cavernosum urethræ. No strongly marked tunica albuginea is present, and the erectile tissue is practically bounded by the firmly adherent skin. Surrounding the urethra, which in this part of the penis is represented by a laterally compressed slit-like passage, is a mass of fibro-elastic tissue which forms a kind of median septum within the glans. This septum is continued backwards to join the sheath of the conical end of the corpora cavernosa, and ventrally it gives attachment to the frenulum of the prepuce. It imperfectly divides the erectile tissue of the glans into right and left portions, which, however, freely communicate dorsally. From the septum, trabeculæ pass out in all directions into the tissue of the glans.

Loosely surrounding the corpora cavernosa penis and the corpus cavernosum urethræ is a fibrous sheath containing numerous elastic tissue fibres. This sheath is termed the *fascia penis*, and reaches as far as the base of the glans, where it becomes fixed to the floor of the groove limited by the corona of the glans. In its proximal part the sheath gives insertion to many of the fibres of the bulbo-cavernosus and ischio-cavernosus muscles.

Superficial to the fascia penis is a layer of extremely lax areolar tissue, and more superficial still is a prolongation of the dartos tunic of the scrotum, covered by the delicate skin of the penis. Numerous sebaceous glands are present in the skin, especially on the urethral aspect of the penis.

In some mammals, such as the walrus, dog, bear, and baboon, a bone called the **os penis** is developed in the septum which intervenes between the corpora cavernosa penis.

The penis receives its **arterial supply** from branches of the internal pudendal artery. The erectile tissue of the corpora cavernosa penis is supplied chiefly by the deep arteries of the penis, while that of the corpus cavernosum urethræ receives its arterial supply from the artery to the bulb. Branches of the dorsal artery of the penis piercing the fibrous coat of the corpora cavernosa penis furnish additional twigs to the erectile tissue of these structures. The glans receives its chief blood-supply from branches of the dorsal artery. The small branches of these arteries run in the trabeculæ of the erectile tissue, and the capillaries, into which they lead, open directly into the cavernous venous spaces. As they lie in the finer trabeculæ the smaller branches often present a peculiar twisted appearance, and hence the name **arteriæ helicinæ** is sometimes applied to them.

The **veins** with which the cavernous spaces communicate carry the blood, for the most part, either directly into the pudendal plexus, or into the dorsal vein and so to the pudendal plexus. The dorsal vein of the penis begins in tributaries from the glans and prepuce, and lies in the groove between the corpora cavernosa penis as it ascends to pass beneath the arcuate ligament of the pubis to join the pudendal plexus. On each side of it lies the dorsal artery, and still farther from the median plane lies the dorsal nerve (Fig. 993).

The **lymph-vessels** of the penis are arranged in a deep and superficial series, and end in the medial glands of the inguinal group of lymph-glands.

The **nerve-supply** of the penis is derived from the pudendal nerve (2nd, 3rd, and 4th sacral nerves), and from the hypogastric and pelvic plexuses. The branches of the pudendal are the dorsal nerve of the penis, and branches from the perineal nerves. These supply the cutaneous structures of the penis, while the sympathetic filaments from the hypogastric and pelvic plexuses, which reach the penis through the prostatic nerve plexus, end in the erectile tissue.

PROSTATA.

The **prostate** is a partly glandular, partly muscular organ of a dark brown-red colour which surrounds the beginning of the urethra in the male. It lies within the pelvis behind the symphysis pubis, and is enclosed by a dense sheath derived from the pelvic fascia. Through the various connexions of this sheath the prostate is firmly fixed within the pelvic cavity. The ejaculatory ducts traverse the prostate in their course downwards and forwards to join the urethra as it descends through the gland (Fig. 998). The size of the prostate varies considerably in different individuals, but its transverse, or longest, diameter is usually from one and a quarter to one and a half inches; its antero-posterior diameter about three-quarters of an inch; and its vertical diameter about one and a quarter inches. Superficially the prostate is separated from the bladder by deep wide lateral grooves directed downwards and forwards, and by a narrow posterior groove which is horizontal.

In connexion with the prostate we describe an apex which is directed downwards, a base looking upwards, a posterior, and two lateral surfaces. The general outline of the organ has been often compared with that of a Spanish chestnut. The upper surface, or *base of the prostate,* is directed upwards against the inferior aspect of the bladder, in the neighbourhood of its urethral opening. The greater part of this surface is structurally continuous with the bladder wall; only a narrow portion remains free on each side and forms the lower limit of the deep groove which marks the separation of the bladder and prostate (Fig. 971). The *lateral surfaces* of the prostate are convex and prominent, especially in their posterior and upper portions, and rest against the fascia covering the levatores ani muscles. They are directed for the most part laterally, downwards, and somewhat forwards, and meet together in front in a rounded anterior border, sometimes called the "anterior surface" of the prostate. Posteriorly the prostate presents a flattened somewhat triangular *posterior surface,* directed backwards and downwards against the anterior wall of the rectum, through which it may be felt in the living subject. This flattened posterior surface is separated on each side from the lateral surfaces by a rounded border which, beginning above at the prominent lateral part of the prostate, ends below at the apex of the organ. The apex of the prostate points downwards, and is in relation to the sphincter urethræ membranaceæ muscle, from which it is separated by the superior fascia of the uro-genital diaphragm. From the apex the rounded anterior border, which separates the lateral surfaces, passes upwards in the median plane behind the symphysis pubis and retro-pubic pad of fat. This border is interrupted in its lowest part by the passage of the urethra.

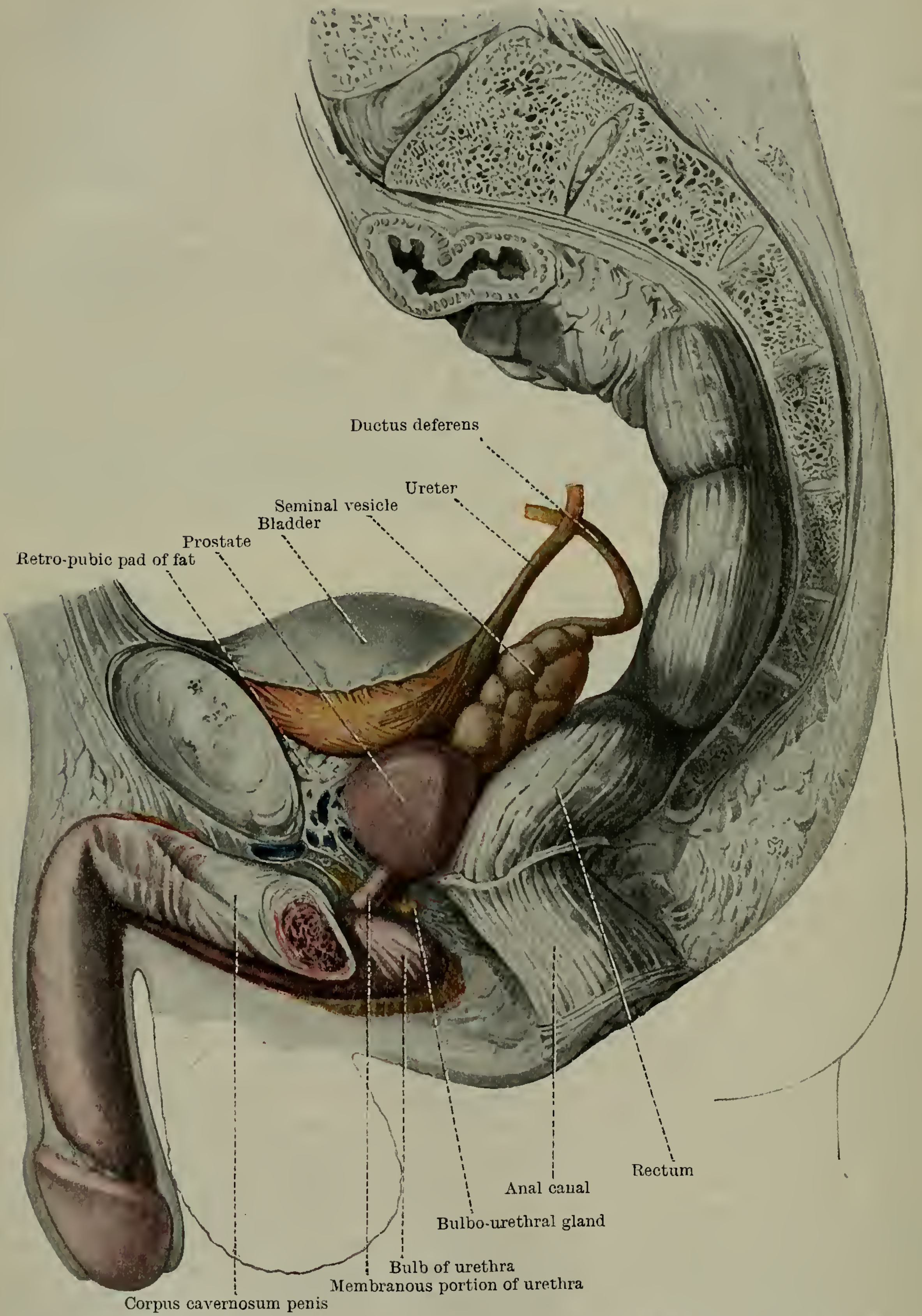


Fig. 995.—Dissection of the Male Pelvic Organs and of the Penis, from the Side
The dorsal vein of the penis and the pudendal venous plexus are coloured blue.

When the thick fibrous sheath formed by the pelvic fascia is stripped off the prostate the organ has a more rounded outline, and the surfaces just described are not so clearly defined. The anterior border may now appear to be rather a surface than a border, and the antero-posterior diameter of the whole organ is considerably reduced.

The urethra enters the prostate at a point near the middle of its upper surface or base, and leaves it at a point situated on its anterior border, just above and in front of the apex. As it descends, the urethra describes a curve which is concave forwards, and in median section it is seen to lie, on the whole, nearer to the posterior surface than to the anterior border of the gland.

The ejaculatory ducts, entering a slit-like interval, or hilum, situated just in front of the border which separates the base from the posterior surface of the prostate, run downwards, medially, and forwards, to open into the prostatic portion of the urethra very close to one another.

The somewhat wedge-shaped portion of the prostate, which lies between these ducts and the posterior aspect of the urethra, receives the name of *middle lobe* (Fig. 997). It projects upwards against the bladder, and is continuous with the part of the bladder wall lying immediately behind the urethral orifice. When hypertrophied, as it often is in old people, the middle lobe of the prostate may cause a considerable elevation in the cavity of the bladder, which possesses considerable surgical interest (p. 1265), and to which the term uvula vesicæ is applied.

The rest of the prostate is described as being composed of two large *lateral lobes*, which are, however, not marked off from one another superficially.

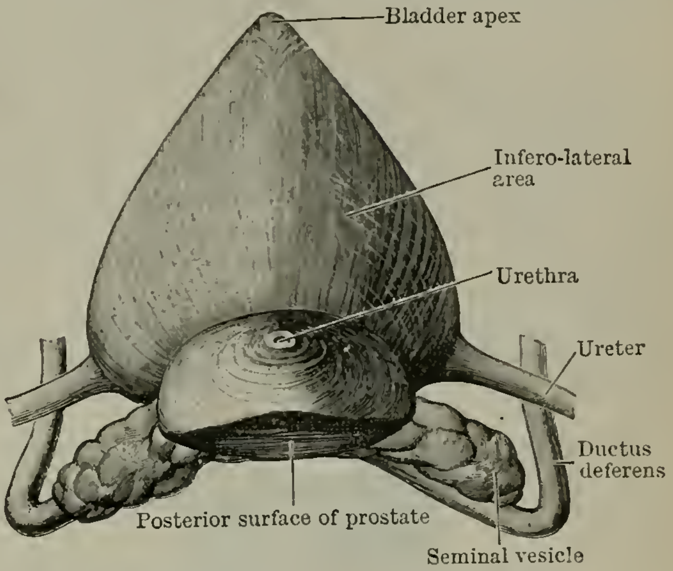


Fig. 996.—Prostate, Urinary Bladder, and Seminal Vesicles seen from below.

Drawn from a specimen hardened *in situ*. The lateral surfaces of the prostate are seen one on each side of the urethra and in front of the posterior surface.

In front of the prostate, between it and the pubis, is the rich venous pudendal plexus, in which the dorsal vein of the penis terminates. This plexus is continued backwards, on each side, round the lateral aspect of the prostate, and joins the large thin-walled veins which are collected for the most part in the deep sulcus between the bladder wall and the prostate, and form the prostatico-vesical plexus. Most of the veins forming this plexus lie partly within and partly outside the dense fibrous sheath of the prostate, which is derived from the pelvic fascia (Fig. 997).

Fibrous Sheath of the Prostate.—The sheath of the prostate is formed by the pelvic fascia, and closely invests the gland on its lateral and posterior aspects. Inferiorly at the apex of the prostate the sheath becomes continuous with the superior fascia of the uro-genital diaphragm, which lies above the sphincter urethræ membranaceæ muscle, and is attached to the pubic arch. In front two thickened bands pass forwards from the anterior aspect of the sheath, one on each side of the median plane, to reach the back of the lower part of the pubis, where they are attached to the periosteum. These constitute the pubo-prostatic ligaments, and contain smooth muscle fibres, as well as dense connective tissue. Some of the muscle fibres in connexion with the pubo-prostatic ligaments, passing upwards as well as backwards, gain the bladder wall, and are spoken of as the pubo-vesical muscles. Between the right and left pubo-prostatic ligaments there is a shallow fossa, or depression, the floor of which is formed by a thin layer of fascia connecting the anterior aspect of the sheath of the prostate with the back of the pubis. This layer forms a part of the wall of the retro-pubic space which lies in front of the prostate and below the bladder (Fig. 995). Below the pubo-prostatic ligaments the medial edges of the levatores ani muscles pass medially and almost meet together in front of the apex of the prostate. When followed backwards, the medial edges of these muscles are seen to embrace the apex of the prostate.

On each side the lateral aspect of the sheath of the prostate is continuous with the strong fascia which covers the pelvic surface of the levator ani muscle. When the fibrous sheath of the prostate is traced upwards beyond the level of the upper margin of the gland it becomes thinned out and disappears. Posteriorly the upward prolongation of the sheath is continuous with the fascial layers which enclose the ampullæ of the deferent ducts and the seminal vesicles, and it is adherent to the peritoneum of the recto-vesical pouch. In this position it is often spoken of as the recto-vesical fascia.

Structure of the Prostate.—Beneath the fibrous sheath of the gland the superficial part of the prostate is seen to be largely composed of matted interlacing bundles of smooth muscle and connective tissue fibres, which form a kind of capsule for the deeper parts of the organ. This **capsule** is not sharply defined, but from its deep aspect fibrous and muscular strands pass inwards, converging towards the posterior wall of the urethra, to become continuous with the mass of smooth muscular tissue which surrounds this canal as it traverses the prostate. The somewhat radially arranged strands divide the prostate into a number of incompletely defined lobules, of which there appear to be about fifty. The yellowish-coloured glandular tissue which forms the lobules is composed of minute, slightly branched tubules, the walls of which in certain places show numerous saccular dilatations. In the upper portion of the gland the tubules are slightly dilated and shorter than in the lower part, where they are longer and more convoluted. The glandular tubules lead into the minute prostatic ducts, which open into the urethral canal as it traverses the prostate. The **prostatic ducts** number about twenty or thirty, and open for the most part into a groove, the **prostatic sinus**, on each side of the median elevation, or **crista urethralis**, in the posterior wall of the urethra (Fig. 999).

The bulk of the glandular tissue is situated at the sides of and behind the urethra. In front of the upper part of the prostatic portion of the urethra there is a mass of smooth muscular fibres, which is continued upwards and backwards on the sides of the urethra to form a part of the "sphincter vesicæ." At a lower level striped muscular tissue, which is continuous with the deep part of the sphincter urethræ membranaceæ muscle, occupies a position in front of the urethral canal.

The muscular tissue of the prostate is to be regarded as the thickened muscular layer of the wall of the urethra, broken up and invaded by the prostatic glands which arise and are developed from the lining layer of the canal during embryonic life.

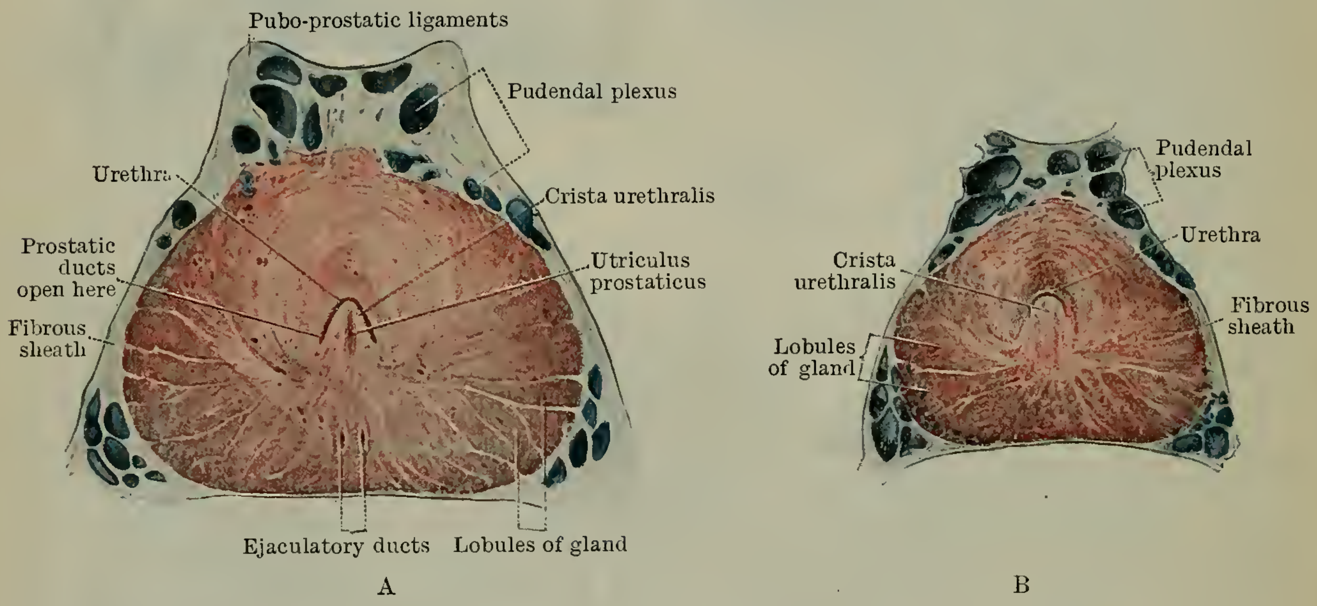


FIG. 997, A and B.—HORIZONTAL SECTIONS THROUGH THE PROSTATE. Section A lies at a higher level than B.

In old age the prostate frequently undergoes a hypertrophy, which may affect chiefly the glandular tissue, or the entire organ. Not infrequently calcareous concretions are found embedded in the prostate.

The prostate receives its **arterial supply** from branches of the hæmorrhoidal and inferior vesical arteries, while the large plexus of **veins**—the pudendal plexus—which surrounds it, and into which the veins of the penis open, communicates with the vesical plexus, and drains into the hypogastric veins. In old people the veins of the prostate usually become much enlarged.

The **nerves** of the prostate are derived from the pelvic plexus.

GLANDULÆ BULBO-URETHRALES.

The **bulbo-urethral** or **Cowper's glands** are a pair of small bodies placed in relation to the second, or membranous, part of the urethra. They are each about the size of a pea, and are of a yellowish-brown colour. Situated in the space between the two fasciæ of the uro-genital diaphragm, they lie below the level of the apex of the prostate, and above that of the bulbus urethræ (Figs. 995 and 999). Each gland is made up of a number of closely applied lobes or lobules, and is of the compound racemose type. The ductules of the gland unite to form a single **excretory duct**, which pierces the bulbus urethræ, and, after a relatively long course, ends by opening into the cavernous portion of the urethra by a minute aperture. The secreting acini are lined with columnar epithelium.

The glands receive their arterial supply from the artery to the bulb.

In old age these glands are often difficult to find without a microscopic examination

URETHRA VIRILIS.

The **urethra** in the male is a channel of about eight inches in length leading from the bladder to the external urethral orifice at the extremity of the glans penis. The canal serves not only for the passage of urine, but it also affords an exit for the seminal products, which enter by the ejaculatory ducts, and for the secretion of the prostatic and bulbo-urethral glands. In addition, numerous minute **urethral glands** pour their secretion into the urethra.

As it passes from the internal urethral orifice to its external opening, the urethra describes a somewhat ∽ shaped course, and it is customary to divide it into certain sections, which have received distinctive names. The first part of the urethra lies within the pelvic cavity, and has a somewhat vertical course as it traverses the prostate. Turning more forwards, the urethra passes below the pubic arch, and pierces the fibrous layers which form the pelvic wall in this region. Leaving the pelvis minor, the canal enters the bulbus urethræ, where the latter is attached to the inferior fascia of the uro-genital diaphragm, and throughout the rest of its course it lies in the erectile tissue of the corpus cavernosum urethræ and of the glans penis. The part of the urethra which lies embedded in the prostate is called the **pars prostatica**; the short part which pierces the pelvic wall is called the **pars membranacea**, and the part surrounded by the corpus cavernosum urethræ receives the name of **pars cavernosa**. Of these three sections of the urethra the cavernous portion is much the longest, and the membranous is the shortest.

The **prostatic part** of the male urethra descends through the prostate from the base towards the apex, describing a slight curve which is concave forwards. It is about one inch in length, and is narrower above and below than in its middle portion, which is, indeed, the widest part of the whole urethral canal. Except while fluid is passing, the canal is contracted, and the mucous membrane of the anterior and posterior walls is in contact, and thrown into a series of longitudinal folds. When distended, the middle, or widest part of the canal, may normally have a diameter of about one-third of an inch. The posterior wall, often termed the "floor" of the prostatic urethra, presents a distinct median ridge or elevation called the **crista urethralis** (Fig. 999). This projects forwards into the urethra to such an extent that the canal in transverse section presents a somewhat crescentic outline (Fig. 997). The groove on each side of the crista urethralis is known as the **prostatic sinus**, and into it the numerous ducts of the prostatic glands open by minute apertures. Some few ducts from the middle part of the gland open nearer the median plane, on the sides of the urethral crest. On the summit of the crista urethralis is a small slit-like opening which leads backwards and upwards for a distance of about a quarter of an inch, as a blind pouch, in the substance of the prostate. This little cavity is known as the **prostatic utricle**, and represents the fused caudal ends of the Müllerian ducts, from which the uterus and vagina of the female are developed. On each side of the mouth of the utricle is the much more minute opening of the ejaculatory duct. When traced upwards towards the bladder, the urethral crest, diminishing in height, becomes indistinct, but it can often be traced as a slight median ridge as far as the uvula vesicæ. When followed in the opposite direction the ridge becomes less marked, and can be followed on the urethral wall into the membranous portion of the canal, where it divides into a pair of inconspicuous folds or elevations, which gradually fade out into the urethral wall (Fig. 999).

The curvature and, to a less degree, the length of the prostatic urethra depends upon the amount of distension of the bladder and of the rectum (compare Figs. 967 and 968).

The second or **membranous portion** of the urethra leads downwards and forwards from the apex of the prostate to the bulbus urethræ, and is the shortest and narrowest of the three subdivisions of the canal, its length being somewhat less than half an inch. It begins at the superior fascia of the uro-genital diaphragm, a layer of pelvic fascia which lies above the sphincter urethræ membranaceæ muscle. Here it is continuous with the prostatic portion of the urethra. It ends, having pierced the inferior fascia of the uro-genital diaphragm, by becoming continuous with the cavernous portion of the urethra. Placed in front of the anal canal, it lies about one inch behind and below the arcuate ligament of the pubis. It is surrounded by fibres of the sphincter urethræ membranaceæ muscle, and behind it, on each side of the median plane, lies the bulbo-urethral gland. The posterior part of the bulbus urethræ projects backwards and overlaps the posterior wall of the membranous part of the urethra to a considerable extent (Fig. 995).

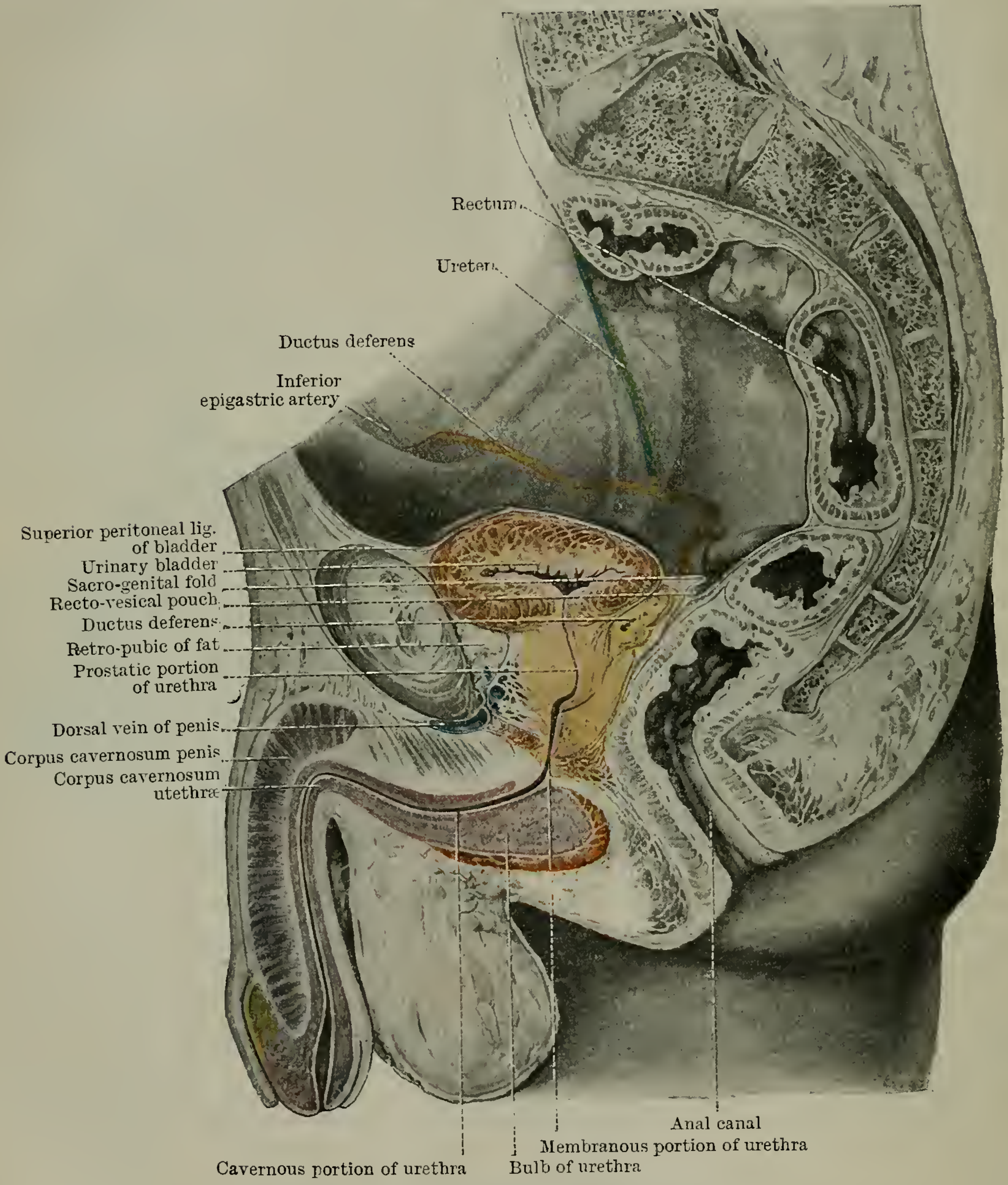


FIG. 998.—ADULT MALE PELVIS IN MEDIAN SECTION.

The urinary bladder is empty and firmly contracted. The urethra is opened up in its entire length.

The membranous portion of the urethra is the most firmly fixed and, excepting the external urethral orifice, least dilatable part of the passage.

A slight medial elevation, which is continuous above with the crista urethralis, projects into the canal from its posterior wall, and, becoming less marked as it is traced downwards, is often seen to divide into two faint ridges. When the canal is empty other longitudinal folds or ridges are usually to be seen on the mucous membrane, but these become obliterated when the passage is distended. The lumen of the empty tube, in transverse section, presents a stellate outline.

It is important to note that the end of the membranous portion of the urethra, where it is overlapped by the urethral bulb, lies in front of the uro-genital diaphragm. It is considerably wider than the upper part of this subdivision of the canal, and is very thin-walled. This is the part of the canal which is most liable to rupture (Figs. 995 and 999).

The third, or **cavernous portion**, of the urethra is much the longest of the three subdivisions. It begins at a point about half an inch in front of the posterior end of the bulbus urethræ, and ends at the external urethral orifice on the glans penis. Its proximal, or perineal, portion has a fixed position and direction, while its distal part varies with the position of the penis. The canal is about six inches in length, and is related throughout its whole extent to the erectile tissue of the corpus cavernosum urethræ and of the glans penis. Directed at first forwards through the bulbus urethræ, the canal turns downwards and forwards at the point where it comes to lie in front of the lower part of the symphysis pubis (Fig. 998). This bend in the direction of the canal, roughly speaking, corresponds to the place of attachment of the suspensory ligament to the dorsum of the penis. When the penis is drawn upwards towards the front of the abdomen, the direction of the terminal half of the canal is, of course, changed, and at the same time the whole length of this subdivision of the urethra becomes more uniformly curved.

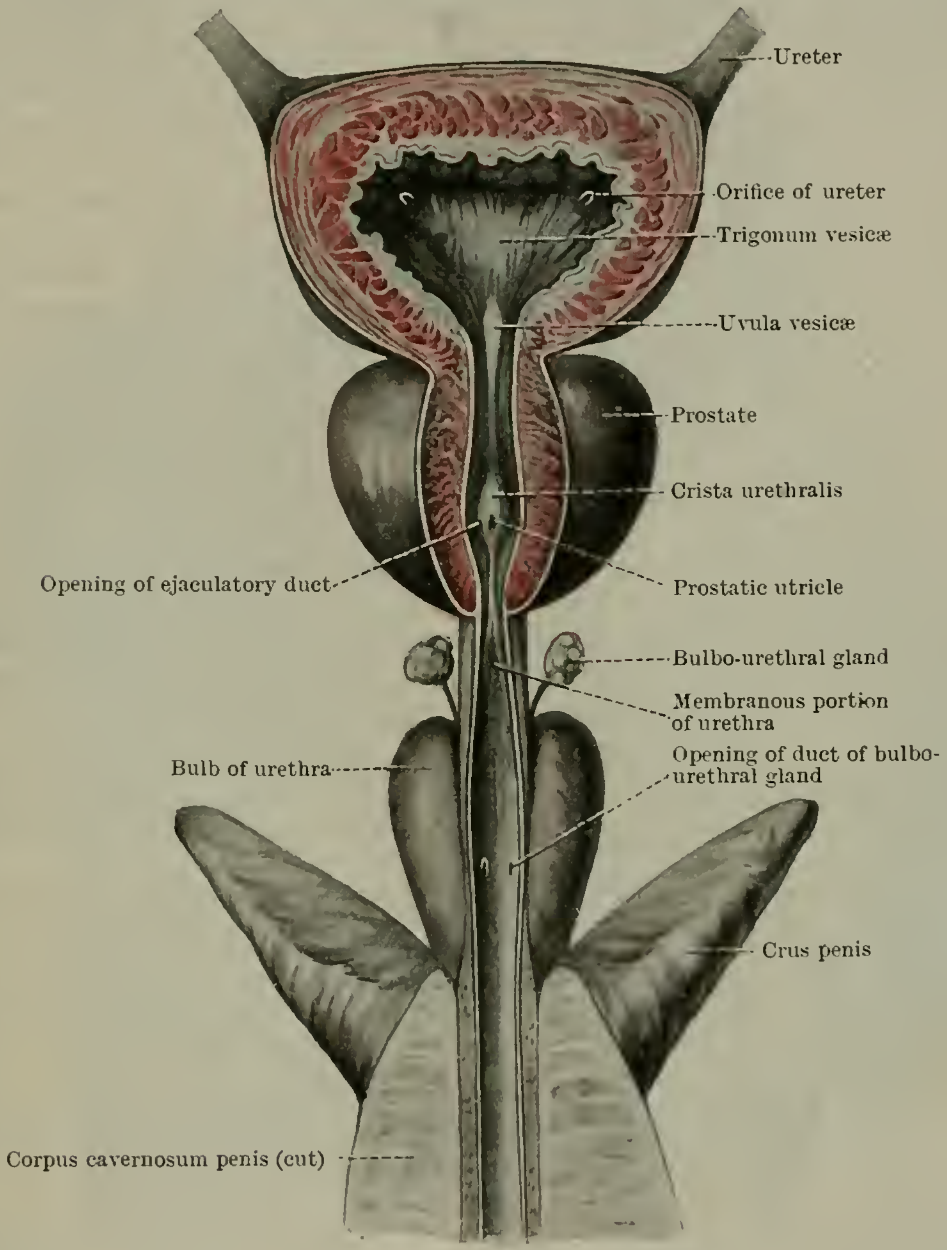


Fig. 999.—Dissection showing the Trigonum Vesicæ and the Posterior Wall or Floor of the Urethra in its Prostatic, Membranous, and the Proximal Part of its Cavernous Subdivisions.

The canal has been opened up by removing its anterior and upper wall.

The urethra passing obliquely downwards and forwards enters the bulb at a point nearly half an inch from its posterior extremity. Immediately after the canal has pierced the inferior fascia of the uro-genital diaphragm its posterior aspect comes into relation with the erectile tissue of the bulb, but the anterior wall remains uncovered for a distance of about a quarter of an inch (Fig. 998). The wall of the urethra is here very thin, and the passage is more readily dilatable than in other parts. In this region the urethral wall may readily be torn through, if undue force is used, or if the handle of an instrument is depressed too soon when attempting to pass it into the narrower more fixed part of the canal. The urethra lies at first in the upper part of the erectile tissue, but as it passes forwards it sinks deeper, and comes to occupy the middle part of the corpus cavernosum urethræ (Fig. 998). In the glans, on the other hand, the erectile tissue lies on the dorsal and lateral aspects of the urethra. Like the other parts of the urethral passage, the cavernous portion is closed except during the passage of fluid, the closure being effected by the apposition of its dorsal and ventral walls except in the portion of the canal which lies in the glans penis, where the side walls of the canal come into contact. Thus the lumen of the first part of the canal, when empty, is represented in cross section by a transverse slit, and that of the terminal part by a vertical slit (Fig. 994). The cavernous part of the urethra does not present a uniform calibre throughout, but is narrower in its intermediate part, where it traverses the corpus cavernosum urethræ, than it is in those portions of its course which are surrounded by the bulb and the glans. The terminal dilated part of the passage is termed the **fossa navicularis urethræ,** and opens on the surface by the vertically placed slit-like **external urethral orifice,** which is the narrowest and least dilatable part of the whole urethral canal.

The ducts of the bulbo-urethral glands open by very minute apertures in the inferior wall of the proximal part of the cavernous portion of the urethra. Before opening into the canal, they lie for some distance immediately beneath its mucous membrane. A number of little pit-like recesses, called the **urethral lacunæ,** also open into the cavernous part of the urethra, and are so disposed that their openings lead for the most part obliquely into the canal in the direction of its external orifice.

In some cases a valve-like fold of the mucous membrane is found in the upper wall of the urethra in the region of the fossa navicularis. The free edge of this fold is directed towards the external urethral orifice, and may engage the point of a fine instrument introduced into the urethra.

Structure.—The mucous membrane of the urethra contains numerous elastic fibres and varies in thickness in different parts of the canal. In many positions it shows distinct longitudinal folds and also minute depressions or pits—the urethral lacunæ already mentioned. The lining epithelium is composed of many layers of cells, and is continuous through the internal urethral orifice with the epithelium of the bladder, which at first it closely resembles. In the region of the fossa navicularis the lining cells, which throughout the cavernous portion of the canal are of a columnar type, become flat and scaly.

Numerous minute glands—**urethral glands**—open into the urethra. These are most plentiful in the upper, or anterior, wall, but they also occur in smaller numbers in the floor and side walls. They are most numerous in the anterior half of the cavernous portion of the canal, and in the membranous subdivision of the urethra.

The larger glands are deeply placed beneath the mucous coat, and communicate with the urethra by long slender obliquely placed branched ducts. The smaller glands lie in the mucous coat and form flask-like depressions with very short ducts. The ducts of some of the glands open into the lacunæ, but many of the latter have no connexion with the urethral glands.

Frequently two or more elongated ducts belonging to some of the larger glands open into the urethra quite close to its termination. These are sometimes spoken of as *para-urethral ducts,* and may be traced backwards for some distance beneath the mucous membrane forming the roof of the urethra. Morphologically they do not correspond to the ducts which have in the female received the same name.

The muscular wall in the upper part of the urethra consists of smooth muscle fibres directed for the most part longitudinally, but some circularly arranged fibres are also present. It is probable that throughout the greater part of the cavernous urethra a muscular coat is not represented.

Round the beginning of the urethra there is an obliquely placed band of circularly arranged smooth muscle fibres, which is continued downwards and forwards from below the anterior part of the trigone of the bladder. The lower and anterior fibres of this band lie in the anterior wall of the upper part of the prostatic urethra. The band is sometimes spoken of as the sphincter vesicæ internus. At a lower level, in front of the prostatic urethra, is a band of striped muscular fibres which is continuous inferiorly with the inner circularly disposed part of the sphincter urethræ membranaceæ.

Like the latter it is probably to be regarded as a part of a primitive voluntary uro-genital sphincter muscle, such as is represented also in the female subject.

THE FEMALE REPRODUCTIVE ORGANS.

The reproductive glands in the female are a pair of **ovaries** placed one on each side of the cavity of the pelvis. In connexion with each ovary is an elongated passage or tube—the **uterine** or **Fallopian tube**—which leads to the uterus and opens into its cavity. There is no direct continuity between the ovary and the uterine tube, such as exists between the other glands of the body and their ducts, but the ova, when shed from the ovary, pass into the open end of the tube, and are thus conducted to the uterine cavity. The **uterus** is a hollow muscular organ which occupies a nearly median position in the pelvis. It is joined by the uterine tubes above, and communicates with the upper part of the vagina below. The ovum, having passed through the tube, reaches the cavity of the uterus, and in it, if fertilisation has taken place, the ovum undergoes its development into the embryo and fœtus. The **vagina** is the passage which leads from the uterus to the exterior, and has its external opening behind that of the urethra, within the **rima pudendi** or uro-genital cleft. In connexion with the uro-genital cleft are a number of structures which are included under the term *external genital organs,* and which represent in the female the various parts of the penis and scrotum in the male. These are the **labia majora** and the **mons pubis,** the **labia minora,** the **clitoris,** and the **bulbus vestibuli.** The **larger vestibular glands,** placed one on each side of the lower part of the vagina, are accessory organs of the female reproductive system, and represent the bulbo-urethral glands in the male.

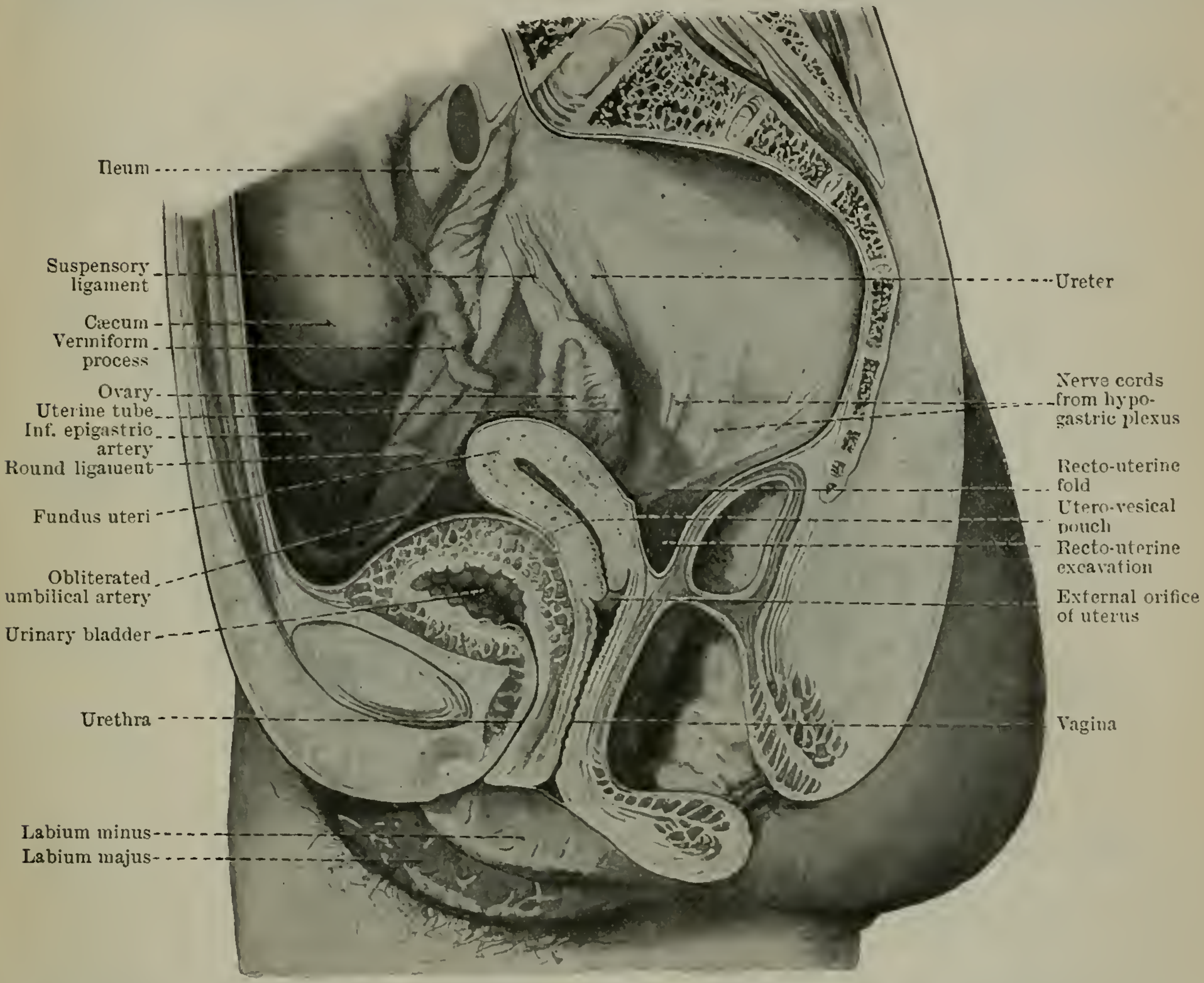


FIG. 1000.—MEDIAN SECTION THROUGH THE FEMALE PELVIS.
Drawn for the most part from a model made from a dissection by Professor Edward H. Taylor.

OVARIUM.

The **ovary** is a solid body, flattened from side to side, and about the size and shape of a large almond. Its length is usually between one and one and a half inches, and the thickness from side to side between a quarter and half an inch. In the adult the ovary is placed against the side wall of the pelvic cavity, and is connected by peritoneal folds with the broad ligament of the uterus and with the side wall of the pelvis. The position occupied by the ovary within the pelvic cavity is fairly constant, although these peritoneal ligaments do not hold the organ firmly fixed in any definite place.

In the ovary we recognise two extremities — a *superior*, larger, and more rounded, and an *inferior*, somewhat pointed. The term **tubal extremity** is applied to the superior end of the ovary, as it is most intimately connected with the uterine tube; the term **uterine extremity** is used with reference to the inferior extremity, since this part of the ovary is connected with the uterus by a fibrous cord, termed the **ligament of the ovary**. The flattened **surfaces** of the ovary are called **medial** and **lateral**, and the *borders* separating them the **mesovarian border**, and the **free border**. The free border is convex; while the mesovarian border, which is straighter and narrower, is connected by a very short peritoneal fold, the mesovarium, with the posterior layer of the broad ligament of the uterus. The vessels and nerves enter the ovary at this mesovarian border, which is therefore often termed the **hilum** of the ovary.

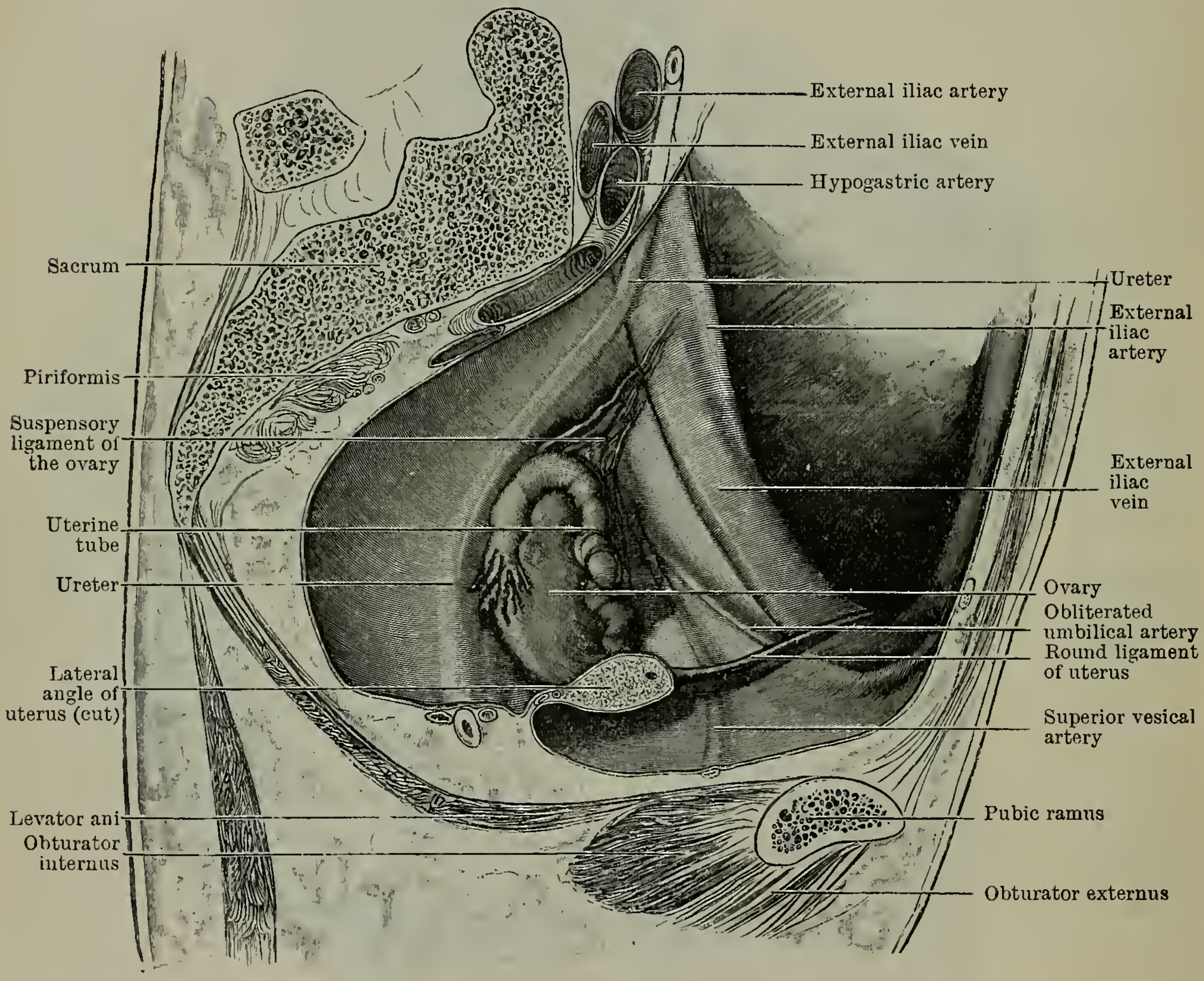


Fig. 1001.—Side Wall of the Female Pelvis, showing the position of the ovary and its relation to the uterine tube. The pelvis has been cut in section parallel to, but at some distance from, the median plane.

Position and Relations of the Ovary.—When the ovary occupies its most usual, or typical, position the long axis of the gland is vertical. Its lateral surface lies against the wall of the pelvis, and its medial surface looks into the pelvic cavity. The peritoneum of the pelvic wall, where the ovary lies against it, is depressed to form a little fossa termed the *fossa ovarii*, within which the ovary is placed. Beneath the peritoneum forming the floor of this fossa are the obturator nerve and vessels. The tubal extremity of the ovary lies below the level of the external iliac vessels, and its uterine extremity is placed just above the level of the peritoneum covering the pelvic floor. The fossa ovarii, in which the ovary lies, extends as far forwards as the obliterated umbilical artery, and backwards as far as the ureter and uterine vessels. Thus the mesovarian border of the ovary lies just behind the line of the obliterated umbilical artery, and the free border is on a plane anterior to that of the ureter (Fig. 1001). The medial surface of the ovary is almost completely covered by the uterine tube, which, passing upwards on it near its mesovarian border, arches over the tubal extremity, and then turns downwards in relation to the free border and posterior part of the medial surface (Fig. 1001).

In some cases the ovary is found to lie behind, or more rarely in front of, the fossa described above, and its long axis may be oblique instead of vertical. The description given corresponds to the typical position of the organ in women who have not borne children. When the uterus is much inclined towards the right side of the body the left ovary has its long axis directed obliquely downwards and medially, the right gland remaining vertical.

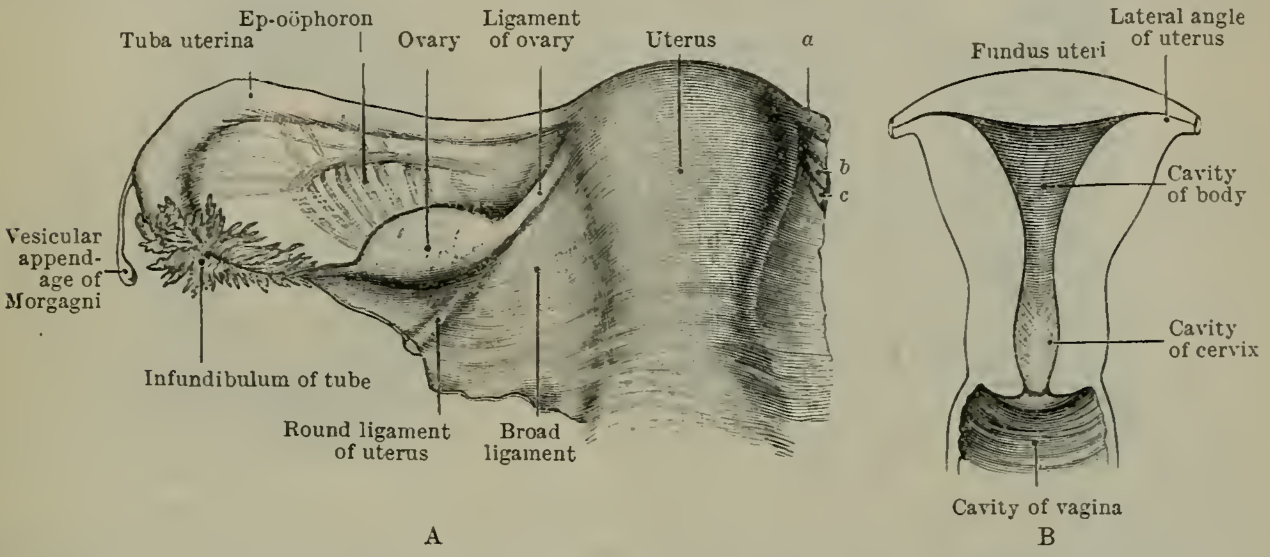


FIG. 1002.—A, THE POSTERIOR ASPECT OF THE UTERUS AND BROAD LIGAMENT (the broad ligament has been spread out).

a, *b*, and *c*, the isthmus tubæ, the ligament of the ovary, and the round ligament of the right side cut short.

B, DIAGRAMMATIC REPRESENTATION OF THE UTERINE CAVITY OPENED UP FROM ITS ANTERIOR ASPECT.

Connexions of the Ovary.—When the ovary is in position a small somewhat triangular peritoneal fold passes upwards from its tubal extremity, and becomes lost in the peritoneum covering the external iliac vessels and the psoas major muscle (Fig. 1001). This fold has received the name of **suspensory ligament of the ovary**, and is a portion of the superior and lateral part of the broad ligament of the uterus, which here contains between its two layers the ovarian vessels and nerves as they pass down into the pelvis to reach the hilum of the ovary. The vessels and nerves entering the ovary along its mesovarian border are enclosed in a sheath of peritoneum derived from the posterior layer of the broad ligament. In this way the ovary is connected along the whole length of its anterior border by a very short mesentery, or **mesovarium**, to the posterior aspect of the broad ligament (Fig. 1002). The uterine extremity of the ovary is connected with the lateral angle of the uterus by a ligament called the **ligamentum ovarii proprium** or *ligament of the ovary*. This has the form of a rounded cord enclosed between the peritoneal folds of the broad ligament, and is attached to the uterus, behind and below the point of entrance of the uterine tube. It is composed chiefly of smooth muscle fibres continuous with those of the uterus. The tubal extremity of the ovary is directly connected with one of the largest of the fimbriæ surrounding the abdominal end of the uterine tube, which receives the name **ovarian fimbria** (Fig. 1002).

Descent of the Ovary.—Like the testes, the ovaries at first lie in the abdominal cavity, and only later assume a lower position. At birth the ovary lies partly in the abdominal, and partly in the pelvic cavity; soon, however, it takes up a position entirely within the pelvis minor. As in the male, a gubernaculum is present in the early stages of development. The ligament of the ovary represents the upper part of the gubernaculum which is developed within the plica testis inferior in the male, and the round ligament of the uterus represents the inferior part, which is formed within the plica inguinalis (see p. 1280). It is a rare abnormality for the ovary, instead of entering the pelvis, to take a course similar to that of the testis, and pass through the inguinal canal into the tissue of the labium majus.

Structure of the Ovary.—The ovary is for the most part composed of a connective tissue, called the **stroma of the ovary**, richly supplied by blood-vessels and nerves. The stroma contains very numerous spindle-shaped connective tissue fibres, and some elastic tissue. The surface of the ovary is covered by a layer of epithelium, which is composed of columnar cubical cells, and is continuous with the flat-celled epithelium of the peritoneum forming the mesovarium. The ovarian epithelium is a persistent portion of the germinal epithelium of the embryo which covers the genital ridges, and from which the oöcytes and other cells of the ovarian follicles are derived. The position in which it becomes continuous with the peritoneum can usually be distinguished as a fine white line near the hilum of the ovary. Shining through the epithelium of the fresh ovary (except in old age) are usually to be seen a variable number of small vesicles—the **vesicular ovarian follicles**, in which the egg cells or oöcytes are contained. The number of follicles visible, and also the size which each follicle reaches before it ruptures and sheds its contents, is by no means constant. When a follicle ruptures and discharges the oöcyte its walls at first collapse, but later the cavity becomes filled with extravasated blood and cellular tissue of a yellowish colour. The resulting structure, called a **corpus luteum**, slowly degenerates unless impregnation has taken place, in which case it develops and becomes larger during pregnancy. As it atrophies the cells of the corpus luteum disappear, and the structure, losing its yellow colour, receives the name of **corpus albicans.** After a time the corpus albicans completely disappears. Owing to the periodic rupture of the ovarian follicles, the surface of the ovary, which is at first smooth and even, becomes in old age dimpled and puckered.

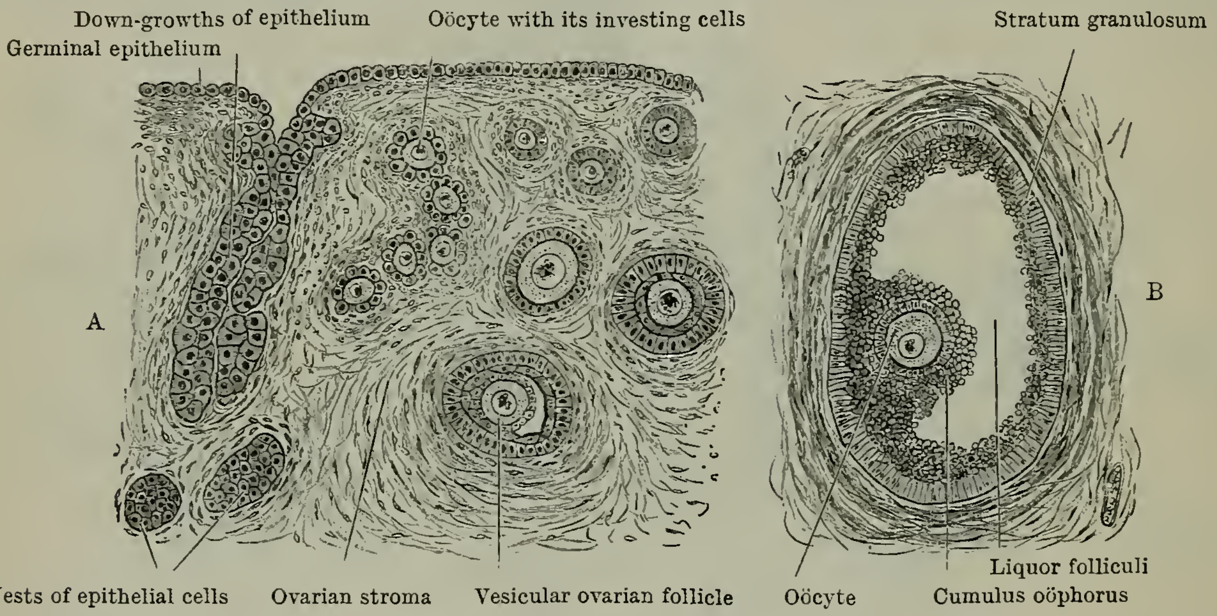

Down-growths of epithelium
Oöcyte with its investing cells
Stratum granulosum
Germinal epithelium
A
B
Liquor folliculi
Nests of epithelial cells
Ovarian stroma
Vesicular ovarian follicle
Oöcyte
Cumulus oöphorus

FIG. 1003.—A. DIAGRAMMATIC REPRESENTATION OF THE MANNER IN WHICH THE VESICULAR FOLLICLES ARISE DURING THE DEVELOPMENT OF THE OVARY. B. DIAGRAM ILLUSTRATING THE STRUCTURE OF A RIPE OR VESICULAR OVARIAN FOLLICLE.

A section through the ovary, especially in young children, presents in its superficial part a somewhat granular appearance, which is due to the presence of large numbers of small follicles, or collections of epithelial cells, embedded in the connective tissue near the surface of the ovary. The larger follicles lie deeper in the stroma, but when they become fully developed they pass towards the surface, where the ripe follicles are often seen slightly projecting and ready to burst. In the deepest part of the ovary the blood-vessels are most numerous, and here also some smooth muscle fibres are found.

The oöcytes and the other cells that compose the ovarian follicles are derived originally from the germinal epithelium which covers the developing ovary in the embryo. The epithelium, at first simple, grows down into the underlying tissue in the form of branching tube-like processes, or "egg tubes." This takes place during fœtal development, and the branching cellular processes so formed become broken up, within the stroma, into little nests or clumps of cells, each of which becomes a follicle. From the beginning some cells of the egg tubes are larger than the others; these become the future ova, while the cells round them become the investing cells of the follicle. The investing cells, at first flattened, form a single layer round each oöcyte. Later, becoming columnar, as the follicle increases in size and sinks more deeply in the stroma, these cells divide in such a manner that the oöcyte becomes surrounded by a double layer of cells. Fluid—**liquor folliculi**—accumulates between the two cellular layers, except at one place where the inner cells surrounding the ovum remain attached to the outer layer or **stratum granulosum**. To the inner cellular mass enclosing the oöcyte, the term **cumulus oöphorus** is applied (Fig. 1003). The ripe follicle contains a relatively large amount of fluid, and the surrounding stroma becomes differentiated to form a capsule or **theca folliculi**. This capsule is composed of an inner more *vascular layer*, the **tunica interna**, and an outer more *fibrous layer*, the **tunica externa**. There is reason to believe that in the human subject the formation of ova and follicles ceases before birth, and that the appearances which have led to the belief that they may originate during the first years of extra-uterine life have been due to pathological conditions. In the young child there are numerous small follicles in the superficial parts of the ovary, but in old age none are found in this situation.

The appearance and structure of the ripe ova are described on pp. 17-19.

Vessels and Nerves of the Ovary.—The **ovarian arteries**, corresponding to the testicular arteries of the male, are a pair of long slender vessels which spring from the anterior aspect of the aorta, below the level of origin of the renal vessels. Each gains the pelvis minor in the fold of peritoneum forming the suspensory ligament of the ovary, and enters the ovary at its mesovarian border. The ovarian artery anastomoses freely, near the hilum, with other vessels, derived from the **uterine arteries**. The blood is returned by a series of communicating veins, similar to the **plexus pampiniformis** in the male.

The **nerves** of the ovary are derived chiefly from a plexus which accompanies the ovarian artery, and which is continuous above with the renal plexus. Other fibres are derived from the inferior part of the aortic plexus, and join the plexus on the ovarian artery. The afferent impulses from the ovary reach the central nervous system through the posterior root fibres of the tenth thoracic nerve.

The **lymph-vessels** of the ovary join with those from the upper part of the uterus, and end in the lumbar lymph-glands.

TUBÆ UTERINÆ.

The **uterine** or **Fallopian tubes** are a pair of ducts or passages which convey the oöcytes, discharged from the follicles of the ovaries, to the cavity of the uterus. Each tube is about four and a quarter inches in length, and opens at one end into the pelvic cavity near the ovary, and at the other end by a smaller opening into the lateral part of the uterine cavity. The tube is enclosed in a fold of peritoneum called the **mesosalpinx**, which is a portion of the broad ligament of the uterus.

The opening of the tube into the pelvic cavity—the **abdominal ostium**—is of small size, being only about 2 mm. in diameter when its walls are relaxed, and much narrower when the muscular coat of the tube is contracted. This opening is placed at the bottom of a funnel-like expansion of the tube called the **infundibulum**, the margins of which are produced into a number of irregular processes or **fimbriæ**. The presence of these fimbriæ, many of which are branched or fringed, has given the name *fimbriated extremity* to this end of the uterine tube. The surface of the fimbriæ which looks into the cavity of the infundibulum is covered by a mucous membrane continuous with that lining the tube, while the outer surface is clothed by peritoneum. The mucous surfaces of the larger fimbriæ present ridges and grooves which are continued into the folds and furrows of the mucous coat of the tube. One of the fimbriæ, usually much larger than the rest, is connected either directly or indirectly with the tubal extremity of the ovary, and to it the name **ovarian fimbria** is applied. The part of the tube continuous with the infundibulum, and into which the ostium abdominale leads, is called the **ampulla**. This, the widest and longest portion of the uterine tube, is usually tortuous and of varying diameter, being in some places slightly constricted, and in others distended. The wide, thin-walled ampulla ends in the narrower, thicker-walled, and much shorter **isthmus** of the tube which joins the lateral angle of the uterus. The last portion of the canal, or *pars uterina*, is embedded in the substance of the uterine wall, which it traverses to reach the cavity of the uterus (Fig. 1004). The opening into the uterus, or **ostium uterinum**, is smaller than the abdominal ostium, being about 1 mm. in diameter. The lumen of the canal gradually increases in width as it is traced outwards from the uterus towards the ovary.

Course of the Uterine Tube.—Traced from the lateral angle of the uterus the uterine tube is directed at first horizontally in a lateral direction towards the uterine extremity of the ovary. It then passes upwards in relation to the medial side of the mesovarian border of the ovary, until it reaches the tubal extremity of the gland. Next arching backwards, it descends along the posterior or free border of the ovary and rests against its medial surface (Fig. 1001). As the uterine tube describes this loop it often covers almost the entire medial surface of the ovary. The fimbriated end of the tube is applied against the free border and inferior part of the medial surface of the ovary, and from it the ovarian fimbria passes upwards to gain attachment to the tubal extremity of the gland.

The fimbriated end of the uterine tube lies in the abdominal cavity until the ovary in its descent has entered the pelvis.

Structure of the Uterine Tubes.—The wall of each tube, which is surrounded by a **serous coat**, derived from the peritoneum, is composed of a number of concentric layers. Immediately beneath the peritoneum is a thin layer of loose connective tissue, the **tunica adventitia**, in which lie many vessels and nerves. Beneath this is the **muscular coat** composed of two strata of smooth muscle fibres—a more superficial thin stratum of longitudinally arranged fibres, and a deeper thicker layer, the fibres of which are circularly disposed. Deeper is a *submucous layer*, and then the lining membrane or **mucous coat.** In the part of the tube near the uterus the muscular layer is thicker than towards the other end, and in the isthmus it forms the chief part of the wall. The mucous membrane, on the contrary, is thickest towards the fimbriated end, and here it forms the chief part of the tube wall. The stratum of circular muscle fibres is especially well developed near the uterus. The mucous membrane is thrown into numerous longitudinal folds, or **plicæ**, which in the ampulla are exceedingly complex, the larger ones being beset on the surface by smaller folds. In transverse sections of this part of the tube the folds of the mucous membrane look like large branching processes projecting into, and almost completely filling up, the lumen of the tube. The mucous membrane is covered by a ciliated epithelium, the cilia of which tend to drive the fluid contents of the tube towards the uterus. The epithelium is continuous with that of the uterus, and at the fimbriated end joins the peritoneum.

Vessels and Nerves of the Uterine Tube.—The uterine tube receives its chief **blood supply** from a tubal branch of the uterine artery, but it also receives small branches derived from the ovarian artery. The veins of the tube pour their blood partly into the uterine and partly into the ovarian veins. The **lymph-vessels** join the lumbar group of lymph-glands. The **nerves** are derived from the plexus that supplies the ovary, and also from the plexus in connexion with the uterus. The afferent fibres are believed to belong to the eleventh and twelfth thoracic and the first lumbar nerves.

EP-OÖPHORON AND PAR-OÖPHORON.

The ep-oöphoron and the par-oöphoron are two vestigial structures found between the layers of the broad ligament.

The **ep-oöphoron** or **parovarium** lies in the mesosalpinx between the uterine tube and the ovary. In the adult it consists of a number of small rudimentary blind tubules lined by an epithelium. One of these tubules—the **longitudinal duct** (of Gärtner)—lies close to, and runs nearly parallel with, the uterine tube. It is joined by a number of **transverse ductules** which enter it at right angles, from the neighbourhood of the ovary. The longitudinal duct is a persistent portion of the Wolffian duct, and represents the canal of the epididymis in the male, while the tubules which join it are derived from the mesonephros and represent the efferent ductules of the testis (and probably also the ductuli aberrantes of the duct of the epididymis). The ep-oöphoron is best seen when the part of the broad ligament in which it lies is held up to the light.

One or more small pedunculated cystic structures, called **vesicular appendices**, are often seen near the infundibulum of the uterine tube. These are supposed to represent portions of the cephalic end of the Wolffian duct.

The **par-oöphoron** is a collection of very minute tubules also enclosed by the layers of the mesosalpinx, but lying nearer the uterus than the ep-oöphoron. These represent the paradidymis in the male, and are derived from the part of the mesonephros which lies nearer the caudal end of the body of the embryo. Though sometimes visible in the child at birth, the par-oöphoron in the adult can only be recognised by microscopic examination.

UTERUS.

The **uterus**, or womb, is a hollow, thick-walled, muscular organ placed within the pelvis between the bladder in front and the rectum behind. The ova discharged from the ovary enter the uterus through the uterine tubes, and, if fertilisation has taken place, undergo their development within it. In form the uterus is somewhat pear-shaped, the wide upper end of the organ projecting freely upwards and forwards into the pelvic cavity, while the lower more constricted part is connected with the vagina. The usual length of the adult uterus (when non-pregnant) is three inches, its greatest breadth is nearly two inches, and its maximum thickness is about one inch. In the description of the uterus we distinguish between an upper larger portion, somewhat flattened from before backwards, forming the fundus and body, and a lower more cylindrical part called the cervix (Fig. 1004).

The part of the uterus that lies above the level of a line joining the points of entrance of the uterine tubes is called the **fundus uteri**. The fundus is convex from before backwards and from side to side, its anterior and posterior aspects being directly continuous with the anterior and posterior surfaces of the body of the organ.

The **corpus uteri**, when seen from in front or from behind, has a somewhat triangular outline, and lies below the fundus, with which it is continuous. The base of the triangle is directed upwards and is formed by a line joining the lateral angles of the uterus, or points of entrance of the uterine tubes; and the sides of the triangle correspond to the lateral borders of the uterus, which extend on each side from the lateral angle to the cervix. The **lateral borders** separate the **anterior** or **vesical surface** from the **posterior** or **intestinal surface** of the body. Both these surfaces are convex, but the intestinal is much the more rounded. The vesical surface rests against the upper aspect of the bladder, from which usually it is separated by the layers of peritoneum forming the utero-vesical pouch. The intestinal surface forms the chief part of the anterior wall of the deep recess situated between the uterus and rectum, and is usually in contact with some part of the small intestine or the pelvic colon. The broad ligament passes laterally on each side of the uterus from the lateral border of the organ.

The **cervix uteri** is cylindrical, and at its commencement it is sometimes marked off from the body by a slight constriction. Its length is about one inch, and its inferior end, tapering somewhat, enters the upper part of the vagina. The cervix is attached to the margin of the opening in the vaginal wall, through which it passes, and in this way a **supravaginal portion** is marked off from a **vaginal portion** of the cervix. In the vaginal portion of the cervix there is an opening, the **external orifice**, through which the cavity of the uterus communicates with that of the vagina. In a uterus which has not been pregnant this opening is nearly circular, but in women who have borne children it is usually a transverse slit with a somewhat irregular outline. In front of, and behind, this opening the cervix forms two lips, an anterior and a posterior. The *anterior lip* is thicker, and slightly more rounded; it is placed upon a lower level than the *posterior lip*, which is slightly longer and thinner. The cervix enters the vagina through the upper part of its anterior wall in such a manner that the external orifice of the uterus is directed backwards and downwards against the upper part of the posterior vaginal wall (Fig. 1000).

Cavum Uteri.—In comparison with the size of the organ, the **cavity of the uterus** is of small size owing to the great thickness of the uterine wall. In the body, the cavity is merely a narrow chink between the anterior and posterior walls, which are almost in contact (Fig. 1000). When, however, the uterus is opened from above downwards in frontal section of the organ, the cavity of the body has a triangular outline (Fig. 1004). The base of the triangle is directed upwards, and corresponds to a line drawn between the openings of the uterine tubes, while the apex is directed downwards towards the cervix. The sides of the triangle are convex inwards towards the cavity. The cavity of the body becomes continuous with that of the cervix by an opening called the **internal orifice** of the uterus, which is a little smaller and more circular than the external orifice of the uterus. The cavity of the cervix, or **cervical canal**, extends from the internal orifice of the uterus, where it joins the cavity of the body, to the external orifice, where it opens into the vagina. It is a somewhat spindle-shaped passage, which is narrower above and below than in its middle part. Sections show also that its antero-posterior diameter is shorter than its transverse, owing to an approximation of its anterior and posterior walls. In the body of the uterus the walls of the cavity are smooth and even, but in the cervical canal the mucous membrane forms a remarkable series of folds, called the **plicæ palmatæ**. These consist of an anterior and a posterior longitudinally directed fold or ridge, from which a large number of secondary folds, or rugæ, branch off obliquely upwards and laterally (Fig. 1004, B).

Connexions of the Uterus and its Relations to the Peritoneum.—In addition to the uterine tubes at its upper lateral angles, and the vagina below, the uterus possesses other important connexions. Some of these are simply peritoneal folds passing from the uterus to neighbouring structures; others contain fibrous connective tissue, or smooth muscle fibres.

The peritoneum covering the fundus of the uterus is continued down over the vesical surface as far as the junction of the body and cervix, where it leaves the uterus to be reflected on to the bladder, forming the *utero-vesical fold*, or "anterior ligament of the uterus." The peritoneal recess between the bladder and the uterus is called the **vesico-uterine excavation**, or *utero-vesical pouch*. Below the level of this pouch the anterior aspect of the cervix is connected by loose tissue with the wall of the bladder. Posteriorly the peritoneum covers the whole of the uterus, except the small portion of the cervix which projects into the upper part of the vagina. The peritoneum covering the intestinal surface of the uterus is continued to such a depth that it invests a small portion of the upper part of the posterior wall of the vagina before it is reflected on to the rectum, to form the *recto-vaginal fold* or "posterior ligament of the uterus" (Fig. 1005). The deep pouch between the uterus and vagina in front and the rectum behind is called the **recto-uterine excavation**, or *pouch of Douglas*, and its entrance is bounded on each side by a crescentic peritoneal fold, which passes from the posterior surface of the cervix uteri to the posterior wall of the pelvis, and ends near the side of the rectum. These are known as the sacro-genital folds, or **recto-uterine folds** of Douglas, and each contains between its layers a considerable amount of fibrous and smooth muscular tissue. A few of these fibres, which are continuous with the uterine wall, pass backwards to reach the rectum and constitute the **recto-uterine muscle**; others are said to gain an attachment to the front of the sacrum, and form a *utero-sacral ligament*. In many cases the recto-uterine folds become continuous with one another across the median plane behind the cervix uteri, and form, in this position, a transverse ridge termed the *torus uterinus*. The recto-uterine pouch of the female represents the recto-vesical or recto-genital pouch of the male, and the folds which bound it on each side, namely, the recto-uterine folds, correspond to the sacro-genital folds (sometimes called posterior peritoneal ligaments of the bladder) in the male sex (p. 1268).

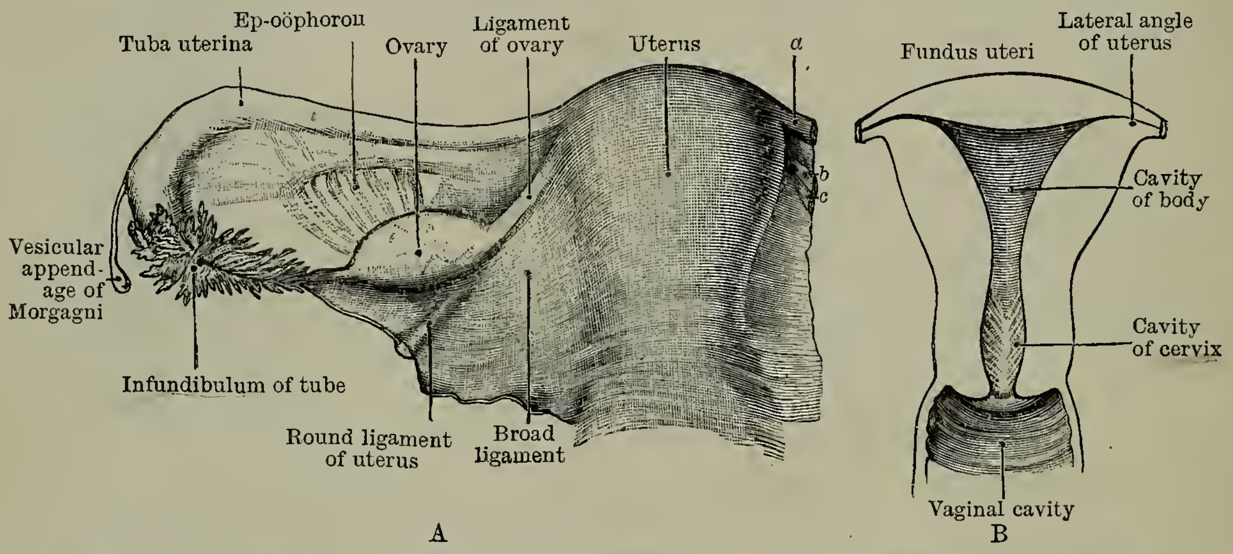


Fig. 1004.—A. The Posterior Aspect of the Uterus and Broad Ligament (the broad ligament has been spread out).

a, *b*, and *c*, the isthmus tubæ, the ligament of the ovary, and the round ligament of the right side cut short.

B. Diagrammatic Representation of the Uterine Cavity opened up from its Anterior Aspect.

The peritoneum of the vesical and intestinal surfaces, leaving the uterus along each lateral border to reach the side wall of the pelvis, forms the broad ligament of the uterus.

LIGAMENTUM LATUM UTERI.

The **broad ligament of the uterus** is a wide peritoneal fold which passes from the lateral border of the uterus to the pelvic wall, and contains between its layers several important structures (Fig. 1004). The plane of the medial part of the ligament is determined by the position of the uterus. When the uterus is placed normally, the ligament has an anterior surface which looks downwards as well as forwards, and a posterior one which looks upwards and backwards. Near its attachment to the pelvis the ligament is placed more vertically. The free edge of the ligament contains the uterine tube, and follows the course pursued by that structure. Thus, in the undisturbed condition of parts, it at first passes laterally towards the uterine extremity of the ovary, and then ascends to arch over the tubal pole of the ovary on its medial side. Owing to the course pursued by the uterine tube round the ovary, the broad ligament forms a kind of curtain over the gland, and the ovary lies in a little pocket formed by the broad ligament, to which the name of **bursa ovarica** is applied (Figs. 1000 and 1001). This bursa ovarica is not to be confused with the *fossa ovarii*, or depression on the side wall of the pelvis, against which the ovary is usually placed (p. 1295).

The various structures in connexion with the broad ligament are most easily demonstrated when the ligament is spread out as flat as possible.

The ovary is connected with the posterior layer of the broad ligament by a very short mesentery, called the **mesovarium**, which, passing to the hilum, encloses the ovarian vessels and nerves as they reach the ovary.

The part of the broad ligament which slings the uterine tube is called the **mesosalpinx.** When the ligament is spread out, the mesosalpinx has the form of a narrow triangle, the apex of which is at the lateral angle of the uterus, while the upper side is formed by the uterine tube, and the lower one by the ligament of the ovary and the ovary itself. The narrow base of the triangle is directed laterally. In the normal position of the parts the mesosalpinx is folded round the ovary in the manner described above to form the bursa ovarica. Between the layers of this part of the broad ligament are situated the ep-oöphoron and the par-oöphoron (Fig. 1004).

The part of the broad ligament below the level of the mesosalpinx is termed the **mesometrium.** It contains, especially in its lower part, a considerable amount of connective tissue and unstriped muscle fibres. The ureter and the uterine vessels lie in the lowest part of the broad ligament where it joins the pelvic floor. The fibrous and smooth muscle tissue which occupy the interval between the layers of the lower part of the broad ligament, immediately below the uterine artery, form what is known as the *lateral cervical ligament* of the uterus. This ligament is continuous with the dense tissue surrounding the branches of the hypogastric artery, and in vertical antero-posterior section has a triangular outline near its attachment to the cervex uteri.

The highest part of the attached lateral portion of the broad ligament forms the **suspensory ligament of the ovary,** and contains between its layers the ovarian vessels and nerves as they enter or leave the pelvis.

The **ligament of the ovary** is a rounded fibrous cord, of about one inch in length, which is attached by its lateral end to the uterine pole of the ovary, and by its medial end to the lateral angle of the uterus immediately below and behind the entrance of the uterine tube. This ligament, which is largely composed of unstriped muscle fibres continuous with those of the uterus, is enclosed in a slight fold derived from the posterior layer of the broad ligament.

The ligament of the ovary represents the upper portion of the gubernaculum which appears in the embryo.

The **round ligament of the uterus** is a narrow flat band attached to the uterus just in front of, and a little below, the opening of the uterine tube. Near the uterus it contains numerous smooth muscle fibres, which are continuous with those of the uterine wall; more laterally it is composed chiefly of fibrous connective tissue. Lying in the anterior part of the broad ligament, it reaches the wall of the pelvis minor, and is then directed forwards and slightly upwards to cross the obliterated umbilical artery and the pelvic brim. After it has reached the pelvic wall its course is comparable to that of the ductus deferens in the male, and, like the latter, it leaves the abdomen to traverse the inguinal canal (Figs. 1000 and 1001). It finally ends in the subcutaneous tissue and skin of the labium majus. Its terminal part is composed of connective tissue only.

The round ligament of the uterus represents the lower portion of the gubernaculum testis which appears in the male embryo (see p. 1280).

In some cases a minute diverticulum of the peritoneal cavity can be traced accompanying the round ligament through the abdominal wall. This is a vestige of the **processus vaginalis** of the peritoneum which is formed in the embryo in both sexes. The term "canal of Nuck" is sometimes applied to it when it is found in the adult female.

Position and Relations of the Uterus.—The position occupied by the uterus in the pelvis is not always the same, but varies with the conditions of the neighbouring organs. The lower cervical part is, however, much more firmly fixed in place than the body and fundus, which possess a considerable amount of mobility. Usually the level of the external orifice of the uterus will be found to correspond to that of a horizontal plane passing through the upper margin of the symphysis pubis. The uterus rarely lies exactly in the median plane of the body, but bends a little to one or other side, most frequently towards the right.

The vesical surface of the uterus rests against the bladder, and follows the rising or falling of its superior wall as that organ becomes filled or emptied. When the bladder is empty the long axis of the uterus points forwards and upwards, and the organ is said to be in an *anteverted* position. Also, the long axis of the uterus is bent on itself where the body joins the cervix, and so the organ is said to be *anteflexed.* The anteflexion is due to the fact that the more rigid cervix is fixed, while the movable upper part of the uterus sinks forwards, following the bladder wall. With the empty condition of the bladder the angle formed between the long axis of the uterus and that of the vagina is about a right angle. When the bladder becomes filled, the anteversion and anteflexion of the uterus become less marked, owing to the body and fundus being pushed backwards. Finally, if the rectum is empty and the bladder very much distended, the uterus is pushed so much backwards that the long axis of the organ may nearly correspond to that of the vagina. The uterus is then said to be *retroverted.* Superiorly a part of the peritoneal cavity intervenes between the vesical surface of the uterus and the bladder, but lower down the two organs are separated merely by a small quantity of connective tissue.

The intestinal surface of the uterus looks into the recto-uterine excavation, and is usually, like the fundus, in relation to some loops of the small intestine or the pelvic colon. Laterally the uterus is related to the broad ligament. The terminal portion of the ureter passes downwards, medially, and a little forwards across the lateral aspect of the cervix, but is separated from it by an interval of about three-quarters of an inch. The lowest part of the cervix is, as we have seen, enclosed within the cavity of the vagina.

On each side of the cervix uteri and upper part of the vagina there is an interval in which lie numerous large vessels. These are surrounded by bundles of smooth muscle fibres and by loose fatty tissue, which is continued upwards for a considerable distance between the layers of the broad ligament. This loose tissue, which is of surgical importance, has received the name **parametrium.**

Supports of the Uterus.—It is probable that during life the uterus is maintained in its normal anteverted and anteflexed position by the fixation of the cervix at the anterior vaginal wall and by the pull of the numerous strands of smooth muscle fibre which form the utero-sacral, the lateral cervical, and the round ligaments. Inferiorly the uterus is supported by the levator ani muscle forming the pelvic floor. The pressure and counter-pressure exerted by the bladder, colon, and rectum also influence the position of the uterus.

Structure of the Uterus.—The thick uterine wall is composed of three chief layers, which are termed respectively the serous, the muscular, and the mucous coats.

The **serous coat**, or *perimetrium*, is derived from the peritoneum. Over the fundus and body of the uterus it is very firmly adherent to the deeper layers, and cannot be easily peeled off without tearing either it or the underlying muscular tissue. Near the lateral borders of the uterus the peritoneum is less firmly attached, and over the posterior aspect of the cervix it may readily be stripped off without injury to the underlying structures.

The **muscular coat** is composed of unstriped fibres, and forms the chief part of the uterine wall. Inferiorly the muscular coat of the uterus becomes continuous with that of the vagina. The more superficial layer of the muscular coat sends prolongations into the recto-uterine folds, into the round and broad ligaments of the uterus, and into the ovarian ligaments. Other fibres join the walls of the uterine tubes. The main branches of the blood-vessels and nerves of the uterus lie among the muscle fibres. In the deeper layers of the muscular coat a considerable amount of connective tissue and some elastic fibres are to be found. The muscular coat of the cervix contains more connective and elastic tissue than that of the body, and hence the greater firmness and rigidity of the cervical part of the uterus.

The deeper and thicker part of the muscular tissue of the uterus is considered by some anatomists to represent a muscularis mucosæ, and is therefore described as part of the mucous coat. The deep and superficial portions of the muscular coat are, however, quite continuous, and there is no representative of a submucous vascular layer of tissue such as in the alimentary canal separates the muscular coat from the muscularis mucosæ. In the uterus the blood-vessels lie in the muscular coat.

The **mucous coat** in the body of the uterus is smooth and soft, and covered with columnar ciliated epithelium. Simple tubular glands, also lined with a ciliated epithelium, are present in the mucous membrane, and penetrate in their deeper parts into the muscular coat. In the cervix of the uterus the mucous coat is firmer and more fibrous than in the body, and its surface is not smooth, but presents a number of peculiarly disposed ridges which have been already described (p. 1299). Like the mucous membrane of the body of the uterus, that of the cervix is covered with a ciliated epithelium which passes into squamous epithelium just inside the external orifice of the uterus. In addition to unbranched tubular glands, numerous somewhat branched glands are found in the cervix uteri. Both kinds of glands are lined by ciliated epithelium. In many cases little clear retention cysts, "ovules of Naboth," are to be seen in the cervical mucous membrane. These arise as a result of obstruction at the mouths of the glands.

Differences in the Uterus at Different Ages.—At birth the cervix uteri is relatively larger than in the adult organ, and its cavity is not distinctly marked off from that of the body by an internal orifice. At this time also the plicæ palmatæ extend throughout the whole length of the uterus. The organ grows slowly until just before puberty, when its growth is rapid for a time. As the body of the uterus increases in size the mucous membrane becomes smooth and the plicæ palmatæ become restricted to the cervix. In women who have borne children the cavity remains permanently somewhat wider and larger than in cases where the uterus has never been pregnant.

In old age the uterine wall becomes harder and has a paler colour than it possesses in the young subject.

Variations.—In rare cases the uterus may be divided by a septum into two distinct cavities, or its lateral angles may be produced into straight or curved processes, called "horns" or cornua. The latter abnormality recalls the appearance of the bicornuate uteri of some animals. Both the above conditions arise from an arrest in the fusion of the two separate tubes—the Müllerian ducts—which normally unite in the embryo to form the uterus.

Periodic Changes in the Uterine Wall.—At each menstrual period a remarkable series of changes occurs which results in a periodic shedding of the superficial parts of the uterine mucous membrane. For a few days before menstruation begins, the mucous membrane gradually thickens and becomes more vascular, while at the same time its surface becomes uneven. Soon the superficial parts of the mucous membrane disintegrate and hæmorrhage takes place from the small superficial blood-vessels. In this way a hæmorrhagic discharge is caused, and the superficial parts of the uterine mucous membrane are shed at each period. When menstruation is over the mucous membrane is rapidly regenerated.

Pregnant Uterus.—The pregnant uterus increases rapidly in size and weight, so that from being three inches in length and one ounce in weight, it becomes by the eighth month of pregnancy about seven or eight inches in length and sometimes as much as two pounds in weight. In shape the uterus is now oval or rounded, with a thick wall composed chiefly of muscle fibres arranged in distinct layers. The rounded fundus is very prominent. The round ligaments are stronger and better marked, and the layers of the broad ligament become separated in their medial parts by the growth of the uterus between them. The blood-vessels, especially the arteries, are very large and tortuous. The changes which occur in the mucous membrane of the pregnant uterus are intimately connected with the manner in which the developing fœtus receives its nutrition, and have been noticed on p. 61 *et seq.*

The uterus receives its **arterial supply** mainly from the uterine arteries, which are branches of the hypogastric arteries, and also from the ovarian arteries, branches of the aorta. The vessels derived from these two sources communicate freely with one another. Each uterine artery, reaching the side of the lower part of the uterus, divides into a large branch which passes upwards to supply the body and fundus, and a much smaller branch which passes downwards to supply the cervix. The vessels distributed to the body and fundus have an exceedingly tortuous course. The branches of the uterine artery, having entered the muscular coat, break up within its deeper layers into smaller twigs which supply the muscular tissue and the mucous coat. The small uterine branch from the ovarian artery reaches the uterus in the region of the lateral angle. During pregnancy the arteries become enormously enlarged.

The thin-walled **veins** form a plexus which pours its blood into the tributaries of the hypogastric vein.

The **nerves** of the uterus are derived chiefly from a plexus placed in the neighbourhood of the cervix uteri, to which the term plexus utero-vaginalis or "cervical ganglion" is applied. Superiorly this plexus is continuous with the hypogastric plexus, but it also receives fibres from the second, third, and fourth sacral nerves.

Clinical observations indicate that afferent impulses reach the central nervous system from the uterus through the posterior roots of the tenth, eleventh, and twelfth thoracic nerves, the first lumbar, and the second, third, and fourth sacral nerves.

The numerous **lymph-vessels** coming from the body of the uterus join those from the ovary, and end for the most part in the lumbar lymph-glands. Along the course of the round ligament of the uterus there are a few lymph-vessels which establish a connexion between the lymph-network surrounding the uterus and the inguinal lymph-glands. The lymph-vessels from the cervix uteri end in the gland placed near the bifurcation of the common iliac artery.

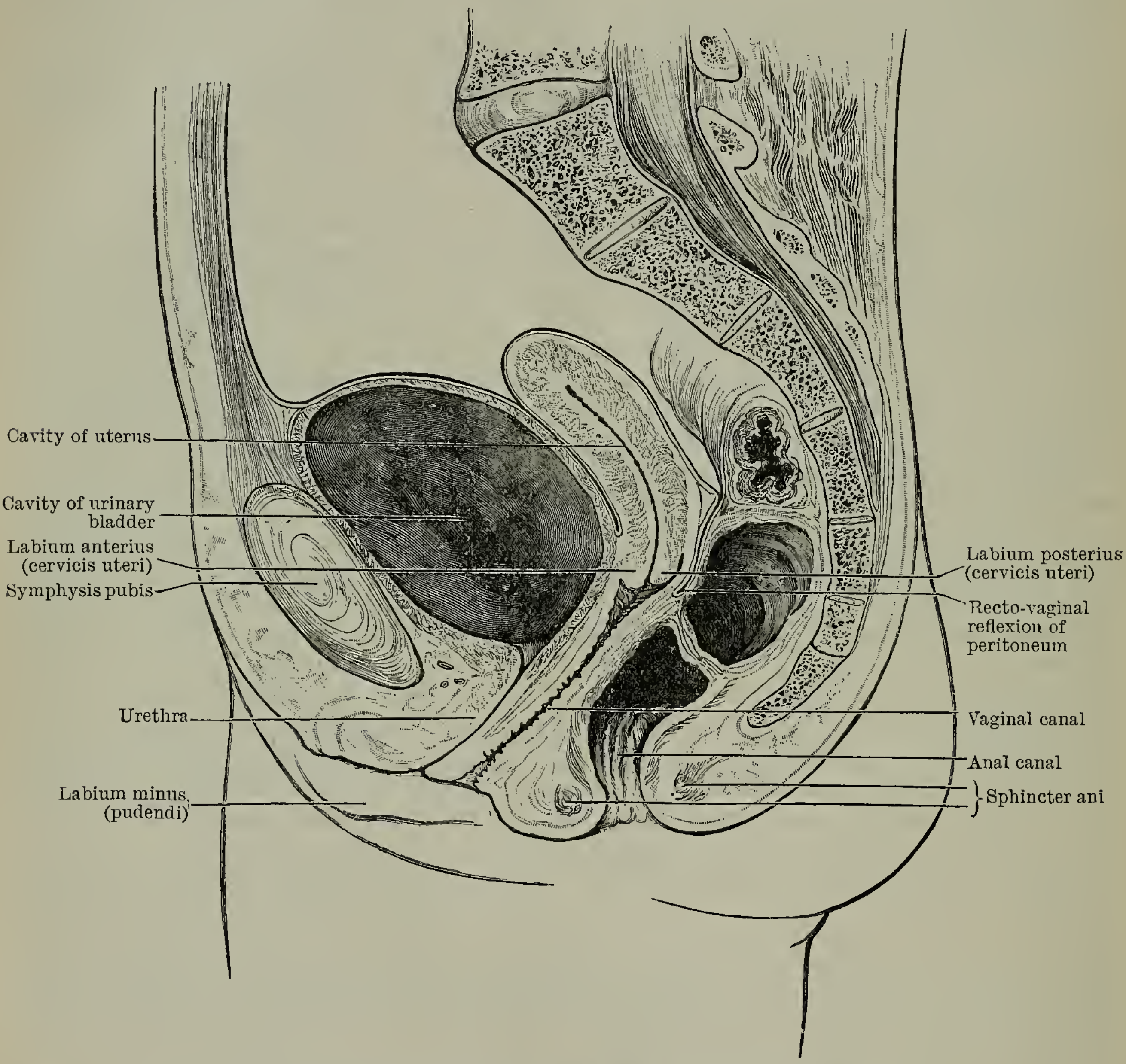

Cavity of uterus
Cavity of urinary bladder
Labium anterius (cervicis uteri)
Symphysis pubis
Urethra
Labium minus (pudendi)
Labium posterius (cervicis uteri)
Recto-vaginal reflexion of peritoneum
Vaginal canal
Anal canal
Sphincter ani

FIG. 1005.—MEDIAN SECTION OF THE PELVIS IN AN ADULT FEMALE.

The cavity of the uterus is indicated diagrammatically.

VAGINA.

The **vagina** is a passage about three inches in length, open at its lower end, and communicating above with the cavity of the uterus. The passage is directed downwards and forwards, describing a slight curve which is convex backwards. The axis of the vagina forms with that of the uterus an angle which is open forwards. This angle is usually somewhat greater than a right angle, but varies with the condition of the neighbouring viscera (p. 1302). The vagina is widest at its upper end (Fig. 1006), and normally its anterior and posterior walls are in contact. In transverse section the lower part is usually an H-shaped cleft, the middle part a simple transverse slit, while the lumen of the upper portion, into which the cervix uteri projects, is more open. The lower part of the cervix uteri has the appearance of entering the vagina through the upper portion of its anterior wall (Fig. 1005). As more of the posterior than of the anterior part of the cervix projects into the vagina, a deeper recess is formed between the vaginal wall and the cervix behind than in front or laterally. The term *anterior fornix* is often applied to the recess in front; *posterior fornix* to the deeper recess behind; and *lateral fornix* to the recess on each side of the cervix uteri, between it and the wall of the vagina. The *anterior* wall of the vagina is shorter than the *posterior*, the former being about three inches in length, the latter about three and a half inches. At its lower end the vagina opens into the **pudendal cleft**, the opening being situated behind the orifice of the urethra and the clitoris, and between the labia minora. The opening is partly closed in the virgin by a thin crescentic or

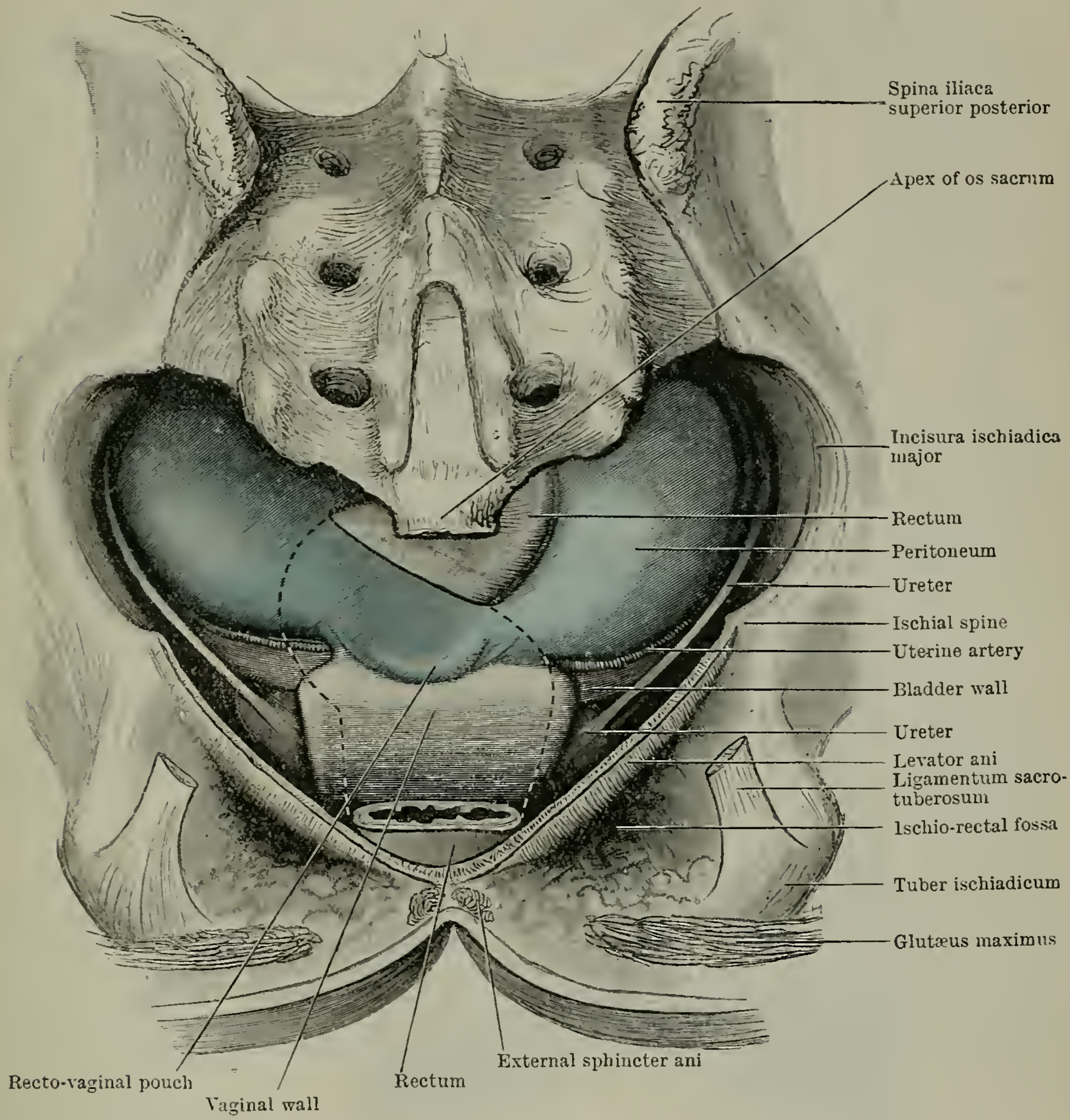


FIG. 1006.—POSTERIOR ASPECT OF THE VAGINA, THE BASE OF BLADDER, AND THE RECTO-VAGINAL POUCH OF PERITONEUM.

The coccyx and the ligamentum sacro-tuberosum and ligamentum sacro-spinosum, together with the muscles attached to them, have been removed. The levatores ani have been separated along the median raphe, and drawn laterally. A considerable portion of the rectum has been removed, but the position which it occupied is indicated by the dotted lines. The peritoneum is indicated by a blue colour. The recto-vaginal pouch is probably not quite so deep as usual. The triangular interval between the ureter and uterine artery was filled by a mass of fibro-muscular tissue, forming the lateral cervical ligament of the uterus.

annular fold, called the **hymen**, torn fragments of which persist round the opening, as the **carunculæ hymenales**, after the fold itself has been ruptured.

Relations of the Vagina.—The anterior wall of the vagina in its upper part lies against the fundus of the bladder, but is separated from it by loose connective tissue. Lower down, the anterior wall in the median plane is intimately connected with the urethra (Fig. 1005). The posterior wall in its upper portion is covered for a distance of about a quarter of an inch by the peritoneum, which here forms the anterior boundary of the deepest part of the recto-uterine pouch. The depth to which the peritoneum of this pouch descends practically corresponds to the level of the ischial spines. Lower down, the posterior wall lies close against the rectum, from which it is separated by a layer of connective tissue. As, however, the orifice of the vagina is approached, the rectum and vagina become separated by a considerable interval, which is occupied by a mass of fibrous and fatty tissue, often called the "perineum" or "perineal body." At the sides the vagina is supported by the levatores ani muscles. The terminal part of the ureter lies not far from the side wall of the upper part of the vagina, as it passes from above and behind downwards, medially and a little forwards to reach the bladder. Near its termination the vagina pierces the inferior fascia of the uro-genital diaphragm, and is related on each side to the bulbus vestibuli, the larger vestibular gland, and the bulbo-cavernosus (sphincter vaginæ) muscle.

Structure of the Vagina.—The vaginal wall has a distinct **muscular coat**, composed of unstriped muscle fibres, most of which are longitudinally disposed. Towards the lower end of the passage circularly disposed bundles of striped muscle fibres, some of which are continuous with those forming a part of the urethral wall, are found in the muscular coat. The thick **mucous coat**, which has a stratified scaly epithelium, is corrugated, and presents a number of transverse ridges or elevations known as vaginal rugæ. In addition to these transverse rugæ, a slightly marked longitudinal ridge, or column, is to be seen on the anterior and on the posterior wall of the vagina. These receive the name **columnæ rugarum**, and, like the transverse rugæ, are best seen in young subjects and in the lower part of the vagina. The urethral canal lies in close relationship to the anterior column of the vagina in its lower part, and hence this portion of the anterior column is sometimes called the **carina urethralis**.

Between the muscular and mucous coats is a thin layer of vascular tissue resembling erectile tissue.

Within the tunica mucosa are to be found small collections, or nodules, of lymphoid tissue.

The vaginal wall is surrounded by a layer of loose vascular connective tissue containing numerous large communicating veins.

The **blood-supply** of the vagina is for the most part derived from the vaginal artery, the vaginal branch of the uterine artery, the vaginal branches of the middle hæmorrhoidal artery, and from the branches of the internal pudendal. The **veins** form a plexus surrounding the vaginal wall, and drain their blood into the tributaries of the hypogastric.

The **lymph-vessels** from the upper part of the vagina join the external iliac and hypogastric groups of glands, while those from the lower part end in the superficial inguinal glands.

The **nerves** of the vagina are derived from the plexus utero-vaginalis and from the plexus vesicalis. Other fibres are derived directly from the third and fourth sacral nerves.

THE FEMALE EXTERNAL GENITAL ORGANS.
(PUDENDUM MULIEBRE.)

The term **pudendum**, or **vulva**, is applied collectively to the female external genital organs, *i.e.* to the labia majora and the structures which lie between them.

Labia Majora.—The **labia majora** represent the scrotum in the male, and form the largest part of the female external genital organs. They form the boundaries, on each side, of the **rima pudendi**, or *uro-genital cleft*, into which the urethra and vagina open. Each labium is a prominent rounded fold of skin, narrow behind where it approaches the anus, but increasing in size as it passes forwards and upwards to end in a median elevation, the **anterior commissure**, or *mons pubis*. The mons pubis lies over the symphysis pubis, and, like the labia majora, it is composed chiefly of fatty and areolar tissue, and is covered with hair. The lateral convex surface of each labium majus is covered by skin containing numerous sebaceous glands and resembling that of the scrotum in the male, but the medial, flatter surface is smooth, and presents a more delicate integumentary covering.

In some cases the posterior narrow ends of the labia majora are connected across the middle line, in front of the anus, by a slight transverse fold—the **posterior commissure.**

Usually, the labia majora are the only visible parts of the external genital organs, since they are in contact with one another, and completely enclose the structures within the pudendal cleft.

The round ligament of the uterus ends in the fatty tissue of the labium majus. The superficial subcutaneous tissue resembles that of the scrotum, but contains no muscular fibres.

The **nerve-supply** corresponds with that of the scrotum, the anterior part of each labium being supplied by the branches of the ilio-inguinal nerve, and the posterior part by branches from the pudendal and by the perineal branch from the posterior cutaneous nerve of the thigh. The **blood-vessels** of the labia majora are derived from the external pudendal branches of the femoral and from the perineal branches of the internal pudendal vessels.

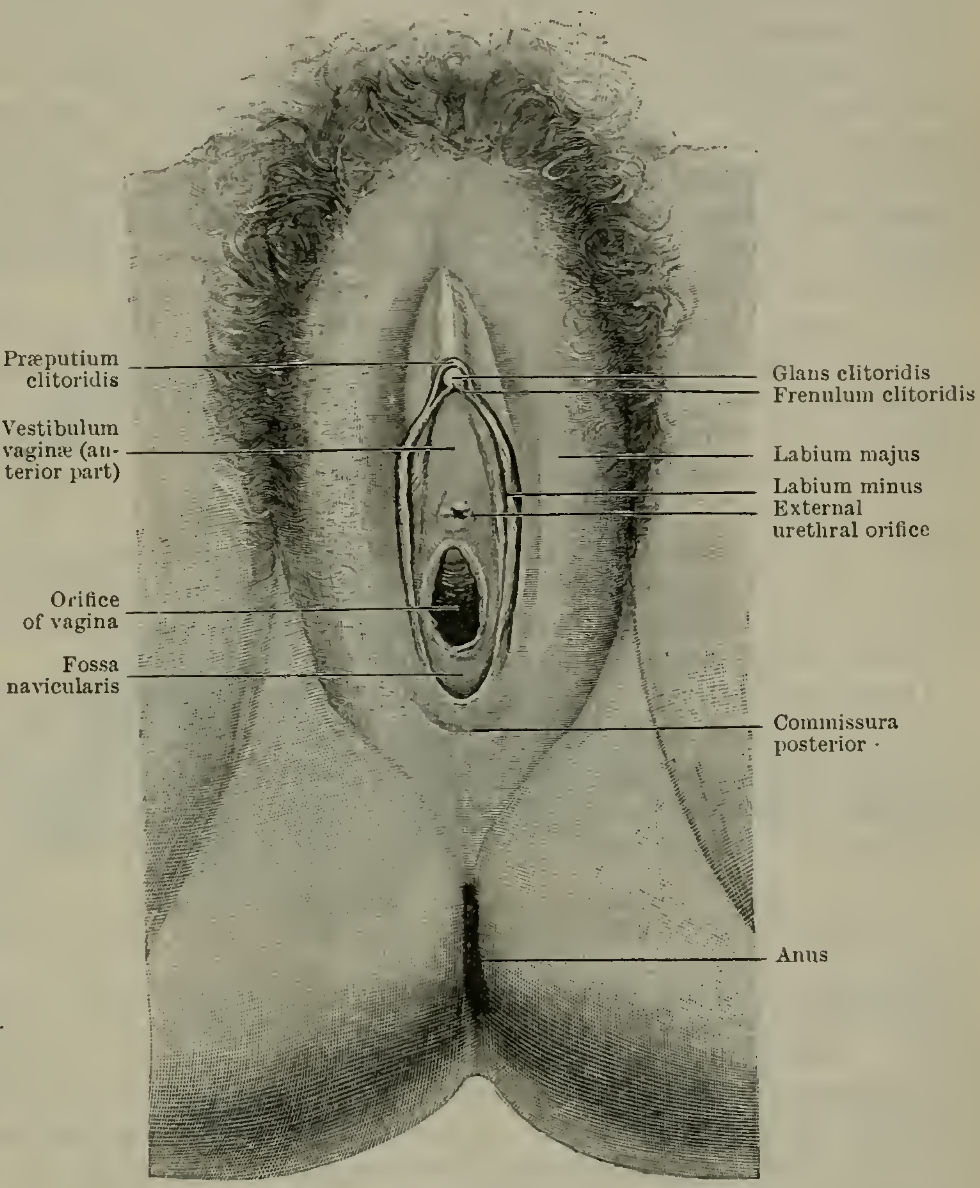


Fig. 1007.—Female External Genital Organs.

The frenulum labiorum is seen stretching across behind the fossa navicularis and in front of the posterior commissure. The ducts of the larger vestibular glands open in the intervals between the vaginal orifice and the medial edges of the labia minora.

Labia Minora.—The **labia minora** are a pair of much smaller and narrower longitudinal folds, usually completely enclosed within the cleft between the labia majora. Diminishing in size, and becoming less marked in their posterior parts, the labia minora end by gradually joining the medial surfaces of the labia majora. In the young subject, a slightly raised transverse fold is usually seen connecting the posterior ends of the labia minora; to this fold the term **frenulum labiorum pudendi** or **fourchette** is applied. Traced forwards, each labium minus divides into two portions, a lateral and a medial. The lateral portions of the two labia unite over the glans clitoridis, and form for it a fold or covering called the **præputium clitoridis.** The medial portions, uniting at an acute angle, join the glans and form the **frenulum clitoridis.** The skin of the labia minora resembles the integument on the medial or deep surface of the labia majora, being smooth, moist, and pink in colour. The medial surfaces of the labia minora are in contact with one another; their lateral surfaces are applied against the medial aspects of the labia majora.

The openings of the urethra and vagina are placed in the median plane, in the interval between the labia minora, which must be separated to bring them into view.

Vestibulum vaginæ.—The *vestibule* is the name applied to the cleft that lies between the labia minora and behind the glans clitoridis. In its floor are the openings of the urethra, the vagina, and the minute ducts of the larger vestibular glands.

The **fossa navicularis** is the part of the vestibule placed behind the vaginal opening and in front of the frenulum labiorum pudendi.

The **external urethral orifice** lies immediately in front of that of the vagina, and is about one inch behind the glans clitoridis. The opening has the appearance of a vertical slit, or of an inverted V-shaped cleft, the slightly prominent margins of which are in contact. Sometimes on each side of the urethral orifice there may be seen the minute opening of the ductus paraurethralis (see p. 1270).

The **orifice of the vagina** lies behind and below the orifice of the urethra. The appearance of the opening varies with the condition of the **hymen**—a membrane which in the young subject partly closes the aperture. When the hymen is intact the opening is small, and is seen only when the membrane is put on the stretch. When the hymen has been ruptured the opening is much larger, and round its margins are often seen small projections—**carunculæ hymenales**—which are to be looked upon as persistent fragments of the hymen.

The **hymen** is a thin membranous fold, partially closing the lower end of the vagina, and perforated usually somewhat in front of its middle point. The position of the opening gives the fold, when stretched, a crescentic appearance. The opening in the hymen is sometimes cleanly cut, sometimes fringed. The membrane is not stretched tightly across the lower end of the vagina, but is so ample that it projects downwards into the rima pudendi, and the parts of its upper surface are in contact with one another on each side of the opening. The opening is thus a median slit whose margins are normally in contact. The upper surface of the hymen is directly continuous with the vaginal wall, and on it are to be seen slight ridges continuous with the vaginal rugæ.

Developmentally the hymen appears to be a portion of the vagina.

On each side of the vaginal opening, and close against the medial side of the attached margin of the labium minus, is the minute opening of the duct of the **greater vestibular gland** (Bartholin). This is usually just large enough to be visible to the unaided eye.

Numerous minute mucous glands, the **lesser vestibular glands**, open on the surface of the mucous membrane of the vestibule, between the urethral and vaginal orifices.

Clitoris.—The **clitoris** is the morphological equivalent of the penis, and is composed of a body and two crura. Upon the summit of the body is a minute glans. Unlike the penis, the clitoris is not traversed by the urethra.

The **corpus clitoridis** is composed for the most part of erectile tissue resembling that of the penis in the male. It is about an inch or an inch and a half in length, and is bent upon itself, forming an angle open downwards. The body of the clitoris tapers towards its distal end, which is covered by the glans clitoridis. The organ is enclosed in a dense fibrous coat, and is divided by an incomplete **septum** into two symmetrical and somewhat cylindrical portions, the **corpora cavernosa clitoridis.** These represent the corpora cavernosa penis of the male, and diverge from one another at the root of the clitoris to form the **crura clitoridis.** A fibrous suspensory ligament passes from the body of the clitoris to the symphysis pubis (Fig. 1008).

The **glans clitoridis** is a small mass of erectile tissue which is fitted over the pointed end of the body. It possesses, like the glans penis, which it represents, a very sensitive epithelium. The **præputium**, or fold of skin which covers it, and the **frenulum clitoridis**, which is attached to it inferiorly, are continuous with the labia minora (Fig. 1007).

The **crura clitoridis** diverge from the body posteriorly, and are attached to the sides of the pubic arch. Each is continuous with one of the corpora cavernosa, and has a firm fibrous sheath, which is covered by the corresponding ischiocavernosus. In structure the crura and body of the clitoris resemble the corpora cavernosa penis, while the glans more closely resembles the bulbus vestibuli, with which it is continuous through a structure known as the pars intermedia (Fig. 1008).

In the seal and some other animals, a bone, which represents the os penis of the male, is developed in the septum of the clitoris. This bone receives the name *os clitoridis.*

The **arterial supply** of each crus is a special branch from the internal pudendal. The glans is supplied by the dorsal artery of the clitoris.

The **nerve-supply** of the clitoris is derived partly from the hypogastric sympathetic plexus and partly from the dorsal nerves of the clitoris, which are branches of the pudendal nerves.

Bulbus Vestibuli.—The **bulb of the vestibule** is a mass of erectile tissue, in the female, which corresponds developmentally to the corpus cavernosum urethræ of the male. In the female the fusion of the two halves of this structure is not nearly so complete as in the male, for the vagina and urethra separate the bulbus vestibuli into right and left portions which are only slightly connected in front by a narrow median part called the *pars intermedia.* Each half of the bulb is thick and massive posteriorly, and more pointed in front, where it joins the pars intermedia. It rests against the lateral wall of the vagina, and upon the superficial aspect of the inferior fascia of the uro-genital diaphragm. It represents one-half of the corpus cavernosum urethræ of the male. Superficially it is covered by the bulbo-cavernosus muscle. The pars intermedia lies above the opening of the urethra, and becomes continuous with the tissue of the glans clitoridis.

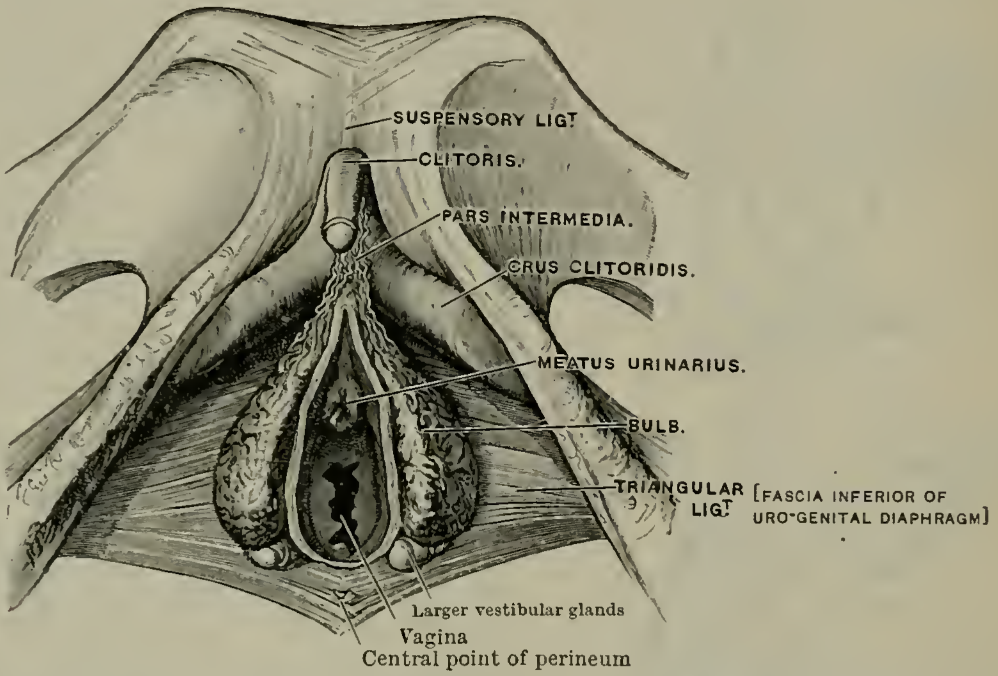


Fig. 1008.—Dissection of Female Perineum to show the Clitoris, the Bulb of the Vestibule, and the larger Vestibular Glands. (D. J. Cunningham.)

The bulb of the vestibule is for the most part composed of minute convoluted blood-vessels, held together by a very small amount of connective tissue. These vessels frequently anastomose with one another, and those of each half communicate with the vessels of the pars intermedia and the glans clitoridis.

The **blood-supply** of the bulb is derived, on each side, from a special branch of the internal pudendal.

Glandulæ Vestibulares Majores.

The **greater vestibular glands** or *glands of Bartholin* are placed one on each side of the lower part of the vagina, and represent the bulbo-urethral glands in the male. They are often overlapped by the posterior ends of the bulbus vestibuli, and are covered by the bulbo-cavernosus muscle. Each is about the size and shape of a small bean, and possesses a long slender duct which opens into the vestibule in the angle between the attached border of the labium minus and the vaginal opening.

DEVELOPMENT OF THE URO-GENITAL ORGANS.

The Uro-genital Passages.

General Account.—In tracing the developmental history of the uro-genital passages we may for convenience begin with an embryo of about $2\frac{1}{2}$ mm. in length. At this time a duct, which runs in a longitudinal direction, and occupies a position on the lateral side of the protovertebral somites, begins to develop on each side of the body. With the exception of the anterior portion of the cloaca and the proximal part of the allantois, this duct, which has received the name of **primary excretory** or **Wolffian duct**, is the earliest formed structure from which, or in connexion with which, the parts of the adult uro-genital system arise.

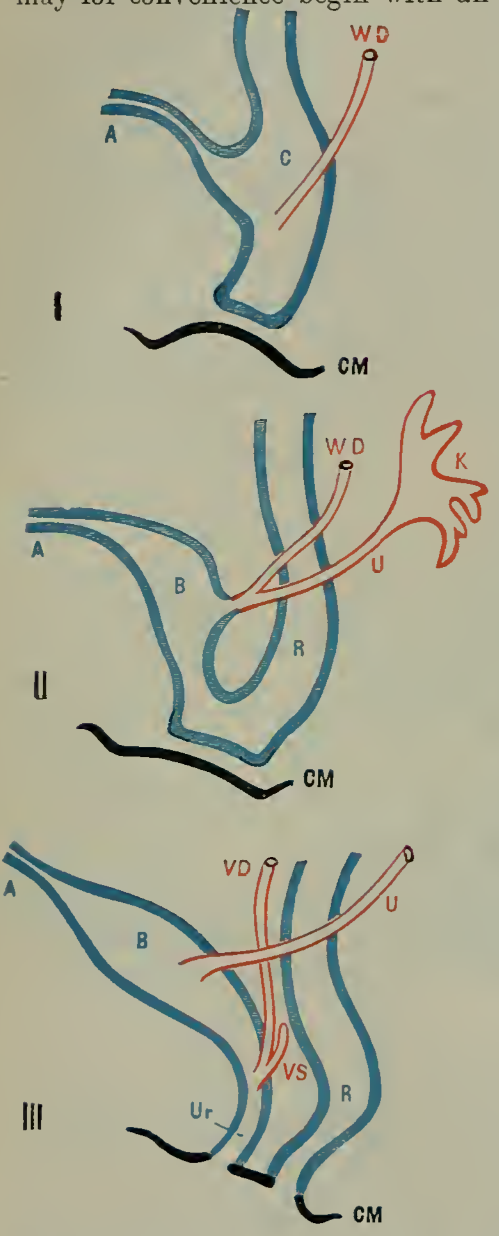


Fig. 1009.—Diagram to illustrate the Manner in which the Ureter, the Ductus Deferens, and the Urinary Bladder arise in the Embryo.

The structures developed from the cloaca are indicated in blue, those from the Wolffian duct in red, and the ectoderm in black.

The manner in which the rectum and bladder become separated and acquire openings into the ectodermal cloacal fossa is shown in II. and III. (A. H. Young and A. Robinson.)

A. Allantois.
B. Bladder.
C. Cloaca.
CM. Ectoderm of cloacal fossa.
K. Pelvis of kidney.
R. Rectum.
Ur. Uro-genital canal.
U. Ureter.
VD. Ductus deferens.
VS. Seminal vesicle.
WD. Wolffian duct.

The Wolffian duct serves as the canal, or duct, for the primitive excretory organs—the pronephros and the mesonephros of the embryo. With the atrophy of these the duct suffers modification, yet both sexes in the adult possess structures which have their embryonic origin from the Wolffian duct. In the male the **duct of the epididymis**, the **ductus deferens**, and the **ejaculatory duct**, are to be looked upon as directly developed from the Wolffian duct of the embryo; while in the female the **longitudinal duct of the ep-oöphoron** and the **vesicular appendices** are rudimentary structures having a like origin. The **ureter** and its **pelvis** arise in both sexes as an outgrowth from the Wolffian duct. In the male the **vesicula seminalis** is developed as a diverticulum of the Wolffian duct.

The primitive excretory organs, the **pronephros** and the **mesonephros**, develop in connexion with the anterior part of the Wolffian duct (p. 1311), and, during the early life of the embryo, are important structures. Even in the embryo, however, the pronephros soon becomes vestigial and it is replaced by the far more important mesonephros. With the development of the permanent kidney the mesonephros atrophies, yet some of its tubules persist in the adult. The **ductuli efferentes**, the **ductuli aberrantes** and the rudimentary **paradidymis** (organ of Giraldès) in the male, and the rudimentary tubules of the **ep-oöphoron** and of the **par-oöphoron** in the female, are structures which owe their origin to the tubules of the mesonephros.

Soon after the formation of the Wolffian ducts two other longitudinally disposed canals, called the **Müllerian ducts**, are developed. These open at their cephalic ends into the body cavity, and at their caudal ends, unlike the Wolffian ducts, they unite with one another in the median plane. From them are formed, in the female—the **uterine tubes**, the **uterus**, and the **vagina**; and in the male—the **appendices** of the testis and the **utriculus prostaticus**.

The Wolffian and Müllerian ducts open at their caudal ends into the ventral or uro-genital part of the **cloaca**, which in the course of development becomes transformed into the **bladder** and the **uro-genital canal** of the embryo. The developing ureter at first arises as a diverticulum from the Wolffian duct, at a short distance from the point where the latter joins the cloaca. Soon, however, the ureters acquire independent openings into the cloaca, which become gradually shifted further from one another and from those of the Wolffian ducts. The ureters are now found to open into the anterior portion of the cloaca which lies nearer to the head of the embryo than the part with which the Wolffian ducts are connected. This cephalic portion of the anterior subdivision of the cloaca which receives the ureters becomes the bladder and the upper part of the urethra. The caudal part, lying below the level of the entrance of the Wolffian ducts, is called the uro-genital canal and is represented in the adult male by the lower part of the prostatic and by the membranous portions of the urethra; in the female by the lower part of the urethra and the part of the uro-genital fissure which immediately surrounds the openings of the urethra and vagina (Figs. 1016, 1017). The united Müllerian ducts open into the lower part of the cloaca or uro-genital canal between the Wolffian ducts of opposite sides. In the male the position of this opening, which is represented in the adult by the orifice of the utriculus prostaticus, remains almost unchanged; in the female, on the other hand, a downgrowth from the fused Müllerian ducts gives origin to a new passage, the vagina, which establishes an opening behind that of the urethra in the uro-genital fissure of the adult.

After the complete separation of the cloaca into anterior or uro-genital and posterior or rectal subdivisions, the rectum establishes a communication with the exterior in the floor of the shallow depression known as the ectodermal cloacal fossa. At a little later time the uro-genital canal also joins this fossa at a point in front of the opening of the rectum. The ectodermal cloacal fossa lies in front of the vestigial tail, and extends forwards as far as a tubercle known as the **cloacal tubercle**, which later gives rise to the **genital eminence** and a pair of elevations called the **labio-scrotal folds**. The genital eminence becomes converted into the clitoris or penis according to the sex. The labio-scrotal folds extending backwards on each side form the labia majora of the female, and, fusing posteriorly, give rise to the scrotum in the male. In the female the slit-like opening of the uro-genital canal retains its position, and its margins becoming elongated, form the labia minora. The vaginal opening arises, as we have seen, by a downgrowth of the fused Müllerian ducts which lies in front of the rectum and behind the primitive uro-genital canal. The latter becomes the urethra in the female. In the male the slit-like opening of the uro-genital canal is prolonged anteriorly by an active growth at the base of the genital eminence, and its margins uniting, give rise to the penile portion of the urethra.

THE WOLFFIAN DUCT AND EMBRYONIC EXCRETORY ORGAN.

The Wolffian Duct.—The Wolffian duct arises in the mesoderm, about the fifteenth day, as a solid cord of cells occupying a position immediately to the lateral side of the protovertebral somites and to the medial side of the body cavity (Fig. 1010). When first recognised the duct lies immediately beneath the ectoderm, and as it grows backwards to reach the cloaca it is often found to be intimately connected with the ectoderm. This close connexion of the duct with the ectoderm, in the early stages, is by some authorities supposed to indicate a primitive ectodermal origin of the canal, but by others, and apparently with more reason, to be a trace of the opening of ducts on the surface of the body, such as exists in connexion with the excretory organs of lower animals. During the third week the cellular cord which represents the Wolffian duct acquires a lumen, and about the end of the same week the duct in its growth reaches the cloaca. As soon as the cloaca has become divided into dorsal and ventral subdivisions, the Wolffian duct is seen to end in the cephalic part of the ventral subdivision, which becomes the bladder and uro-genital canal (Fig. 1012).

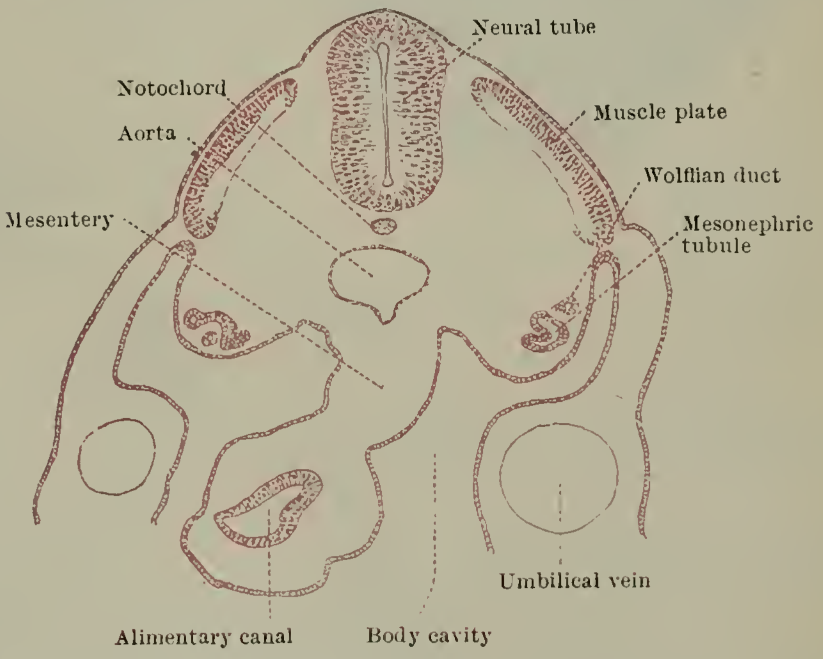


FIG. 1010.—TRANSVERSE SECTION THROUGH THE TRUNK OF A HUMAN EMBRYO OF ABOUT 5 MM. LENGTH.

The **mesonephros** or **Wolffian body** is developed in the mesoderm of the "intermediate cell mass," immediately adjoining the Wolffian duct, and consists of a number of transversely arranged canals or tubules, each of which opens by one end into the Wolffian duct, while its other extremity ends blindly. These transverse tubules, like the canal into which they open, are at first solid cellular structures, and only later acquire a distinct lumen. Increasing rapidly in size and number, the tubules become twisted and tortuous, and the blind end of each dilates to form a capsule invaginated upon itself and containing a bunch of capillary blood-vessels similar to the glomeruli of the adult kidney. It would appear that primitively one tubule is developed in the portion of the intermediate cell mass (nephrotome) corresponding to each mesodermic somite, but, in higher vertebrates at all events, such a correspondence between the number of somites and the number of tubules cannot be demonstrated. In the posterior part of the mesonephros the number of tubules is very numerous, and greater than the number of segments in this region. The tubules of the mesonephros arise in all segments from the sixth cervical to the third lumbar. The tubules in the anterior part atrophy and disappear at a very early time, even while others are being formed towards the caudal end of the embryo. When at its greatest development (fifth to eighth week) the mesonephros forms a relatively large glandular mass, composed of tubules resembling in a general way those of the adult kidney. At this time it projects into the dorsal part of the body cavity, and extends from the region of the liver to the caudal end of the body cavity. Along its lateral aspect lies the Wolffian duct.

As the permanent kidney, or metanephros, is developed the mesonephros atrophies; a portion of it, however, is retained *in the male*, and forms the excretory apparatus of the testis.

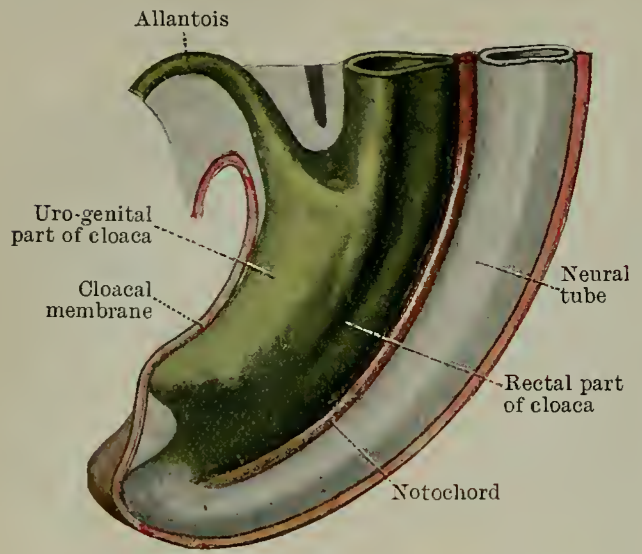


FIG. 1011.—TAIL END OF HUMAN EMBRYO BEFORE THE TIME AT WHICH THE WOLFFIAN DUCTS REACH THE CLOACA. (Drawn from a model constructed by Prof. F. Keibel.)

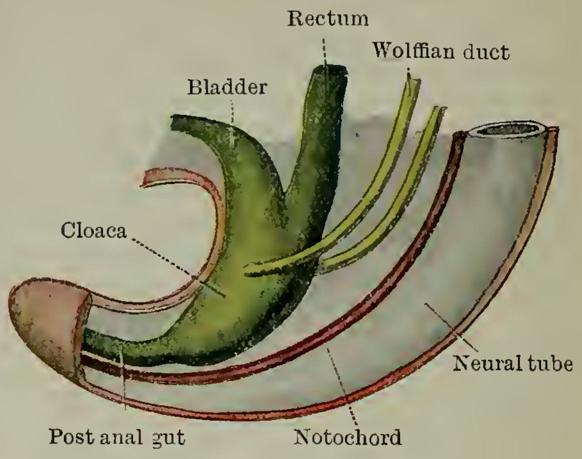


FIG. 1012.—TAIL END OF HUMAN EMBRYO. The Wolffian ducts open into the anterior part of the cloaca. (Drawn from a model constructed by Prof. F. Keibel.)

The Wolffian duct becomes the canal of the epididymis and the ductus deferens of the adult (see p. 1316). *In the female*, when the permanent kidney is formed, the mesonephros and its duct undergo atrophy to a greater extent than in the male, and they are only represented in the adult by the vestigial structures present in the broad ligament of the uterus (see pp 1298 and 1316).

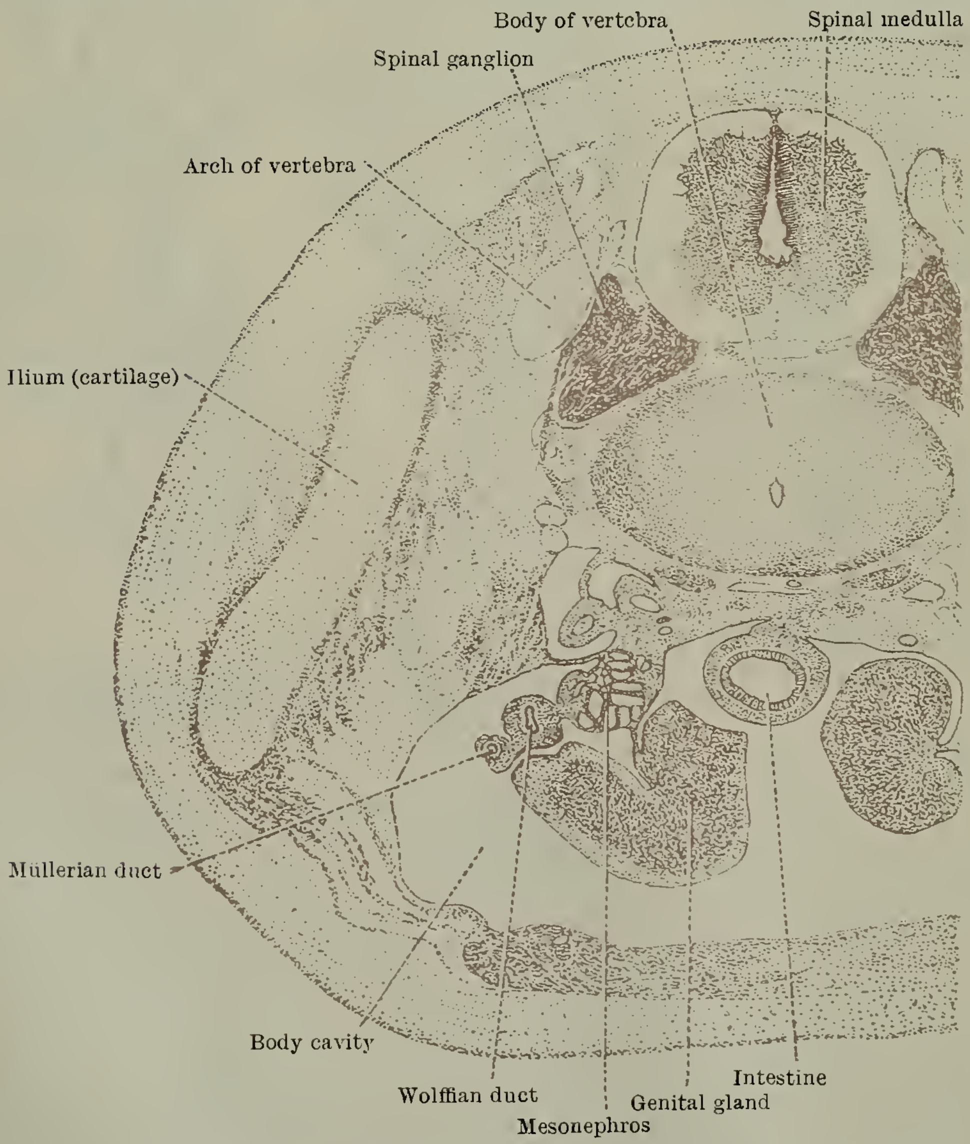


FIG. 1013.—TRANSVERSE SECTION THROUGH THE LOWER PART OF THE TRUNK OF A HUMAN EMBRYO OF ABOUT 7 WEEKS. (Specimen in the possession of Prof. J. Symington.)

In anamniate vertebrates—fishes and amphibia—the mesonephros persists as the excretory organ of the adult.

Pronephros.—From what is known regarding the development of lower animals, it seems certain that the Wolffian duct originally served as the duct of the still earlier excretory organ—the **pronephros.** In man the pronephros arises earlier than the mesonephros, and its tubules can only with difficulty be distinguished from those of the later appearing mesonephros. The tubules of the pronephros arise in all the segments from the fifth cervical to the third lumbar.

THE URETER AND PERMANENT KIDNEY.

The ureter arises as a tubular diverticulum from the Wolffian duct close to the point where the latter joins the cloaca (Figs. 1014 and 1015). This diverticulum is seen first during the fourth week, and grows from behind forwards, dorsal to the body cavity. Even in its very early condition the portion of the outgrowth which lies nearest to the Wolffian duct, and from which the adult ureter is developed, is more slender than the distal part, which becomes branched, and grows out to form the pelvis and calyces of the ureter. From the calyces numerous collecting tubules grow out into the developing kidney and acquire connexions with the glandular or uriniferous tubules of the kidney. The uriniferous tubules of the kidney arise independently of the ureter in a backward prolongation of the tissue which, further forward, gives origin to the tubules of the mesonephros. The tissue in which the permanent kidney tubules arise lies behind the third lumbar segment. The blind distal end of each tubule soon dilates to form a capsule which, becoming invaginated on itself, encloses a tuft of capillary blood-vessels. The renal corpuscles arising in this manner are found in the human kidney as early as the eighth week.

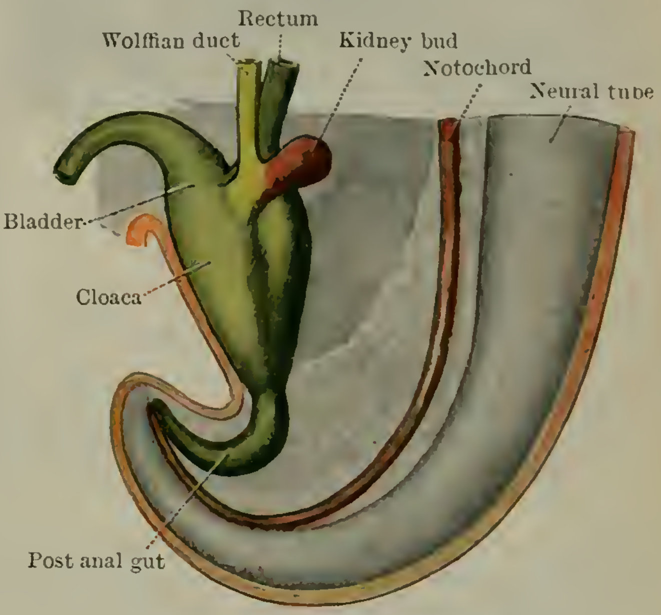


FIG. 1014.—TAIL END OF A HUMAN EMBRYO ABOUT 25 DAYS OLD.

The cloaca is dividing into rectal and urino-genital subdivisions. The ureter is arising as a bud from the Wolffian duct. (Drawn from a model constructed by Prof. F. Keibel.)

As regards their origin in the embryo we distinguish between the collecting tubules and their branches, and the uriniferous secretory tubules of the kidney. The former arise from the calyces of the ureter, and hence are derived from the Wolffian duct; the latter are formed in mesoderm, known as the metanephric cell mass, which is continuous at its anterior end with the tissue from which the mesonephros is derived. The short junctional tubules of the adult lie in the region where these developmentally distinct portions of the kidney unite.

As the ureter increases in length, it becomes separated from the Wolffian duct, and acquires a distinct opening into the anterior part of the cloaca nearer the head of the embryo than that of the Wolffian duct. This part of the cloaca receiving the ureters becomes the bladder. The kidney is at first a distinctly lobulated body, and shows at birth, and sometimes even in the adult, distinct traces of its original subdivision into lobules.

The metanephric cell mass, in which the uriniferous tubules arise, lies at first on the medial side of the bud-like outgrowth which represents the ureter; at a later time it comes to lie dorsally. As the ureter grows towards the head end of the embryo the cell mass which gives rise to the uriniferous tubules follows it; hence the metanephric tissue ceases to lie to the caudal end of the mesonephros. As the ureter divides to form the calyces, the metanephric cell mass becomes broken up into cap-like portions, one for each branch of the ureter, and later one for each of the collecting tubes which grow out from the calyces.

The formation of uriniferous tubules within the cell masses is continued until a few days after birth.

THE BLADDER.

The main portion of the bladder is formed from the superior (cephalic) part of the anterior subdivision of the cloaca. This at an early time becomes flattened dorso-ventrally, and produced laterally into two horn-like projections in the region where the Wolffian ducts open (Fig. 1015). Inferiorly it becomes constricted to form the uro-genital canal. Little by little the lower ends of the Wolffian ducts open out and are absorbed into the wall of the developing bladder, and soon it comes about that the ureters, which originally were outgrowths of the Wolffian ducts, open directly into the bladder. The openings of the ureters become shifted laterally, but the final position of the openings of the Wolffian ducts is close to the median plane in the upper prostatic part of the urethra. The bladder has therefore a double origin:—its main portion is derived from the entodermal cloaca; its smaller basal part arises from the opened-out lower ends of the Wolffian ducts. The latter portion approximately corresponds to the trigonum vesicæ of the adult, and must be regarded as having its source from the mesoderm. The extreme cephalic end of the anterior part of the cloaca tapers gradually, and beyond the umbilicus is continuous with the allantois. This part of the cloaca loses its lumen about the fifth week, and from it is derived the fibrous cord of the **urachus** or median umbilical ligament, which in the adult reaches from the bladder apex to the umbilicus.

The cavity of the urachus is sometimes not lost so early, and in rare cases it has been found persisting in the child or adult as a pervious channel extending from the apex of the bladder to the umbilicus. Here it may open on the surface of the body.

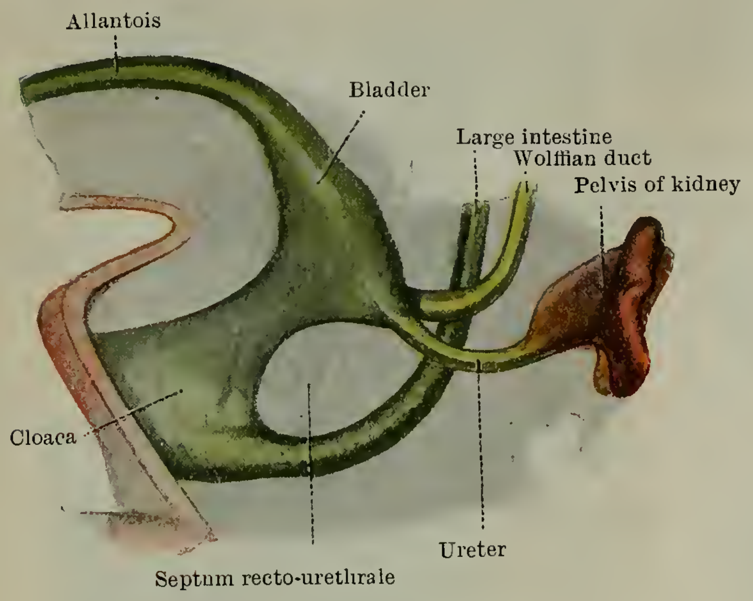


Fig. 1015.—Tail End of Human Embryo about 33 Days Old.

The cloaca is becoming separated into rectal and uro-genital portions by the formation of the septum recto-urethrale. The ureter has acquired a separate opening into the anterior division of the cloaca. (Drawn from a model constructed by Prof. F. Keibel.)

The Male Urethra.

The first part of the male urethra has an origin similar to that of the basal part of the bladder, and is derived from the ends of the Wolffian ducts (see above, p. 1310). The remaining portion, beyond the openings of the ductus deferentes of the adult, is derived from the uro-genital canal, or caudal subdivision of the anterior part of the cloaca. The uro-genital canal is early subdivided into a pelvic part lying within the future pelvis minor and a penile part which occupies the region in which the corpus cavernosum urethræ is developed. The latter part of the uro-genital canal becomes filled with closely and irregularly packed cells, which later, breaking down, re-establish the canal and give origin to a slit-like opening in the region in front of the anus. The canal for some time opens at a rhomboidal fossa situated in the groove at the base of the glans. In the glans penis a septum of densely packed cells passes forwards from this fossa and is known as the urethral septum. At a later stage these cells also break down and form a groove, the lips of which unite and enclose the terminal portion of the urethra. It is doubtful if any portion of the male urethra owes its origin to the ectoderm, but there is some evidence to show that the urethral septum is to be regarded as ectodermal, in which case the part of the canal which traverses the glans must have a like origin.

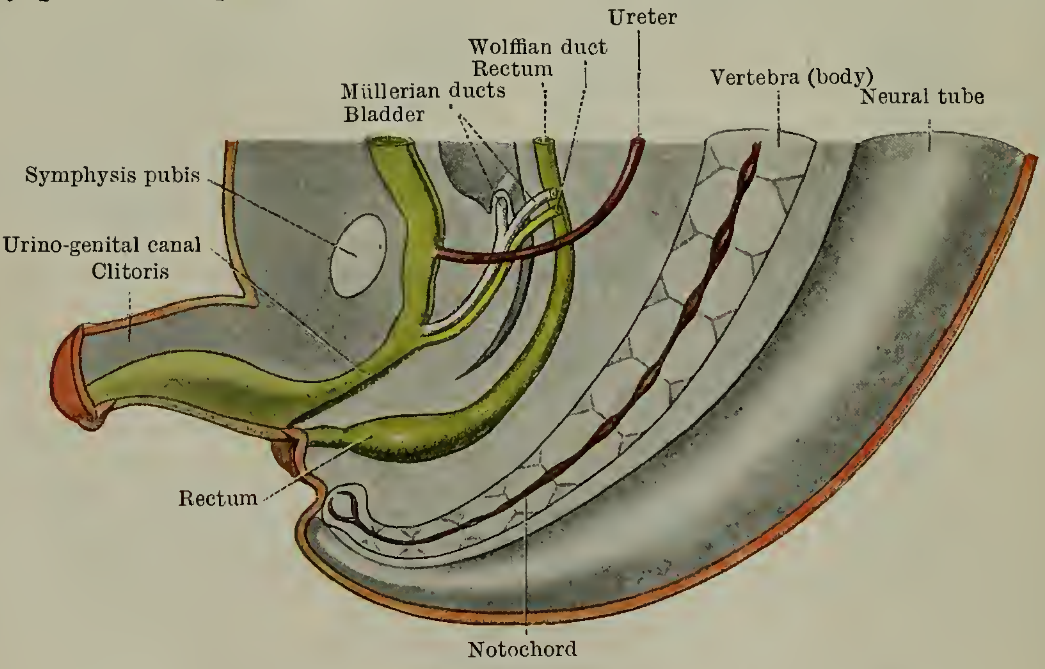


Fig. 1016.—Tail End of Female Human Embryo about 9 Weeks Old.

The rectum has acquired an opening and the entoderm of the uro-genital canal is continued into the genital eminence (clitoris). (Drawn from a model constructed by Prof. F. Keibel.)

The Female Urethra.

In the female the part of the urethra near the internal urethral orifice is developed from the inferior ends of the Wolffian ducts and has an origin similar to that of the basal portion of the bladder. The inferior part of the passage is derived from the uro-genital canal. When the uro-genital canal opens on the surface it is continued forwards as a sulcus on the genital eminence, as in the male sex. The margins of the slit-like opening do not unite, but form the labia minora of the adult, and the sulcus which appears on the glans clitoridis is closed without forming a canal. At first the fused caudal ends of the Müllerian ducts open into the uro-genital canal, but later a downgrowth, which is at first solid, establishes a connexion between these ducts and the surface immediately in front of the rectum and behind the opening of the uro-genital canal. This new connexion becomes the vagina, and the uro-genital canal the urethra. By some embryologists it is believed that a shortening and spreading out of the inferior portion of the uro-genital canal, to form a part of the uro-genital cleft of the adult, is responsible for bringing the opening of the fused Müllerian ducts to the surface. If this latter view is accepted, the female urethra corresponds to the part of the male passage which lies above the opening of the utriculus prostaticus.

THE SEXUAL GLANDS.

Sexual Glands.—In the development of the sexual glands, male and female, a differentiated thickened portion of the peritoneal epithelium is first recognised. This specialised epithelium, which has received the name of **germinal epithelium**, is situated to the medial side of the mesonephros and of the Wolffian and Müllerian ducts. Here it covers a longitudinally disposed ridge or elevation called the **genital ridge**. The germinal epithelium is not strictly limited to this ridge, but extends to some extent beyond its limits. The genital ridge is soon found to have numerous epithelial cells embedded in its connective-tissue stroma which appear to originate, in both sexes, by a proliferation from the deep surface of the germinal epithelium covering the ridge. From these epithelial cells the seminiferous tubules of the male and vesicular follicles with their contained ova of the female are developed. The tissue which gives rise to the genital ridge occurs in all the body segments from the sixth thoracic to the second sacral, but the cephalic end of the ridge atrophies before the germinal epithelium can be recognised in the more caudal segments, and only about one-fourth of the ridge gives origin to the permanent sexual gland. The part of the genital ridge which persists appears to correspond to three or four segments in the region of the 4th or 5th lumbar to the 1st or 2nd sacral segments.

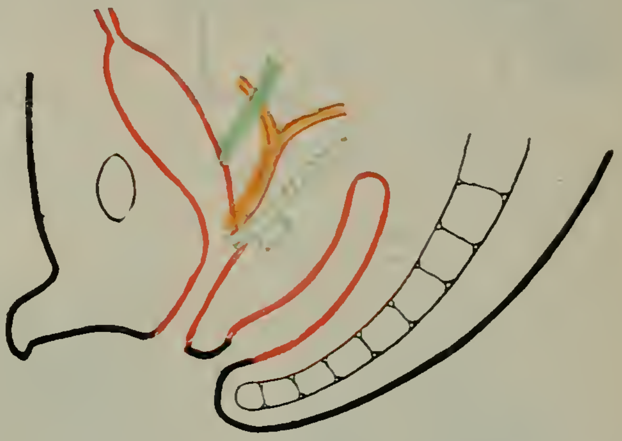


FIG. 1017.—THE URO-GENITAL PASSAGES AT THE INDIFFERENT STAGE OF DEVELOPMENT.

Ureter, green solid outline. Wolffian duct, green dotted outline. The origin of the vesicula seminalis is indicated. Müllerian ducts, orange. Rectum, bladder, and urino-genital canal, red.

In the male, as early as the thirty-third day, the epithelial cells embedded in the stroma of the developing testis have become arranged into a network of anastomosing cords within which certain larger cells are seen to be irregularly scattered. These larger cells have received the name of **primitive sperm cells**, and are relatively few in number. They undergo frequent division, and in the later stages are not to be distinguished from the other cells of the cords. The cellular cords undergo direct transformation into the **seminiferous tubules** of the testis, the **tubuli recti**, and the **rete testis**. At a very early stage the superficial part of the stroma of the developing testis becomes denser, and gives origin to the **tunica albuginea**. The tissue surrounding the cellular cords becomes converted into the septula testis and the mediastinum. A lumen can first be recognised in the seminiferous tubules in the seventh month. The rete testis becomes connected secondarily with the ductuli efferentes which are derived from tubules of the mesonephros, and thus the mesonephric or Wolffian duct becomes the passage for the secretion of the testis.

In the female, large epithelial cells are found in the stroma of the developing ovary, beneath the germinal epithelium, as early as the thirty-third day. These **primitive ova** are much more numerous than the primitive sperm cells of the male, and form a very characteristic feature of the developing ovary. At first they lie isolated, but later—about the fifth week—they become surrounded by other smaller cells having a like origin from the germinal epithelium. Each primitive ovum surrounded by its cells becomes a **primitive follicle**, the further development of which has already been described (p. 1296). During the later stages the epithelium has the appearance of growing down into the stroma in the form of long branching cellular processes which break up into little nests of cells to form the future follicles. The proliferation of cells from the surface epithelium goes on until the seventh month, but it is extremely doubtful if any new ova arise in later months of gestation or after birth.

THE GENERATIVE DUCTS.

Generative Ducts.—As has been already stated, the male ducts arise from the Wolffian and the female from the Müllerian ducts of the embryo. Both sexes at first possess well-developed Wolffian and Müllerian ducts, which are arranged in a very definite manner. The

Wolffian ducts, communicating directly with the tubules of the mesonephros, lie at first parallel to, and at a considerable distance from, one another. As they pass towards the caudal end of the embryo they approach one another, and each becomes enclosed in a fold of peritoneum called the **plica urogenitalis.** More caudally the ducts become closely approximated to each other, and are embedded in a cord-like mass of connective tissue, to which the term **genital cord** is applied. They finally open into the anterior subdivision of the cloaca (Fig. 1017).

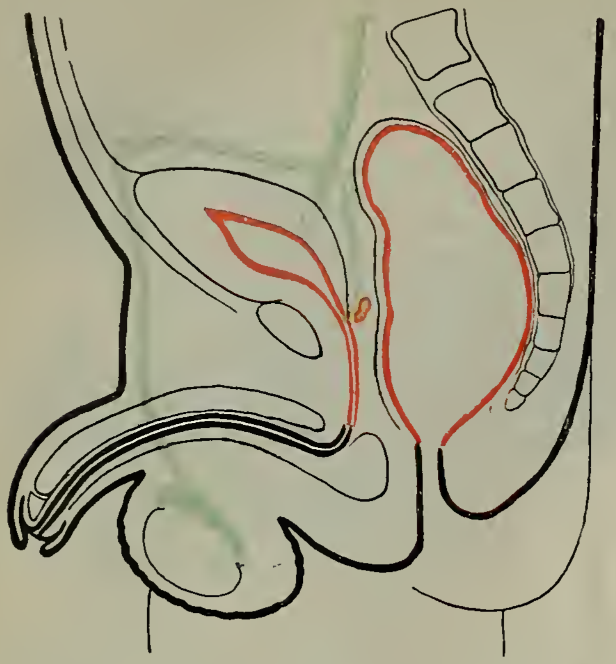


Fig. 1018.—The Uro-genital Passages in the Male.

Ductus deferens, dotted green outline. Ureter, solid green outline. Utriculus prostaticus, orange. Bladder and pelvic part of urethra, red. Penile portion of urethra, black.

The Müllerian ducts, opening freely into the body cavity at their cephalic ends, lie to the lateral side of the Wolffian ducts. As they are traced caudally they are crossed by the Wolffian ducts and enter the genital cord, within which they unite and form a canal, which occupies the median plane, and opens into the anterior subdivision of the cloaca, between the Wolffian ducts (Fig. 1017). The manner in which the ureters become separated from the Wolffian ducts has already been described.

Ducts in the Male.—The seminiferous tubules of the testis become connected with the Wolffian duct through a fusion of certain tubules of the mesonephros with the **rete testis.** The connexion is definitely established in the third month. The number of tubules taking part varies considerably, but corresponds to the number of **ductuli efferentes** found in the adult. The connecting tubules becoming more convoluted, just as they join the Wolffian duct, form the **lobules of the epididymis.** The **canal of the epididymis** is directly formed from the cephalic part of the Wolffian duct, and the **ductus deferens** from the more caudal portion. The **ductuli aberrantes** and the rudimentary tubules of the **paradidymis** are to be looked upon as persistent tubules, of a more caudal portion of the Wolffian body, which have failed to become connected with the tubules of the testis.

The **seminal vesicles** are developed in the third month as evaginations which arise from the Wolffian ducts, near their caudal extremities. Each at first has the appearance of a longitudinal groove in the wall of the ductus deferens, which closes over and becomes cut off from the main tube except at the point where, later, the duct of the seminal vesicle joins the ductus deferens.

The Müllerian ducts atrophy in the male embryo, but the appendices of the testis are vestigial remains of their cephalic portions, while the **utriculus prostaticus** represents the caudal fused portions which, in the embryo, occupy the genital cord.

Ducts in the Female.—The Müllerian ducts in the female retain their openings into the body cavity, and their cephalic portions become the uterine tubes. Their fused caudal parts, which at first join the uro-genital canal, give rise to the **uterus** and **vagina.** The manner in which the original position of the opening of the Müllerian ducts becomes shifted, by the formation of a new passage or by the shortening of the uro-genital canal, has already been mentioned (p. 1315). The final position of the opening is in the uro-genital cleft of the adult.

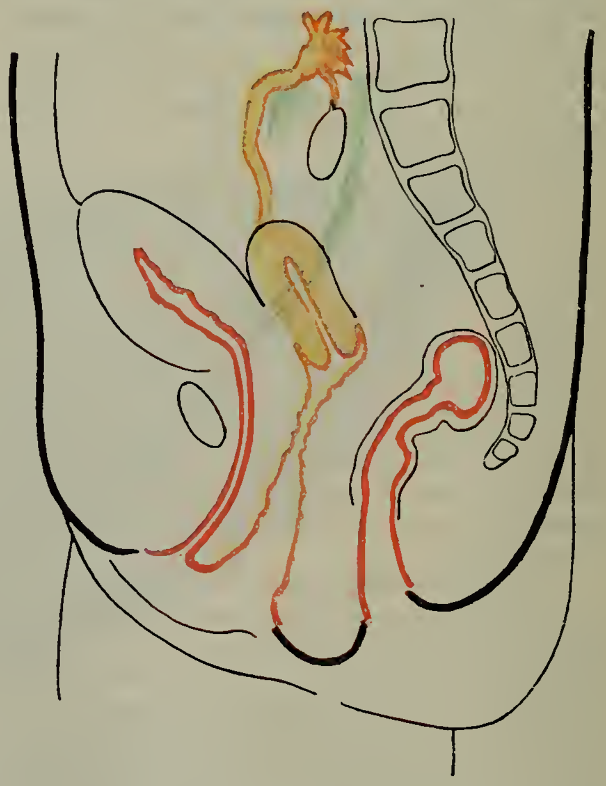


Fig. 1019.—The Uro-genital Passages in the Female.

Derivations of the Müllerian ducts, orange. Ureter, green solid outline. The ep-oöphoron is indicated in green near the opening of Müllerian duct and near the ovary.

The vaginal portion of the fused Müllerian ducts is at first relatively very short, and at the point where it opens into the uro-genital canal a slight fold appears, which is the future **hymen.** The vagina increases rapidly in length as its opening moves downwards towards the uro-genital cleft. In the human embryo during the third month the closely applied Müllerian ducts, which higher up have fused to form the uterus, are represented at their inferior ends by a pair of rapidly elongating solid cellular cords, which at a later stage break down to form the vagina.

The Wolffian ducts and the mesonephros atrophy in the female, but traces of them are to be found in the ep-oöphoron and par-oöphoron of the adult. In the fœtus the Wolffian duct can be traced along the side of the uterus as far as the upper end of the vagina.

Prostate.—The glandular portion of the prostate arises as a series of solid outgrowths from the epithelium of the uro-genital canal during the third month. The outgrowths, which are at first simple, become branched and finally acquire a lumen. They are arranged in three groups—an upper and a lower dorsal, and a ventral group. The glands of the ventral group soon become reduced in number and often completely disappear; those of the upper dorsal group form the chief part of the gland.

The prostatic glands arise in both sexes, but in the female, where they are known as para-urethral glands, they are few in number and not densely packed as in the male. The muscular tissue of the prostate is derived from the muscular wall of the urethra.

The **bulbo-urethral glands** arise in the third month, and appear to be developed from the epithelium of the uro-genital canal.

The **larger vestibular glands** in the female arise as epithelial outgrowths in the same manner as the bulbo-urethral glands.

EXTERNAL GENITAL ORGANS.

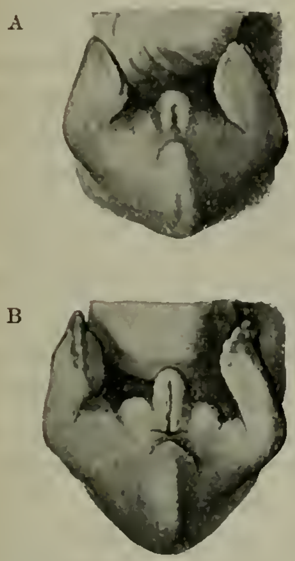


FIG. 1020.—EXTERNAL GENITAL ORGANS, HUMAN EMBRYOS. Indifferent stage. A. Embryo of 20 mm. B. Slightly larger.

The genital eminence and the labio-scrotal folds are well seen.

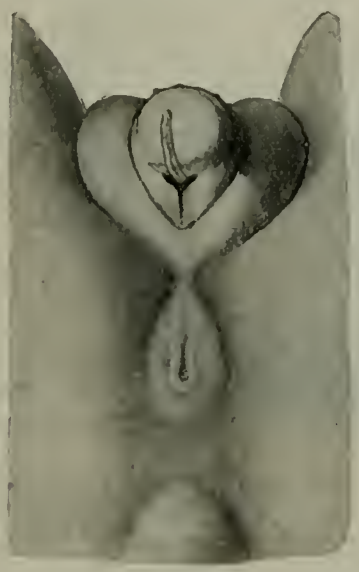


FIG. 1021. — EXTERNAL GENITAL ORGANS, MALE EMBRYO.

Formation of scrotum. The labio-scrotal folds, formerly best marked at the sides of the genital eminence, have grown backwards and united behind the primitive uro-genital opening, to form the raphe scroti. The genital folds embrace the base of the genital eminence or penis. The glans is very prominent.

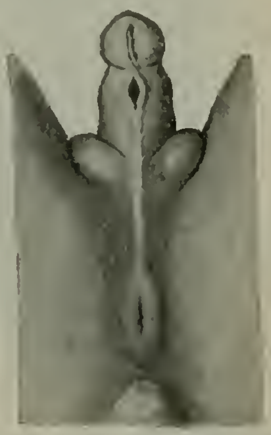


FIG. 1022. — EXTERNAL GENITAL ORGANS, MALE EMBRYO.

Behind the glans penis the urethra opens in a diamond-shaped fossa in the dorsal wall of which the median raphe ends. The prepuce is formed behind the constriction which marks off the glans, and as it grows forwards the constriction disappears.

A little horn-like process of epithelium is present on the summit of the genital eminence.

The external genital organs are developed in the region of the ectodermal cloacal fossa, and those of the male and female cannot be distinguished from one another in the earlier stages. The fossa at first extends on the ventral aspect of the body almost from the tail to the umbilical cord. At its cephalic end is a tubercle known as the **cloacal tubercle**, and behind lies the coccygeal tubercle. Immediately in front of the latter the anus is formed, and between this opening and the cloacal tubercle the uro-genital canal opens on the surface by a median slit-like aperture, the **primitive uro-genital opening**.

The cloacal tubercle early becomes subdivided into an apical **genital eminence** which occupies the middle line and lies at the cephalic end of the slit-like uro-genital opening, and a basal portion which lies nearer to the umbilicus and also curves round the sides of the genital eminence. At a later time the basal part is continued to form a prominent fold on each side of the ectodermal cloacal fossa. These folds are called the labio-scrotal folds and, *in the female*, give rise to the labia majora. The lateral margins of the primitive uro-genital opening give origin to the labia minora, and the genital eminence becomes the clitoris. On the clitoris at a very early date a relatively large glans is marked off by a surrounding sulcus. *In the male* the scrotal folds grow backwards, and meeting behind the primitive uro-genital opening, fuse together. In this way the opening is pushed forwards. The genital eminence elongates rapidly owing to a growth at its basal part, and a sulcus which is formed on its cloacal aspect gradually becomes converted into a canal by the closure of the lateral lips of the primitive uro-genital opening. Soon the uro-genital opening is found to lie nearer the apex than the base of the eminence, which has now given rise to the penis. For some time the opening in the male lies at the base of the glans penis and is somewhat rhomboidal in outline. At a later time, owing to the breaking down of a dense septum of epithelial cells which appears within the glans, a sulcus and finally a canal arises within this part of the penis and thus the terminal part of the urethra is formed. When the opening at the base of the glans is closed the continuous urethral passage is established. The main portion of the urethra is entodermal in origin, but there is some evidence to indicate that the part which traverses the glans has its origin from the ectoderm.

THE MAMMARY GLANDS.

The **mammæ** or breasts are accessory organs connected with the female reproductive system. Each gland is situated in the superficial fascia covering the anterior aspect of the thorax, and usually extends from the level of the second or third to that of the sixth rib. The hemispherical projection formed by the gland lies upon the superficial aspect of the pectoralis major and to a less extent upon the serratus anterior muscle. Near the summit of each mammary elevation, and usually at the level of the fourth or fifth rib, is placed the wart-like **nipple** or papilla mammæ, which is pierced by the minute openings of the lactiferous ducts and is surrounded by a coloured circular area of skin called the **areola**. The skin covering the nipple is thrown into numerous wrinkles, and on the areola exhibits many minute rounded projections due to the presence of underlying cutaneous glands. These **areolar glands** are considered to represent rudimentary portions of the mamma. The colour of the nipple and areola varies with the complexion of the individual, but in young subjects they are usually of a somewhat rosy-pink colour, which changes to a deep brown during the second and third months of first pregnancy. Also, during pregnancy, the areola increases in size and its glands become more marked. The nipple contains a considerable number of unstriped muscle fibres, and becomes firmer and more prominent as a result of mechanical stimulation.

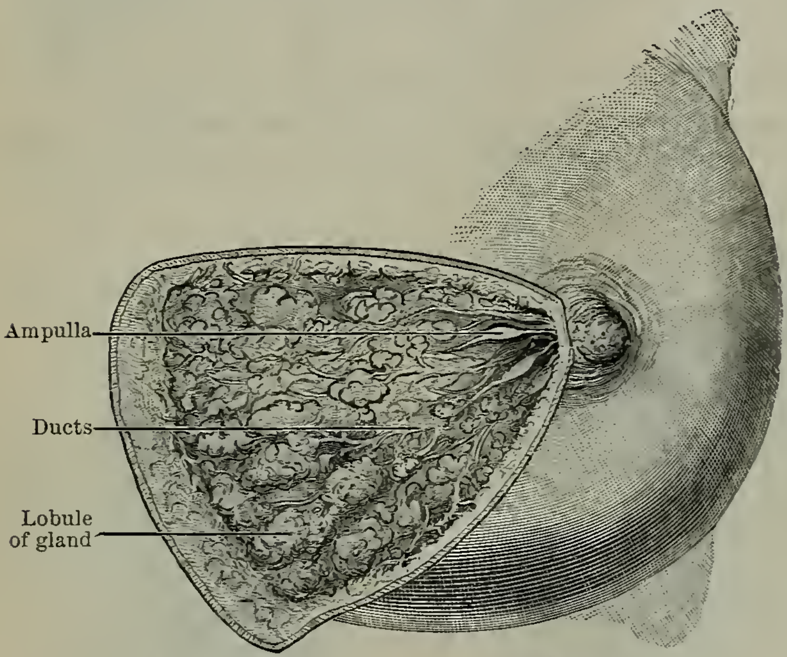


FIG. 1023.—DISSECTION OF THE MAMMA.

The size and appearance of the mammæ vary much, not only in the different races of mankind, but also in the same individual under different conditions. In the young child the mammæ are small, and there is little difference between those of the male and female. Their growth is slow until the approach of puberty, and then the female mammæ increase rapidly in size. At each pregnancy the mammæ become large, and they attain their greatest development during lactation. The size of the mamma depends partly on the amount of superficial fat and partly on the amount of glandular tissue present.

Structure of the Mamma.—The mamma is composed of a mass of glandular tissue traversed and supported by strands of fibrous connective tissue, and covered by a thick layer of fat. The glandular tissue, to which the term **corpus mammæ** is applied, forms a somewhat conical mass, the apex of which corresponds to the position of the nipple, while its base is loosely connected to the fascia covering the pectoralis major and serratus anterior muscles. In section the corpus mammæ is readily distinguished from the surrounding fat by its firmer consistency and by its pinkish-white colour. The corpus mammæ is composed of lobes and lobules, and its superficial aspect and edges are very uneven, the inequalities of its surface being filled up by processes of the fatty tissue which forms a covering for the gland. This fatty covering is incomplete beneath the areola, and here the lactiferous ducts pass into the nipple. The gland is composed of fifteen to twenty **lobes**, which radiate from the nipple, each lobe being quite distinct from the others and possessing its own duct. The lobes are subdivided into secondary lobes and lobules, bound together and supported by a considerable amount of connective tissue which forms the **stroma** of the gland.

The alveoli of the gland and the secretory epithelium lining them vary much under different conditions. At puberty the corpus mammæ is composed chiefly of connective-tissue stroma and the ducts of the gland. At this time the alveoli are small and few in number. During lactation, when the gland is fully functional, the alveoli are enlarged, distended with fluid, and much more numerous. The epithelial cells are cubical and filled with fat globules. When the gland is not secreting, the alveoli become small and reduced in number, while the cells of the lining epithelium, which are now small and glandular, do not contain fat globules.

The **lactiferous ducts**, passing towards the nipple, become enlarged to form small spindle-shaped dilatations, called *ampullæ*, or **sinūs lactiferi**; then becoming once more constricted, each duct passes, without communicating with its neighbours, to the summit of the nipple, where it opens.

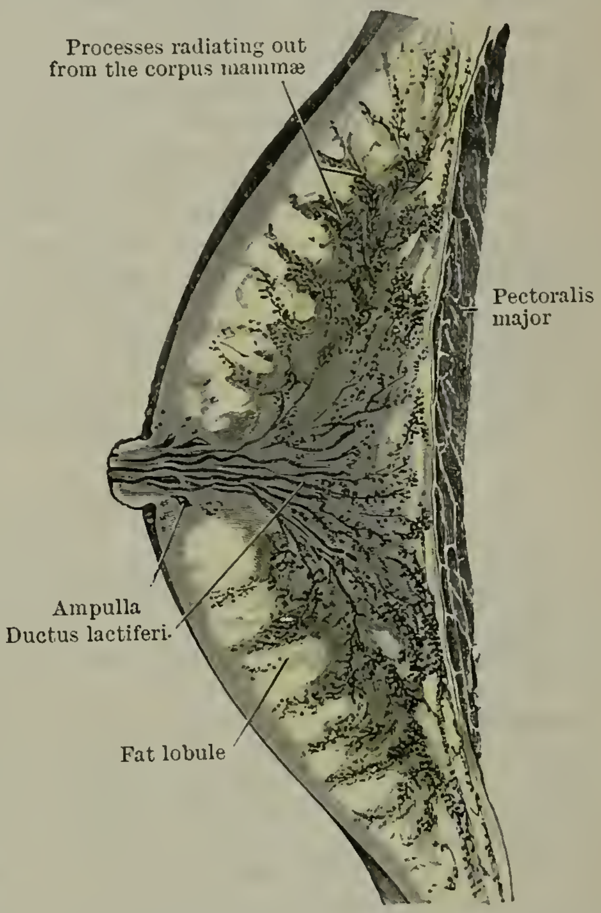


Fig. 1024.—Section through a Mammary Gland. Prepared after immersion in nitric acid as recommended by Sir Harold Stiles. (D. J. Cunningham.)

In the male subject the various parts of the mamma are represented in a vestigial condition.

The presence of milk-glands is characteristic of the class mammalia, and the number of pairs of glands in each group of animals bears some relation to the number of young usually produced at each birth.

Variations.—Asymmetry in the development of the mammæ is very common—the left mamma being very often larger than the right. Absence of one or both mammæ is a very rare abnormality, which may or may not be associated with absence of the nipples. When one nipple only is present it is usually the left. The presence of supernumerary glands or nipples is not very uncommon. The term **polymasty** has been applied to cases in which more than the normal number of mammæ are present, and **polythely** to those in which additional glands, in a vestigial condition, are represented by accessory nipples. Usually the accessory glands, or nipples, are present on the anterior aspect of the thorax, and in most instances they occur below and a little to the medial side of the normal site. When the abnormal glands are found above the normal site they generally lie further from the median plane. Much more rarely accessory glands have been found on the abdomen, in the axilla, or in some other situation, including even the dorsal aspect of the trunk. As many as three extra pairs of mammæ have been found in the same individual, and cases in which the probable representatives of mammary glands were even more numerous have been recorded. Asymmetry is very common in these abnormal structures. It is interesting to note that examples of polymasty and polythely occur in the male rather more frequently than in the female. In some women the accessory breasts have yielded milk during lactation; in most cases the abnormal organs are very rudimentary, and represented only by a minute nipple or pigmented areola. These cases of polymasty and polythely are supposed to represent a reversion to an ancestral condition, in which more than two mammary glands were normally present, and in which probably many young were produced at each birth. In this connexion it is interesting to observe that usually the accessory glands occur in positions normally occupied by mammæ in lower animals. In the course of the development of the mammæ in man, specialised areas of the epidermis, similar to those which give origin to the mammæ, have been observed both superior and inferior to the region in which the adult mammæ are developed. These areas appear to be present normally, but in most cases they disappear at an early stage in the history of the embryo. In some other mammals rudimentary mammæ may occur, as, for instance, in lemurs and in cows.

A slight functional activity of the mammary glands of the male at birth and about the time of puberty is stated to be a not very uncommon occurrence.

Vessels and Nerves of the Mamma.—The breast receives its arterial supply from the perforating branches of the internal mammary artery and from the external mammary branches of the lateral thoracic. Additional supply is sometimes derived from some of the intercostal vessels. The veins coming from the gland pour their blood into the axillary and internal mammary veins. Some small superficial veins from the breast join tributaries of the external jugular.

The **lymph vessels** of the breast are very numerous, and form extensive lymph spaces round the alveoli of the gland. These freely anastomose with the lymph vessels of the skin and more especially with the vessels of a very large anastomotic circle deep to the skin of the nipple. The lymph vessels coming from the deep parts of the mamma for the most part join the lymph glands of the axilla. They first run directly towards the deep surface of the breast, where they enter the fascial lymph vessels contained in, or lying deep to, the fascia of the pectoralis major. These fascial vessels end for the most part in the axillary glands. It is important to remember that while the majority of the lymph vessels first reach the lymph glands lying on the lateral border of the pectoralis major, some free vessels may "short circuit" to glands—(1) in the floor of the axilla, (2) along the circumflex vessels, (3) even to glands along the axillary vein. Yet other lymph vessels of the breast may reach first the glands in the costo-coracoid space. Some vessels from the medial part of the breast, following the course pursued by the perforating arteries, may join the lymph glands situated along the course of the internal mammary artery, but these vessels are fortunately often absent. It is also to be remembered that a few, probably irregular, communications exist across the middle line with the lymph vessels of the opposite breast; and further that lymph vessels from the infero-medial area of the breast regularly join the fascial lymph vessels of the upper part of the sheath of the rectus abdominis, and through these make communication with the lymph vessels of—(1) the round ligament of the liver, (2) the peritoneum generally, and ultimately with the abdominal lymph glands. The surgical importance of the facts regarding the lymphatic drainage of the breast cannot be exaggerated.

The **nerve-supply** of the gland is derived from the **intercostal nerves** of the fourth, fifth, and sixth intercostal spaces. Along the course of these nerves sympathetic filaments reach the breast from the thoracic part of the sympathetic trunk.

DEVELOPMENT OF THE MAMMÆ.

The mammæ are developed as downgrowths of the ectoderm into the underlying mesodermic tissue. In the human embryo a thickened raised area of the ectoderm can be recognised in the region of the future mamma at the end of the fourth week. This thickened ectoderm becomes depressed in the underlying mesoderm, and thus the mammary area soon becomes flat, and finally sunk below the level of the surrounding epidermis. The mesoderm, where it is in contact with this downgrowth of the ectoderm, is compressed, and its elements become arranged in concentric layers, which, at a later stage, give rise to the connective-tissue stroma of the gland. The depressed mass of ectoderm cells soon becomes somewhat flask-shaped, and grows out into the surrounding mesoderm as a number of solid processes, which represent the future ducts of the gland. These processes, by dividing and branching, give rise to the future lobes and lobules, and much later to the alveoli. The mammary area becomes gradually raised again in its central part to form the nipple. A lumen is formed in the different parts of this branching system of cellular processes only at birth, and with its establishment is associated the secretion of a fluid resembling milk, which often takes place at this time. The ampullæ appear as thickenings on the developing ducts before birth.

In those animals which possess a number of mammary glands—such as the cat and pig—the thickening of the ectoderm, which is the first indication of the development of these structures, takes the form of a pair of ridges extending from the level of the forelimb towards the inguinal region. These converge posteriorly, and at their terminations lie not far from the middle line. By the absorption of the intermediate portions the ridges become divided up into a number of isolated areas, in connexion with which the future glands arise. Somewhat similar linear thickenings of the ectoderm have also been recognised in the human embryo, and the usual positions assumed by the accessory glands when present lead us to suspect that in all probability the ancestors of man possessed numerous mammæ arranged, as in lower animals, in lines converging towards the inguinal region.

THE DUCTLESS GLANDS.

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THE title, the *ductless glands* (B.N.A. glandulæ clausæ), denotes a rather diversified group of organs.

Their common character, implied in their designation as glands, is that they elaborate some special product or products. The material thus elaborated passes directly into the circulation without traversing any special channels or ducts.

These products of glandular activity are in several instances chemical substances of more or less definite composition. This is the case with the adrenin produced by the medulla of the suprarenal gland. To the same general category of gland belong the thyreoid and parathyreoid glands, the hypophysis and, probably, the pineal body. Such ductless glands are therefore organs of internal secretion in the definite chemical sense. They are frequently known as endocrine organs.

There are, however, certain other organs, ordinarily reckoned as members of the group of ductless glands, which possess a somewhat different character. In them the elaboration of a chemical internal secretion is not the outstanding and characteristic function. The predominant activity of the spleen, for example, consists in the formation and the destruction of organised structural units in the form of living blood cells. The activity of the thymus gland is likewise in large measure cytoblastic. It is true that there is a good deal of evidence to show that the thymus does exert an influence of a chemical nature upon the general bodily metabolism. But this may also be said of many other organs. The liver, pancreas, gastric and intestinal mucous membranes; the kidneys, testes, and prostate; the uterus and ovaries have all been recognised as sources of more or less active products which enter the general circulation and affect the metabolic balance of the body. But these organs are not on that account reckoned as ductless glands or endocrine organs, though it is not improbable that specific portions of some of them, like the islets of Langerhans in the pancreas and the interstitial cells of the testes and ovaries, are actually entitled to some such recognition.

From the point of view of both its structural and functional affinities the spleen ought to be grouped with other corpuscle-forming or hæmopoietic organs like the lymph and hæmolymph glands. The latter indeed appear to present a structure intermediate between splenic and lymph-glandular tissue.

A valid and perhaps a useful distinction might very well be drawn between organs whose sole or whose characteristic function is to elaborate internal secretions of a chemical nature, and those whose output of material is in the form of organised corpuscular structures.

It is the former group that constitutes the ductless glands *sensu stricto*.

Were this distinction generally recognised it would tend to exclude the spleen—and possibly also the thymus, in spite of its ontogenetic affinity with the thyreoid apparatus—from the class of ductless glands. These organs will nevertheless be here included with the ductless glands proper in accordance with anatomical use and wont.[1]

Under the general heading of ductless glands we include, for descriptive purposes, in this section—

1. The suprarenal gland.
2. The various "paraganglia," including the "aortic bodies."
3. The glomus caroticum or glandula carotica.
4. The glomus coccygeum.
5. The thyreoid gland.
6. The parathyreoid glands.
7. The thymus gland.
8. The hypophysis cerebri (pituitary body or gland).
9. The pineal body.
10. The spleen.

In addition to these more definite and discrete masses, glandular endocrine tissue may be present in the substance of other organs. It is held by many that the so-called "islets of Langerhans" scattered throughout the pancreas, and the "interstitial cells" disseminated throughout the stroma of the testis and ovary, represent specific endocrine tissue. But inasmuch as these disseminated elements, even if genuinely endocrine in function, do not constitute anatomically defined organs or masses, they are not dealt with in the present connexion. There is also a good deal of evidence that the significance of the corpus luteum of the ovary may be summed up in its internal secretory activities. It may be looked upon as a cyclically-appearing ductless gland. Its appearance is described in connexion with the structure of the ovary.

The various members of this rather heterogeneous collection of organs differ amongst themselves in structural features, in physiological characters, and in developmental origin.

They may be divided up into several subordinate groups, although any such attempt at classification is complicated by the fact that several of them exhibit a duplex constitution owing to a dual origin from developmentally distinct primordia.

The following sub-groups may be recognised:—

(1) A chromaffin group, of ectodermal origin, including the medulla of the suprarenal gland and various "paraganglionic" masses.

(2) A cortical group, of mesodermal origin, represented by the cortex of the suprarenal gland and by the occasional "accessory cortical bodies" of similar character.

(3) A pharyngeal pouch group, of entodermal origin, which includes the thyreoid gland, the parathyreoid glands, and the thymus glands. With the thyreoid, in its embryonic condition, are associated also the ultimo-branchial bodies. These, however, soon disappear as such.

(4) A cerebro-glandular group of ectodermal origin, consisting of the pituitary hypophysis and the pineal body.

(5) A lymphoid group, of mesodermal origin.

This group might well be so extended as to become the practical equivalent of the B.N.A. group of "glandulæ vasculares." This includes the spleen, thymus, tonsils, lymph glands (including hæmolymph glands) and the lymphatic nodules or follicles. The group thus established offers, as already suggested, a significant contrast to the preceding, more distinctively endocrine, groups. But existing anatomical convention annexes the description of the lymph glands to the vascular system and that of other lymphatic follicular structures to the alimentary system. The thymus will be dealt with in the company of its developmental congeners, the thyreoid and parathyreoid glands. The spleen, therefore, alone remains to represent in this chapter the lymphoid group of the ductless glands.

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[1] The category of "glandulæ clausæ" of the B.N.A. terminology is obviously the nominal equivalent of the "ductless glands." But the B.N.A. usage excludes from that category the entire group of "glandulæ vasculares" which embraces the spleen, thymus, and tonsil as well as the lymph glands and lymphatic nodules.

1. THE CHROMAFFIN GROUP.

(Synonyms : *Chromaphil, Phæochrome, System.*)

This group consists of a number of masses of glandular tissue containing cells which produce the substance known as adrenin. The tissue is called chromaffin, or chromaphil, tissue, on account of its affinity for chromium salts which give a brown or yellow reaction with the specific granular content of the cells. The general distribution of the masses of tissue forming the system is shown in Fig. 1025. They all originate in intimate association with the primordia of the

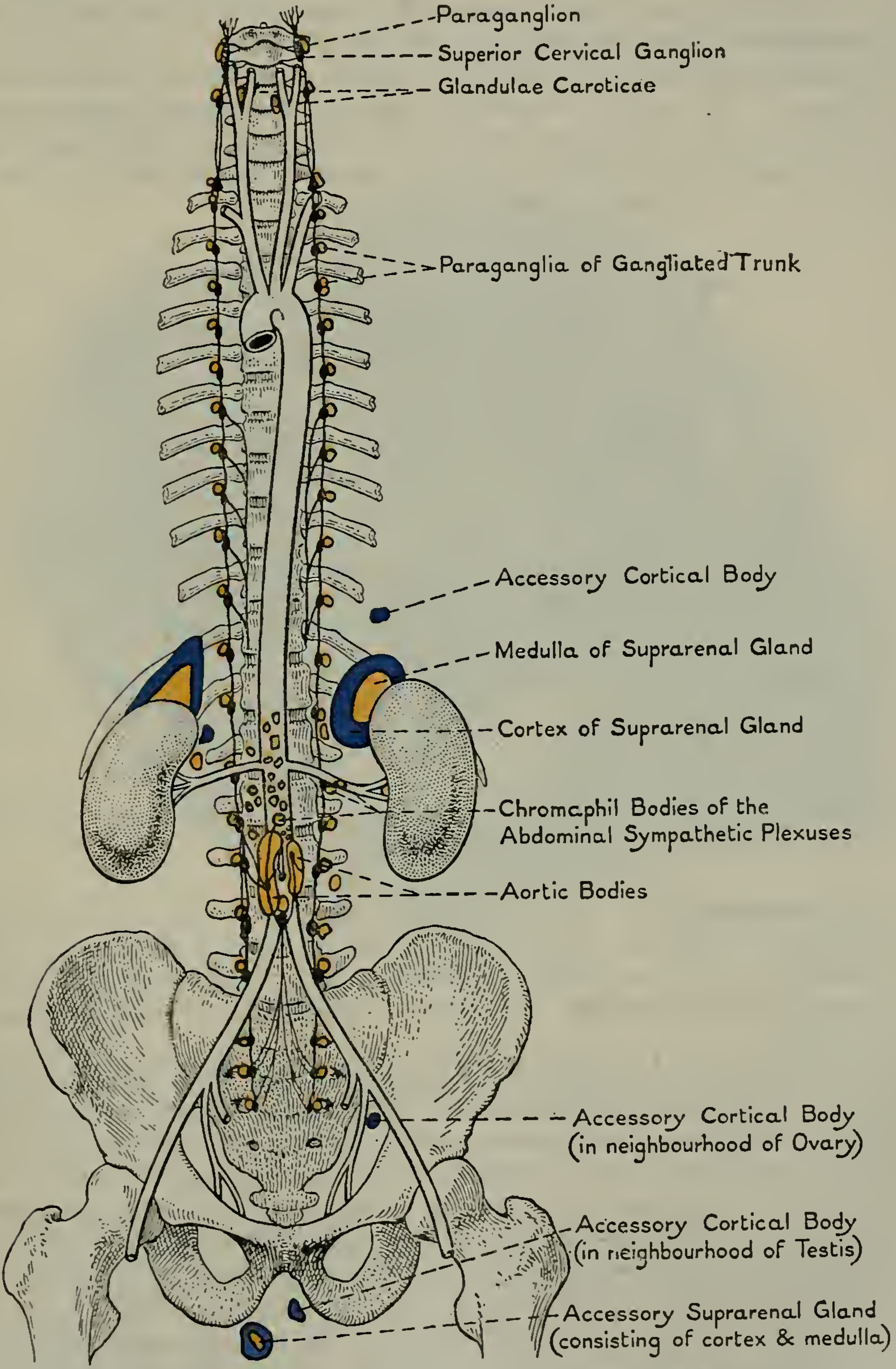
Paraganglion
Superior Cervical Ganglion
Glandulae Caroticae
Paraganglia of Gangliated Trunk
Accessory Cortical Body
Medulla of Suprarenal Gland
Cortex of Suprarenal Gland
Chromaphil Bodies of the Abdominal Sympathetic Plexuses
Aortic Bodies
Accessory Cortical Body (in neighbourhood of Ovary)
Accessory Cortical Body (in neighbourhood of Testis)
Accessory Suprarenal Gland (consisting of cortex & medulla)

Fig. 1025.—Diagram of the Chromaffin and Cortical Systems. Modified from Swale Vincent
Chromaffin tissues = yellow ; cortical tissue = blue.

sympathetic nervous system. Indeed, the characteristic chromaffin cells and the cells of the sympathetic ganglia are both alike derivatives from a common mother type of cell.

The chromaffin group includes (i.) paraganglia associated with the "vertebral" or "lateral" ganglia of the sympathetic trunk; (ii.) paraganglia associated with the sympathetic plexuses, more especially in the abdominal region: these are doubtless cell masses having a common origin with the "prevertebral" or "collateral" ganglia of these plexuses; (iii.) the glandulæ caroticæ (B.N.A. glomera carotica) which are probably likewise paraganglionic in origin; (iv.) possibly, though more doubtfully, the glomus coccygeum: this body, though said to contain no actual chromaffin tissue, appears nevertheless to be connected in development with the sympathetic; and (v.) the medullary portions of the suprarenal glands.

(i.) The **paraganglia** associated with the ganglia of the sympathetic trunk are rounded masses of chromaffin tissue, 1-3 mm. in diameter, placed inside, half inside, or immediately outside the capsules of the ganglia. Typically one paraganglion, but occasionally more than one, is associated with each ganglion. They correspond to the "suprarenal bodies" of the Selachia.

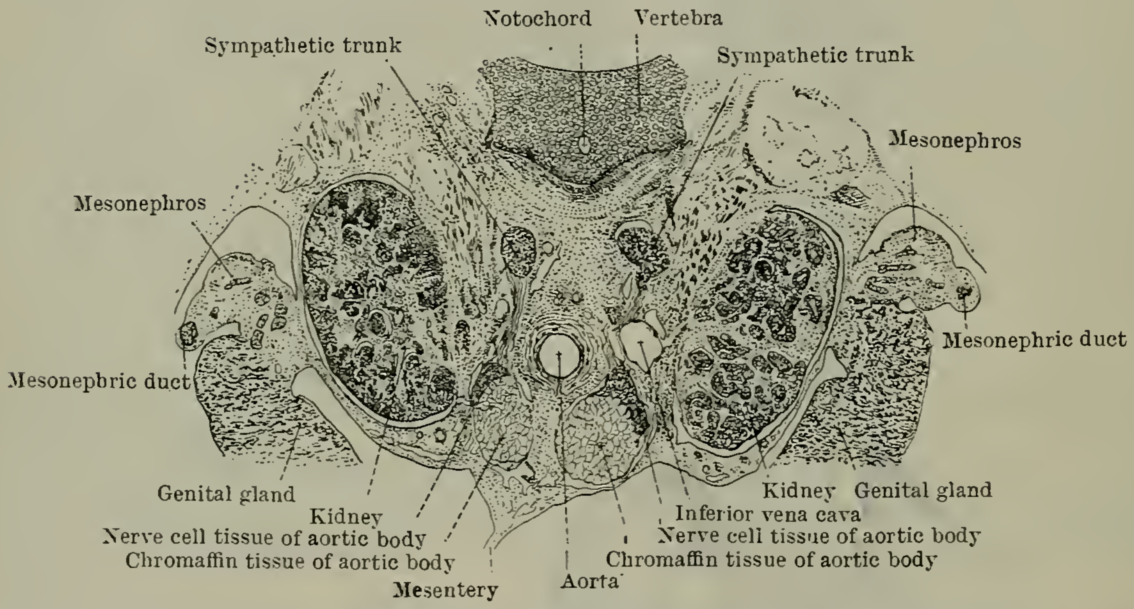

FIG. 1026.—TRANSVERSE SECTION OF PART OF THE ABDOMINAL REGION OF A 25-MM. HUMAN EMBRYO. Seen from below, showing aortic bodies.

(ii.) The **paraganglia** of the sympathetic plexuses occur both in association with the "collateral" ganglia and scattered throughout the plexuses. They may be very numerous—up to as many as seventy have been counted—though the number is usually much smaller. Increase in the number may be due to subdivision of masses.

They are also found in relation to viscera, where they doubtless originate in common with "terminal" or "peripheral" sympathetic ganglionic groups. The viscera to which they have been found related include the kidney with its pelvis and ureter, the suprarenal gland, the prostate, the paroöphoron and ovary, and the epididymis. The most important paraganglia or chromaphil bodies of the sympathetic plexuses are the two *aortic bodies* which lie ventral to the aorta in the region of the origin of the inferior mesenteric artery (Fig. 1026). In the new-born child they are smooth brownish structures, elongated in the cranio-caudal direction, and about a centimetre in length. Their form and arrangement are, however, subject to considerable variation, and they are often united medially by an isthmus. They undergo regressive change as life advances, ceasing to be visible soon after puberty though recognisable microscopically until middle life. In the vicinity of the aortic bodies there are usually numerous small masses of like character and of varying size and shape. Fig. 1026 illustrates the appearance of the aortic bodies as seen in a transverse section through the abdominal region of a human embryo of 25 mm. The relations of the aortic bodies to the aorta, the kidneys, the sympathetic nerve plexuses, and the root of the mesentery are evident. The darker stippled areas along the periphery of the bodies represent developing sympathetic ganglia of the abdominal plexus.

(iii.) The **glandula carotica** (B.N.A. **glomus caroticum**; O.T. **intercarotid body**) is a bilateral paired organ situated in close but slightly variable relation to the bifurcation of the common carotid artery. It is associated with the carotid, or intercarotid, nerve plexus. There is often a localised thickening of the adjacent arterial wall. Frequently it lies deep to the bifurcation; sometimes it is wedged in between the internal and external carotids at their commencement; sometimes it is placed between them at a slightly higher level. Its shape varies with its position. When free from pressure it is oval; when compressed by the internal and external carotids it is wedge-shaped. On the average, its height is 7 mm., its breadth 1·5-5 mm. Not infrequently it is split into two or more nodules. Its colour is grayish, yellowish, or brownish red.

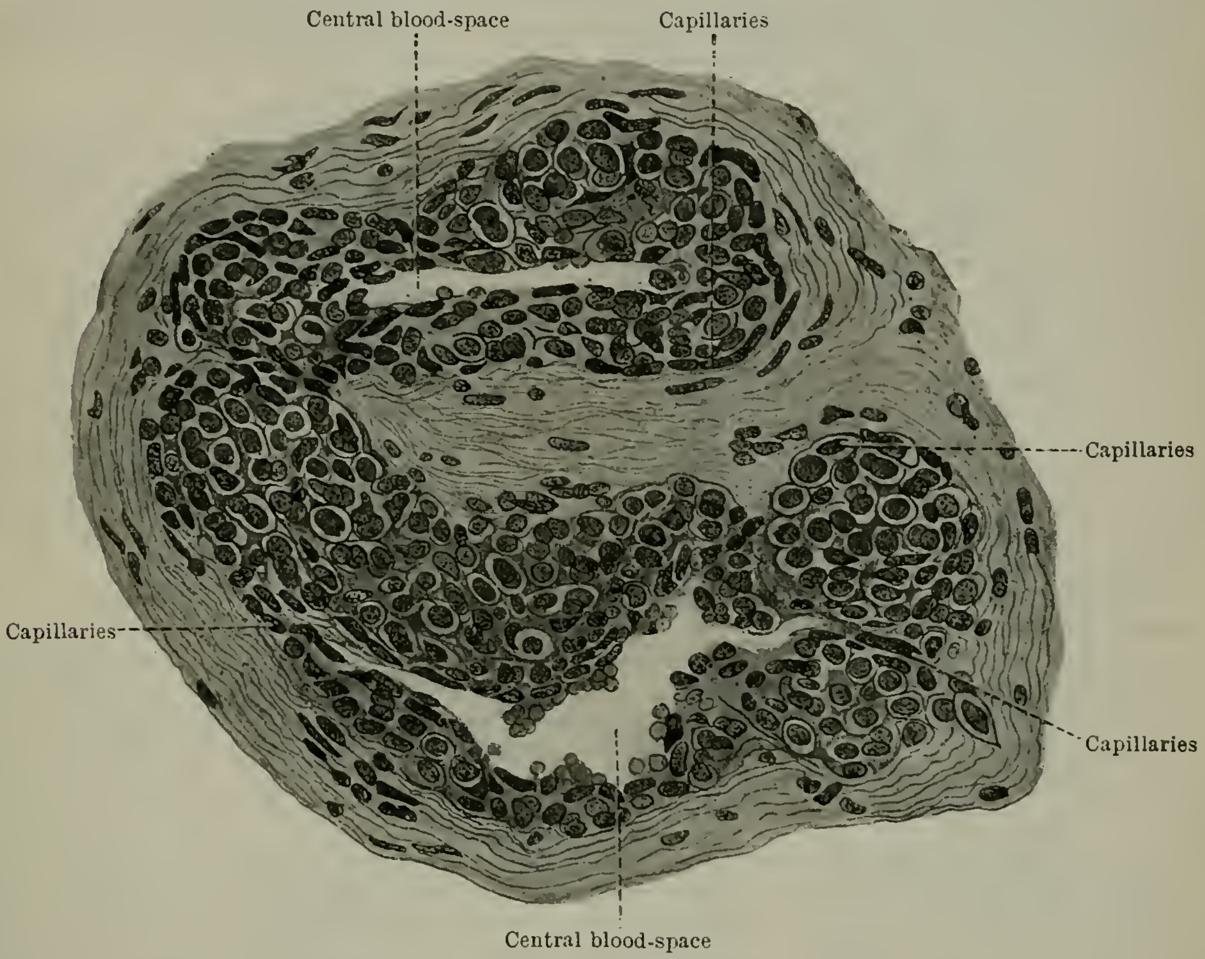

Fig. 1027.—Section through Glomus Coccygeum (highly magnified). (From J. W. Thomson Walker.)

Structure.—The glandula carotica is built up of nodules of chromaffin tissue surrounded and supported by fibrous tissue. The nodules are penetrated by a mass of sinus-like blood capillaries and surrounded by large lymph vessels. Scattered nerve-cells are present, and the whole organ is permeated by non-medullated nerve-fibres, which establish intimate connexion with the chromaffin cells.

(iv.) The nature and affinities of the glomus coccygeum are still uncertain. In spite of its apparently complete lack of chromaffin cells, its general histological resemblance to the carotid gland and its probable association with the sympathetic in development may be held to justify its description in this connexion.

The **glomus coccygeum** is a small vascular body from 2-3 mm. in diameter. It lies immediately anterior to the tip of the coccyx in intimate relation to a branch of the middle sacral artery. Usually its main mass is accompanied by a group of smaller bodies of similar structure and arterial relationship.

Structure.—This usually composite glomus is enclosed in a fibrous capsule giving sheaths both to the chief mass and the satellite bodies. The characteristic structure of the glomus consists of masses of polyhedral cells with large nuclei, surrounding the lumina of a tortuous arrangement of sinusoidal blood spaces (Fig. 1027). From these spaces capillary channels extend among the investing masses of closely packed cells. Apparently none of these cells show the characteristic chromaffin reaction (Stoerk and Zuckerkandl).

Development of the Chromaphil System and of the Glomus Coccygeum.—All chromaffin tissue develops in intimate relation with the sympathetic nervous system. It is not derived from the sympathetic tissue nor is the sympathetic tissue derived from it. Both are the descendants of a primitive, indifferent, sympatho-chromaffin blastema, which in a 16-mm. embryo occupies the regions corresponding to those occupied by the sympathetic system of the adult. It is composed of tightly-packed deeply-staining cells about 5 μ in diameter. The ancestry of these cells can be traced back with strong probability to cells which migrate from the neural crest, or from the wall of the medullary tube, or from both of these regions (see Development of the Sympathetic Nervous System).

The differentiation of chromaphiloblasts from sympathoblasts begins when the embryo is about 18 mm. in length, but is not completed until late in gestation, if then. The process is marked by an increase in size of the chromaffin formative cells and by a diminution in the intensity of their reaction to ordinary stains. Later, the specific chrome reaction develops, but the exact stage at which this occurs is unknown. It is important to note that if any cells in an area differentiate, all do. The result is that, in spite of their intimate relations and common origin, an intermixture of chromaffin and sympathetic cells is extremely rare.

The first of the chromaffin masses to differentiate are the aortic bodies. They are prominent structures in the two-months embryo (*vide* Fig. 1026). Later, the paraganglia of the sympathetic plexuses develop, and last the paraganglia of the gangliated trunk.

The development of the glandula carotica requires special description. It takes origin from a strand of sympatho-chromaffin blastema, which extends ventrally from the region of the superior cervical sympathetic ganglion, deep to the internal carotid artery or between the internal and external carotids. Differentiation begins when the embryo is about 20 mm. in length, and is completed by the time it is 30 mm. long. In connexion with the development of the glandula, there is a peculiar thickening of the wall of the internal carotid artery near the developing gland. In the dog a similar thickening of the wall of the internal carotid artery takes place, although in that animal the glandula lies beside the external carotid. Further, in a 45-mm. fœtus in which the glandula is fully differentiated the thickening is still present. These facts show that in the higher animals the thickening has no connexion with the development of the glandula, though the association of chromaffin bodies with blood-vessels in cyclostomata and elasmobranchs (see Comparative Anatomy of the Chromaffin and Cortical Systems) compels caution in excluding the possibility of there being at least some phylogenetic relation between the two. It has frequently been stated, and is widely held, that the glandula carotica is developed from, or receives some contribution from, the entoderm of the third pharyngeal pouch. This is not the case (see Parathyreoid Glands, Development).

Development of the Glomus Coccygeum.—The earliest stages of development of the glomus are still obscure. Its presence has not been recognised with certainty before the end of the fourth month of fœtal life. Jakobssohn claimed to show its developmental connexion with the sympathetic. This relationship has been rejected as unproved by Stoerk and by V. Schumacher, but their negative arguments are just as unconvincing as Jakobssohn's affirmative statements, inasmuch as they both deal with a stage in which evidence of an original genetic relation might well have disappeared. In any case it cannot be denied that there remains a fairly intimate topographical relationship of the gland with the caudal end of the sympathetic. If, however, the glandular-looking tissue of the glomus does actually originate from sympatho-chromaffin tissue, it seems certain that the chromaffin character is suppressed at an early period.

The alternative view, adopted by Stoerk and V. Schumacher, that the characteristic cells of the glomus are derived from the cells of the tunica media of the branches of the A. sacralis media, is difficult to accept. It may be noted in this connexion that a peculiar reaction of the wall of the carotid artery in relation to the glomus caroticum is noticeable during development, and has by some been erroneously regarded as genetically related to the formation of that organ, now admitted to belong to the chromaffin group by origin as well as by tissue reaction.

(v.) The **medullary** constituent of the suprarenal gland is the most important representative of the chromaffin system.

It is discussed below (p. 1329).

2. THE CORTICAL GROUP.

The single constant representative of this system in higher vertebrates is the mass of tissue forming the **cortex of the suprarenal gland.** Masses of similar tissue, however, are not infrequently met with in various situations, forming **accessory cortical bodies.**

The cortical tissue is peculiarly rich in lipoids, but its function is as yet undetermined. The positions in the human body which may be occupied by accessory cortical masses are indicated in Fig. 1025. They may be associated with chromaffin medullary tissue, as is the case in the suprarenal itself, but the majority, including the smaller bodies, are purely cortical. The justification for regarding the suprarenal cortex, with the occasional accessory cortical masses, as representing a distinct system, is based upon both phylogenetic and ontogenetic considerations. These warrant the conception of an originally more extensive distribution of cortical tissue, distinct from, but more or less co-extensive with, the chromaffin system. In the higher vertebrates the cortical system would appear to have undergone concentration, and has thus come to be represented mainly by the cortex of the suprarenal gland (*vide infra* on Comparative Anatomy of the Chromaffin and Cortical Systems, p. 1330).

GLANDULÆ SUPRARENALES.

The **suprarenal glands** (O.T. **suprarenal bodies** or **capsules, adrenal glands**) are composite products of the chromaffin and cortical systems. Each consists of a relatively thick cortex enclosing a medulla of chromaffin tissue. Typically, there are two suprarenal glands, a right and left, placed in the epigastric region, one on each side of the vertebral column. They lie in the same plane as, and in intimate relation to, the supero-medial aspects of the kidneys. Their colour is yellowish brown; their size varies within wide limits. To some extent it depends upon the cause of death. Average dimensions are: height, 5 cm.; breadth, 3 cm.; thickness, slightly under 1 cm.; weight about 7 gm. They are very little smaller at birth than in the adult.

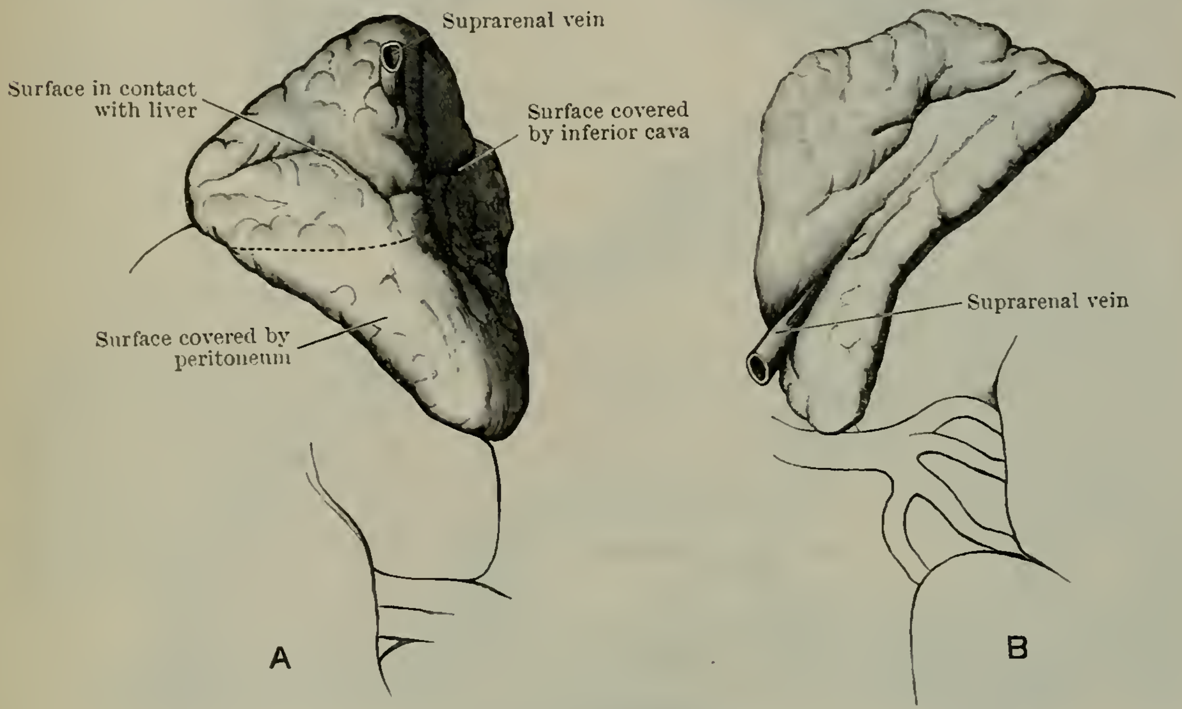
Suprarenal vein
Surface in contact with liver
Surface covered by inferior cava
Surface covered by peritoneum
A
Suprarenal vein
B

FIG. 1028.

A. Anterior surface of right suprarenal gland. B. Anterior surface of left suprarenal gland. The superior and medial parts of each kidney are indicated in outline. On the right gland the dotted line indicates the superior limit of the peritoneal covering.

Rarely only one gland is present; occasionally one is quite small, the other unusually large; as a rule they are unequal in size, the left being more frequently the larger. Sometimes the two glands are fused (cf. horse-shoe kidney). Frequently there are accessory glands. These develop in the neighbourhood of the main gland, and usually remain there, but may become attached, early in embryonic life, to organs which subsequently change their position. As a result, they may be found not only beside the main gland but also in the ligamentum latum uteri, on the spermatic funiculus, or even attached to the epididymis. Like the main glands, accessory suprarenals are compounded of cortex and medulla, and require to be distinguished from chromaffin bodies and accessory cortical bodies, which may be found in any of the positions in which accessory suprarenal glands occur.

Forms and Relations.—The suprarenal glands possess fairly constant forms and relations. The right gland is flat and triangular in outline. It is moulded, antero-laterally by the liver; antero-medially by the vena cava inferior; postero-medially by the diaphragm above, and by the kidney below. In a formalin-hardened specimen these areas are separated by prominent ridges. Near the apex of the gland, within the area of contact with the vena cava inferior, there is a short fissure, the *hilum*. From this emerges a vein which immediately joins the vena cava. The left gland is also flat, but is semilunar in outline. It is moulded antero-laterally, by the stomach above, and by the pancreas below; postero-medially by the diaphragm above, and by the kidney below. Upon the anterior surface, near its lower end, is a well-marked fissure, the *hilum*. From this emerges a vein which almost immediately joins the left renal vein.

The relations of the right and left glands to the kidneys are different. The right lies like a cap upon the superior pole of the right kidney; the left is in contact with the antero-medial border of the left kidney from the hilum to the superior pole. The relation of the glands to the peritoneum is not only different but variable. On the right side the peritoneum may cover the lower part of the antero-lateral surface of the gland; or this part may be in contact with the duodenum, in which case a small area about the middle of the surface may be covered by peritoneum; or the peritoneum may not come into relation with the gland at all. On the left side the upper part of the anterior surface is commonly covered by the peritoneum of the omental bursa, the lower part being crossed by the pancreas and splenic vessels. Sometimes these structures lie at a lower level, when the whole antero-lateral surface is covered by peritoneum of the omental bursa.

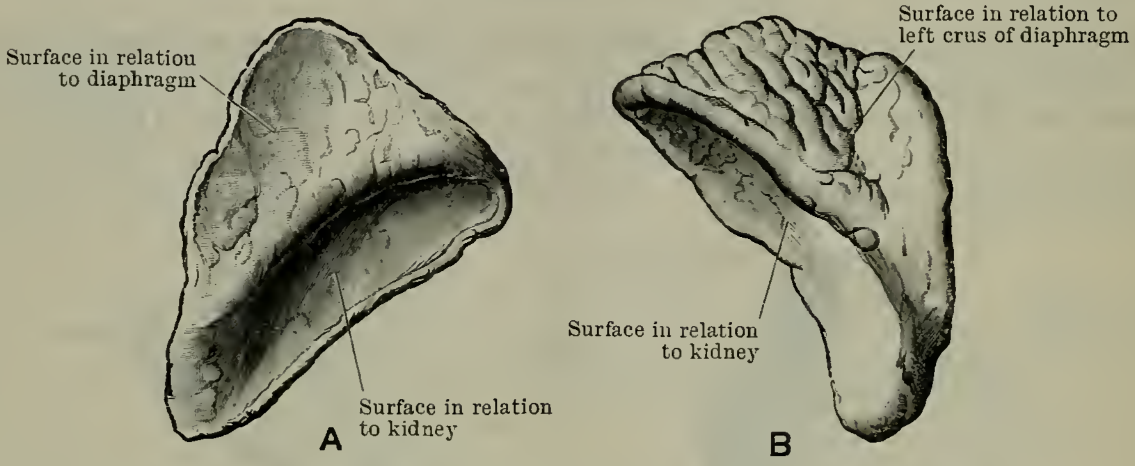
Surface in relation to diaphragm
Surface in relation to kidney
A
Surface in relation to left crus of diaphragm
Surface in relation to kidney
B

Fig. 1029.

A. Posterior surface of right suprarenal gland. B. Posterior surface of left suprarenal gland.

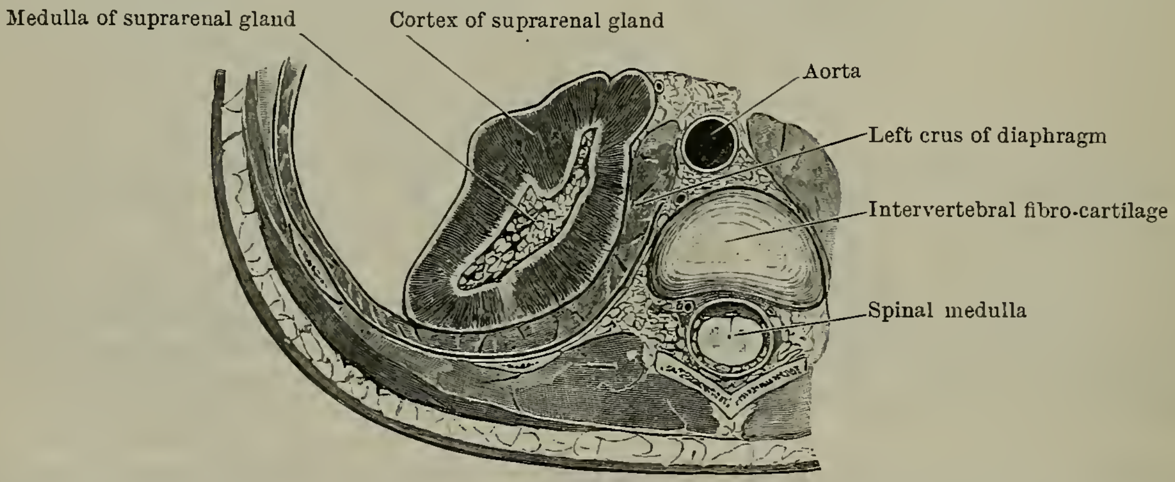
Medulla of suprarenal gland
Cortex of suprarenal gland
Aorta
Left crus of diaphragm
Intervertebral fibro-cartilage
Spinal medulla

Fig. 1030.—Transverse Section through the Suprarenal Gland of a New-born Child *in situ*.

Blood and Lymph Vessels.—The blood supply of the suprarenal is stated to be more abundant than that of any other organ in the body. Typically, each gland receives three arteries: one direct from the aorta, one from the inferior phrenic, and one from the renal artery; and is drained by one vein, which emerges at the hilum, the right to join the vena cava inferior, the left to join the left renal vein. Numerous lymph vessels pass from the suprarenal glands to the lateral aortic lymph glands.

Nerves.—The very numerous nerves passing to and from the glands constitute the suprarenal plexuses. They connect with the renal and cœliac plexuses and with the cœliac ganglia, and include numerous direct fibres from the greater splanchnic nerves, with a smaller number from the vagus and phrenic nerves. Most of them are medullated, but lose their sheaths on passing into small ganglia in, or just within, the fibrous capsule of the gland. Thereafter they pass to the chromaffin tissue of the medulla, either directly, or after first supplying the cortex.

Structure.—A suprarenal gland consists of a highly vascular central mass of chromaffin tissue, the *medulla*, enclosed within a thick capsule of cortical substance, the *cortex*, which in turn is enclosed within a capsule of fibrous tissue, *tunica fibrosa*. From the deep aspect of the fibrous tunic trabeculæ pass inwards to support the glandular tissue. In the superficial part of the cortex the trabeculæ interlace freely to enclose rounded loculi, *zona glomerulosa* (Fig. 1031, 1); in the intermediate part they run vertically to the surface to enclose columnar spaces, *zona fasciculata* (Fig. 1031, 2); in the deepest part of the cortex they become broken up and form a reticulum, *zona reticulata* (Fig. 1031, 3).

The cortex consists of polyhedral cells arranged in the interstices of the fibrous trabeculæ. These cells contain a lipoid substance, which is present in sufficient quantity to give the cortex a yellow colour.

The medulla (Fig. 1031, 4) is formed of a spongework of cell columns bounding anastomosing venous sinusoids. The cells are large, contain numerous granules, and possess the specific chromaffin reaction. In a fresh gland the medulla is of a dark red colour owing to the presence of blood in its sinusoidal circulation.

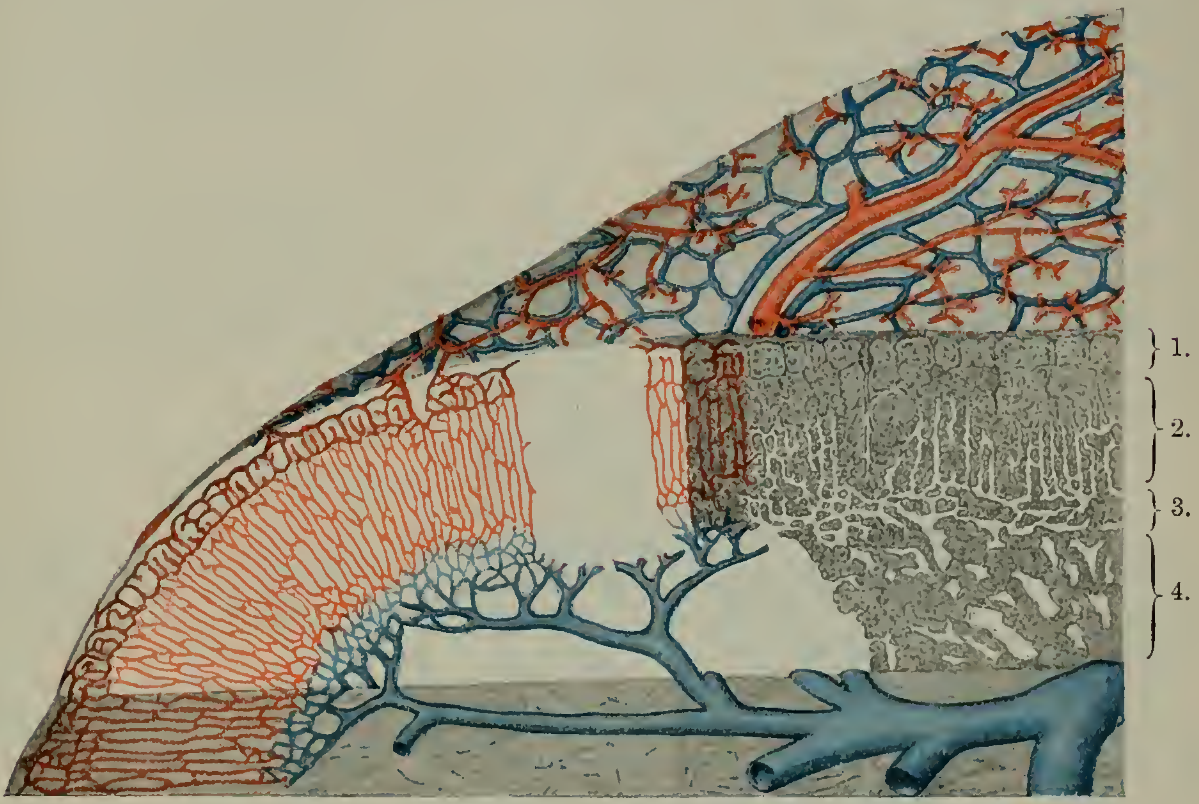

Fig. 1031.—Reconstruction of Suprarenal Gland of a Dog. (From Marshall Flint.)

The upper part shows the arrangement of blood-vessels upon the surface of the gland, the lower part their arrangement within its substance.

1. = Zona glomerulosa corticis.
2. = Zona fasciculata corticis.
3. = Zona reticulata corticis.
4. = Medulla.

The blood-vessels enter at numerous points in the fibrous capsule and run in the trabeculæ, forming a capillary network around the cell masses and columns of the zona glomerulosa and zona fasciculata. In the zona reticulata the blood-vessels open up to form a venous plexus, which is continuous with the sinusoidal plexus in the medulla, and thus mediately as well as more directly with the central efferent vein of the medulla which emerges at the hilus of the organ as the suprarenal vein.

Development of the Cortical System and of the Suprarenal Glands.—The cortical system is a derivative of the cœlomic epithelium (mesoderm). The first indication of its development is given, when the embryo is about 6 mm. in length, by the rapid proliferation of the epithelial cells placed between the mesonephros and the root of the mesentery. Numerous buds form and penetrate the mesenchyme at the sides of and ventral to the aorta. In an 8-mm. embryo these buds have already lost their connexion with the cœlomic epithelium. By the time the embryo is 9 mm. long the developing cortical masses are becoming vascularised. In man the greater part of the tissue thus formed is ultimately included in the cortex of the suprarenal glands, but small masses may escape, either at this stage or subsequently, to form independent cortical bodies.

In 12-mm. embryos the developing suprarenal glands lie in a caudalward continuation of the dorsal portion of the pleuro-peritoneal membrane called the suprarenal ridge, now distinctly marked off, and are composed of cortical tissue only. When the embryo is about 20 mm. in length sympatho-chromaffin cells, destined to form the medulla of the gland, begin to migrate into the developing cortex. The two kinds of tissue are in contact in 10-12 mm. embryos, but penetration of cortical masses by sympatho-chromaffin cells has not been observed earlier than the stage mentioned.

At first the immigrating cells are scattered in numerous columns and strands, and it is not until the embryo is about 10 cm. in length that they begin to reach the central vein and to form a true medulla. When the process of immigration ceases is unknown, probably not until after birth.

The final specialisation of the cortex is a late phenomenon, and does not take place until long after birth. The zona reticulata develops early and is recognisable in a 15-mm. embryo; the zona glomerulosa is not formed until the second or third year, but is represented until then by a layer of small incompletely specialised cells immediately under the fibrous capsule.

During fœtal life the cortex is relatively enormous. This is due to a great proliferation of the cells of the fœtal zona reticulata, which differ from the adult cells of the same zone in not containing lipoids. This fœtal cortex begins to undergo a fatty degeneration soon after birth, and by the end of the first year has disappeared. The new cortex which replaces it develops from the small, superficially placed, incompletely specialised cells already referred to.

Comparative Anatomy of the Chromaffin and Cortical Systems.—A knowledge of the main facts of the comparative anatomy of the chromaffin system is a help to understanding its distribution in man. Chromaffin tissue is first recognised with certainty in the cyclostomata, in which it is arranged in thin strips on the walls of the larger arteries and their branches. In elasmobranchs chromaffin bodies are present (the so-called "suprarenals" of this group of animals), and are arranged segmentally on branches of the aorta in close relation to the ganglia of the sympathetic chain. Cortical tissue is also recognisable in the cyclostomata, in which it is arranged in small lobulated masses (the "interrenal corpuscles"), in the walls of the posterior cardinal veins, and renal arteries. Even in this rudimentary form it is rich in lipoids. In the rays (elasmobranchs) the cortical system is represented by a pair of yellow-coloured, rod-shaped interrenal structures in the region of the kidney. In batrachians the chromaffin and cortical representatives first begin to come together. In the frog the adrenals are golden yellow streaks on the ventral surface of the kidney. The greater part of these are made up of columns of cortical cells, but at the borders or ends of the cell columns masses of chromaffin cells occur. This arrangement is transitional between the complete independence of the chromaffin and cortical systems in elasmobranchs and the partial inclusion of chromaffin tissue within cortical characteristic of the higher mammals (Swale Vincent).

3. THE PHARYNGEAL GROUP.

A third subdivision of the ductless glandular organs includes those which are derived developmentally from the entodermal pouches of the embryonic pharynx. They are (i.) the thyreoid gland, (ii.) the parathyreoid glands, (iii.) the thymus glands.

The embryonic primordia from which these organs are formed are rather numerous and include, in addition to those so named, (iv.) the ultimo-branchial bodies which early disappear, either completely or as distinct and separate structures.

(i.) Glandula Thyreoidea.

The **thyreoid gland** (O.T. **thyroid body**) is placed in the neck, firmly bound by fibrous tissue to the anterior and lateral aspects of the upper part of the trachea and to the sides of the larynx. It is yellowish red, soft, and vascular. It varies in size with age, sex, and general nutrition, being relatively large in youth, in females, and in the well-nourished. In women it increases temporarily with menstruation and pregnancy. Its average dimensions are, height 5 cm., breadth 6 cm., thickness of lateral lobes 1-2 cm., weight 25 gm.; but these measurements are of little value because of the range of variation.

Conventionally, the thyreoid gland is said to consist of two conical, more correctly pyramidal, lateral **lobes** united across the middle line by a narrow band of gland tissue, the **isthmus**. To many thyreoids this description is inapplicable. In men and thin elderly spinsters the gland is not uncommonly horse-shoe shaped; in young well-nourished women and in pregnancy its general contour suggests a sphere, deeply notched superiorly to accommodate the larynx and deeply grooved posteriorly for the trachea and œsophagus. Rarely, the gland is in two separate parts. Not infrequently, it is asymmetrical. In about 40 per cent. of specimens a process of gland tissue, the **pyramidal lobe**, extends from the upper border of the isthmus, upwards, in front of the cricoid and thyreoid cartilages, towards the hyoid bone. This process is seldom median, lying more often on the left than on the right. In rare cases, it is double. Less rarely, it is double below and single above. Sometimes it is represented by a strip of fibrous tissue or a narrow muscle (lig. suspensorium, or m. levator glandulæ thyreoideæ). The muscle may, however, be present independently of the pyramidal lobe.

Small oval accessory thyreoid glands are common in the region of the hyoid bone, and are occasionally met with in relation to the right and left lobes.

The relations of the gland are variable, depending upon its size and its relative level. In a majority of cases the isthmus covers the second, third, and fourth rings of the trachea, but it may cover the cricoid cartilage, or the fourth, fifth, and sixth tracheal rings. Anteriorly, the gland is clothed by the pretracheal lamina of cervical fascia, which separates it from the sterno-thyreoid, sterno-hyoid, and omo-hyoid muscles. Fibro-areolar extensions of this fascial layer form an indefinite capsule for the gland. Of these extensions one median and two lateral constitute ligaments binding the gland to the cricoid and thyreoid cartilages and to the upper cartilaginous rings of the trachea. Postero-medially, the thyreoid gland is moulded by the sides of the trachea and lower part of the larynx, and, when large, comes into contact, behind them, with the pharynx and œsophagus. Postero-laterally, it is in relation to the common carotid arteries, and when large is in intimate relation to the recurrent nerves. Further, it has important relations to the parathyreoid glands (see Parathyreoid Glands, Relations).

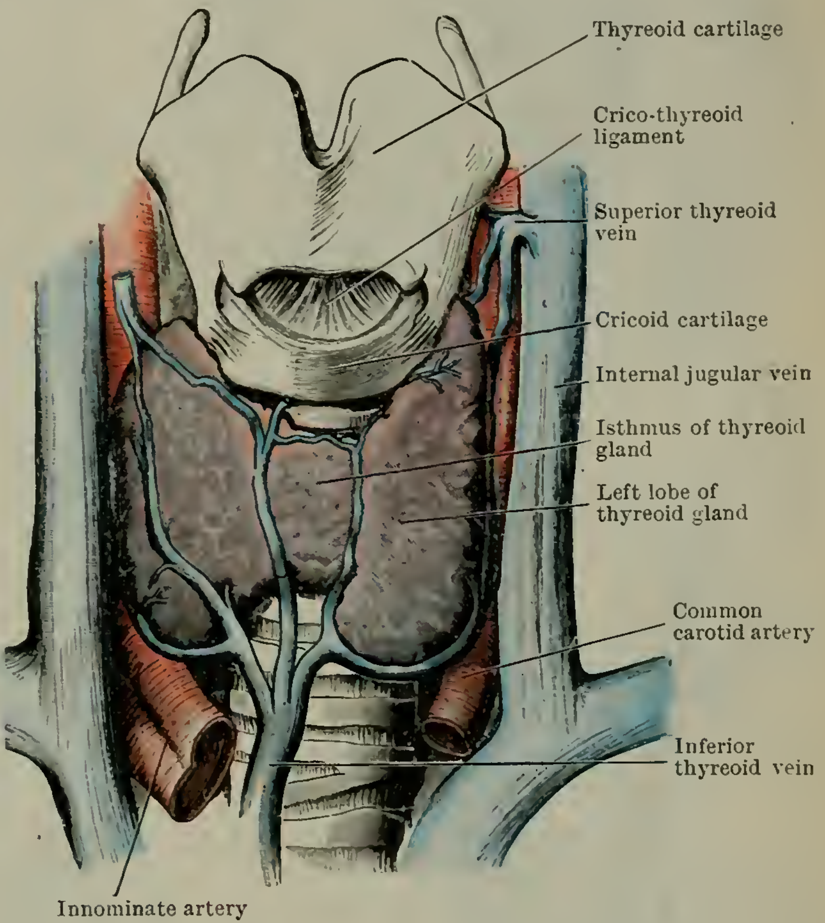

Fig. 1032.—Dissection of the Thyreoid Gland and of the Parts in immediate relation to it.

Blood and Lymph Vessels.—The extraordinarily rich blood supply is effected through the superior thyreoid arteries, branches of the external carotids, and through the inferior thyreoid arteries, branches of the thyreo-cervical trunks. Occasionally (10 per cent of cases) a fifth artery is present, the thyreoidea ima, usually a branch of the innominate. The pyramidal lobe, if well developed, receives a special branch from one of the superior thyreoids, usually the left. These arteries are remarkable for their large size and for the frequence and freedom of their anastomoses. An anastomosing trunk courses up the posterior aspect of each lateral lobe, uniting the inferior and superior thyreoid arteries. It is of interest in connexion with the recognition of the parathyreoid glands. Typically, three pairs of veins drain the gland. The upper two pairs, the superior and middle thyreoid veins, join the internal jugulars; the lower pair, the inferior thyreoid veins, join the left innominate. These vessels take origin from a venous plexus on the surface of the gland or, in the case of the inferior, from a downward extension of the plexus in front of the trachea. When the gland is very large, accessory veins are present, sometimes in considerable numbers. Most of these pass to the internal jugulars. A free, transverse, venous anastomosis is effected along the borders of the isthmus through the superior and inferior communicating veins.

The lymph vessels anastomose freely in the substance and on the surface of the gland. Most pass direct to the deep cervical lymph glands, a few descend in front of the trachea to the pretracheal lymph glands.

Nerves.—The nerves are non-medullated and are derived from the cervical sympathetic. They accompany the blood-vessels forming superior and inferior thyreoid nerve plexuses ending on the walls both of the blood-vessels of the gland and of the gland follicles.

Structure.—The gland is enclosed in a fibrous capsule (tunica propria) which sends prolongations inward to form a framework for the gland tissue proper. This consists of irregular lobar subdivisions made up of lobular groups of spheroidal vesicles or follicles, ·04 mm. to 1 mm. in diameter, lined with cubical epithelium, and filled with "colloid." The size, shape, and cellular characters of the vesicles vary with diet and environment. The vesicular follicles are surrounded by networks of blood capillaries and of lymph vessels.

Development.—The thyreoid gland takes origin from a single median outgrowth from the pharyngeal floor (entoderm). It is recognisable as a shallow bay in a 1·8-mm. embryo, practically simultaneously with the demarcation of the foregut. As the bud grows its end expands whilst its stalk narrows to form the *thyreo-glossal duct.*

In a 4-mm. embryo an elevation is present round the pharyngeal opening of the duct. This is the tuberculum impar. It migrates forwards, the duct backwards, so that in a 5-mm. embryo the duct opens into the furrow immediately caudal to the tuberculum (see Tongue, Development). At about this stage obliteration of the duct begins. This process proceeds slowly and is seldom quite complete, a vestige of the duct, *the foramen cæcum of the tongue*, remaining in the adult.

While these processes are proceeding growth and lateral expansion of the bud continue. It becomes bilobed and has a divided lumen, and all the while it undergoes a continuous relative displacement caudalwards. During this period it usually loses entirely its connexion with the pharyngeal wall and its lumen disappears. In a 9-mm. embryo the developing thyreoid gland is a transverse bar composed of irregular anastomosing cell columns.

In the meshes of this formation is vascular mesenchyme.

In embryos of 24 mm. (Norris) lumina appear amid the cells of the epithelial cords which have become clumped into groups. The "primary follicles" thus arising give origin to "secondary follicles" by processes of budding and constriction. This formation of secondary follicles begins at about the tenth week (55-mm. embryo) and is most active up to the stage of 160 mm.

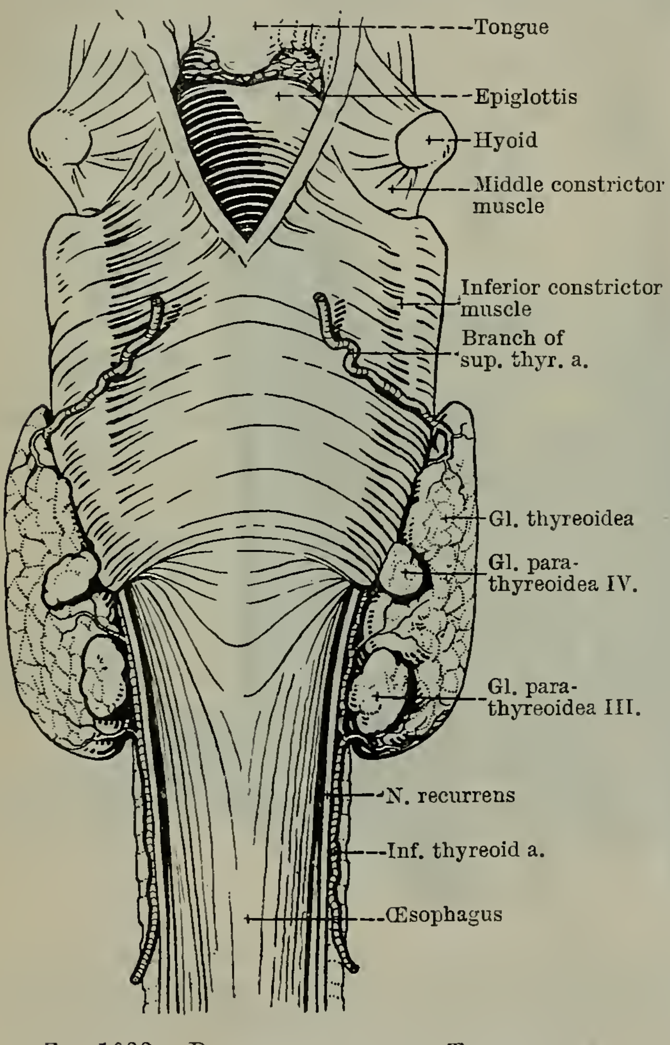

Fig. 1033.—Dissection showing Thyreoid and Parathyreoids of Adult from behind.

In the pig, colloid first appears in the secondary follicles in 75-mm. embryos.

In the later period of fœtal life the glandular growth is probably mainly due to increase in size rather than in number of the follicles.

It is usually stated that, contrary to older views, no permanent contribution to the definite thyreoid is made from any of the lateral pharyngeal pouches. But it is generally admitted that a pharyngeal pouch element—the so-called ultimo-branchial body—becomes temporarily incorporated with the lateral portions of the median thyreoid rudiment. Badertscher (1918–1919) has recently shown that, in the pig, true thyreoid follicles, which develop colloid in their interior, do arise from the material of the ultimo-branchial bodies, embedded in the lateral regions of the thyreoid. A similar view has also been expressed for marsupials. If this interpretation be confirmed the older idea of the composite origin of the thyreoid from median and lateral primordia would be rehabilitated. It is possible, however, that the fate of the ultimo-branchial bodies is a variable one, as Stewart (1918) has recently surmised.

The developmental history of the gland affords a ready explanation of its variations in the adult. Thus the development of a pyramidal lobe and its variations, partial and complete duplication, are due to the development of gland tissue from that part of the thyreo-glossal duct which has a double lumen and the more or less complete fusion or separation of the masses thus formed. Accessory thyreoid glands near the hyoid bone are the result of a similar process in connexion with isolated remnants of the duct.

The occurrence in the adult of a duct leading from the foramen cæcum to, or towards, the hyoid bone (*lingual duct*) is due to a persistence of the upper part of the thyreo-glossal duct. Similarly, *thyreo-glossal cysts* are due to the persistence of short intermediate lengths of the duct.

(ii.) Glandulæ Parathyreoideæ.

The **parathyreoid glands** (O.T. **parathyroid bodies**; *Synonyms*: epithelial bodies, parathymi or parathymic glands, "glandules thymiques" or "glandules thyreoïdiennes" of some French authors) are finely granular, yellowish brown, lenticular, or ovoid structures, from 2 to 20 mm. in diameter and from ·01 to 3 gm. in weight. Most commonly they are lenticular, 5-7 mm. in length, 1-2 mm. in thickness, and from ·01 to ·1 gm. in weight. Normally there are two pairs of parathyreoids, distinguished by the Roman numerals IV. and III. to signify that they develop from the fourth and third pharyngeal pouches. The normal total number may be diminished to three, two, or even one. It may, on the other hand, be increased, since in course of development the parathyreoid buds may divide so that more than four, five to twelve, glands may be present: the numerals are then applied to the groups of glands formed from the pouches.

Parathyreoid IV. is commonly embedded in the tunica propria of the thyreoid gland and lies posterior to the corresponding lateral lobe of that organ, about its middle. Parathyreoid III., similarly embedded, usually lies on the posterior aspect of the inferior extremity of the lateral lobe of the thyreoid gland. As a rule the anastomosing channel, which connects the inferior and superior thyreoid arteries (see Thyreoid Gland, Blood Supply), passes near both parathyreoids and furnishes the best guide to their discovery, but the range of the exceptional positions which the glands may occupy is wide. Thus, parathyreoid IV. may be found (1) behind the pharynx or œsophagus, (2) in the fibrous tissue at the side of the larynx, above the level of the thyreoid gland, (3) behind any part of the corresponding lobe of the thyreoid gland or even embedded in the thyreoid substance (internal parathyreoid); whereas parathyreoid III. may be found (1) near the bifurcation of the common carotid artery, (2) behind any part of the corresponding lobe of the thyreoid gland, (3) on the sides of the trachea, or (4) in the thorax close to the thymus. This wide range of variation in position is explicable by the close association of parathyreoid III. with the main thymus element in development (*v. infra*).

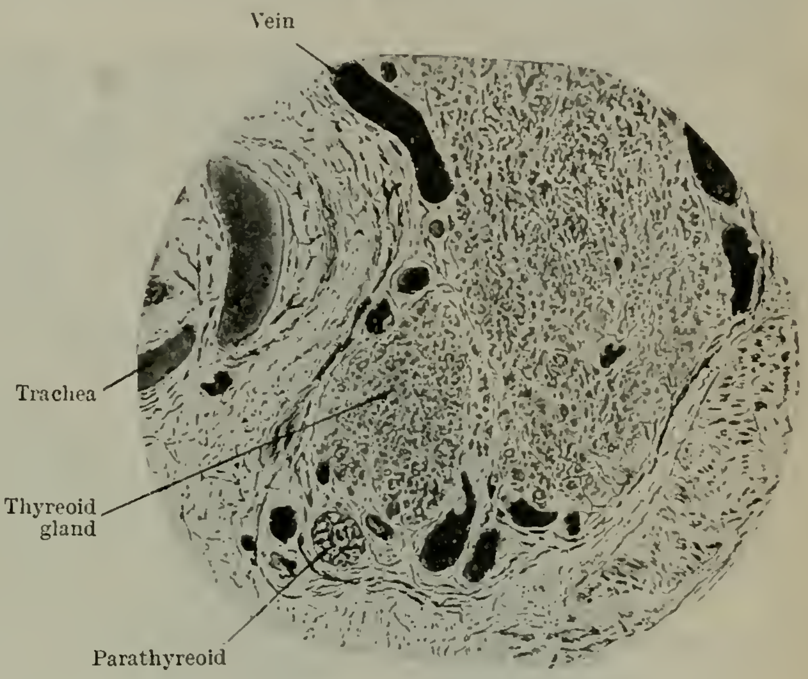

FIG. 1034.—OBLIQUE SECTION THROUGH PART OF THE TRACHEA AND THE RIGHT LOBE OF THE THYREOID GLAND OF A HUMAN FŒTUS 60 MM. LONG. Showing the parathyreoid embedded in the capsule of the gland.

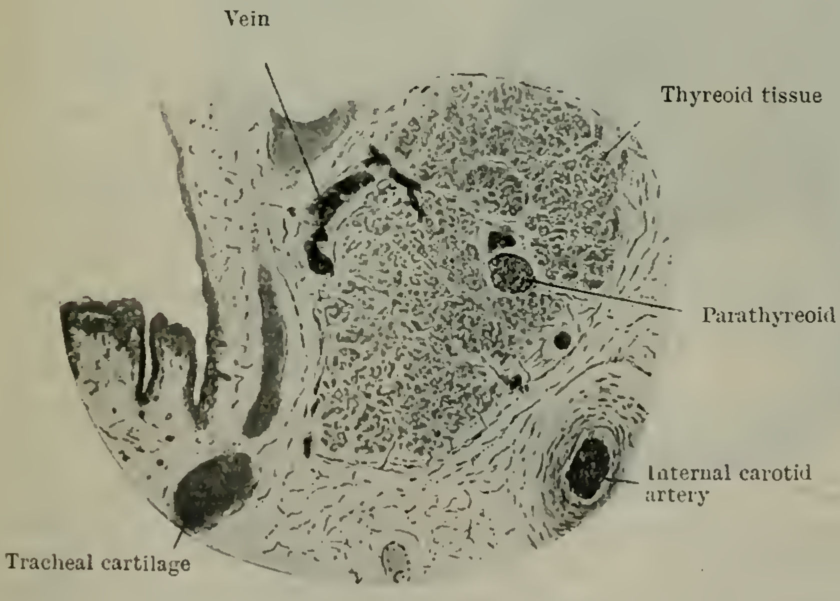

FIG. 1035.—OBLIQUE SECTION THROUGH PART OF THE TRACHEA AND THE LEFT LOBE OF THE THYREOID GLAND OF A HUMAN FŒTUS 60 MM. LONG. Showing the parathyreoid embedded in the thyreoid gland.

Blood-vessels.—The blood supply of each parathyreoid is effected by a single artery which enters the gland at its hilum. It may spring from any branch of the inferior or superior thyreoid arteries, but most commonly is a branch of the large anastomosing channel already referred to.

Structure.—The parathyreoids are built up of intercommunicating trabeculæ of epithelial cells with strands of vascular connective tissue between them. Sometimes the cellular arrangement is of a more compact character. The vascular network of the gland is sinusoidal. The cells are of two kinds, one clear, the other, the minority, containing oxyphil granules. Colloid-containing follicles are not infrequently found, though the colloid is said to differ from that of the thyreoid follicles in the absence of iodine. Thyreoidectomy seems to induce an increase in these colloid-containing follicles.

Development.—The parathyreoid bodies develop from the dorsal diverticula of the third and fourth pharyngeal pouches. The first indication of their development is a proliferation and thickening of the epithelium on the cranial and lateral aspects of the diverticula. This is present in both the third and fourth pouches in 9-10 mm. embryos, but appears to be rather irregular in the time of its appearance. The cells forming it are vacuolated, difficult to stain, and indistinct in outline. Cords of cells grow out from the thickening, and fibrous tissue penetrates between the outgrowing cords, which soon lose their connexion with the pharynx. The differentiation of the two kinds of cells takes place after birth.

Parathyreoid III. is normally drawn by the thymus, as it migrates, caudal to parathyreoid IV. As a rule it halts at the level of the inferior extremity of the lateral lobe of the thyreoid gland, but may continue its descent into the thorax or may not descend at all. In the latter case it remains near the bifurcation of the common carotid artery, where it is apt to be confused with the glandula carotica. It is from this confusion that the idea, that the chromaffin glandula carotica arises from the third pharyngeal pouch, has obtained a foothold in anatomical teaching.

(iii.) Thymus.

Strictly, there are two thymus glands, a right and a left, but they are so intimately related that it is customary to speak of them as a single organ, the **thymus**. This body is placed usually entirely, and always for the most part, in the superior and anterior mediastina, although not uncommonly it extends into the lower part of the neck. Its size varies relatively and absolutely with age, sex, and nutrition. It is pre-eminently an organ of early life. It is already of considerable size at birth and continues to increase throughout childhood, reaching its acme of growth about puberty. After this period it undergoes gradual diminution from involution and fatty degeneration of its parenchymatous structure. On account of its variability it is impossible to say what should be the normal dimensions of the gland at the various ages. In some new-born babes it weighs as little as 2 or 3 gm., in others as much as 15-17 gm. At puberty it may be difficult to find, or may weigh as much as 40 gm. After the age of fifty it may require careful dissection to discover, or may be quite large. According to Hammar the thymus weighs on the average at birth about 13 gm., at puberty about 37 gm., at the end of the adolescent period about 25 gm., and in advanced age about 6 gm. Of these weights the proportion to be ascribed to the proper glandular tissue is much greater in early than in later life, being about two-thirds at puberty. The female thymus weighs 20 per cent less than the male. Conditions of malnutrition affect the size of the gland, and premature permanent

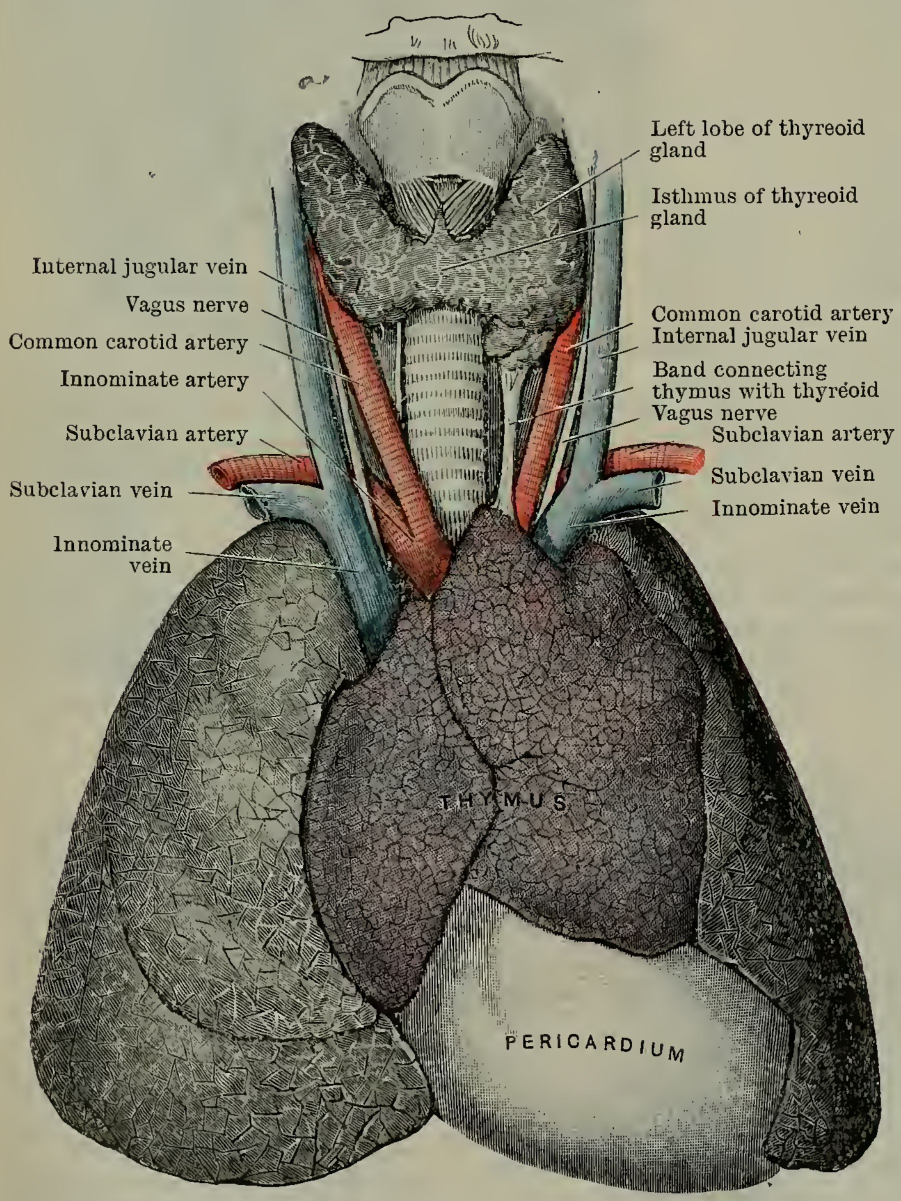

Fig. 1036.—Thymus and Thyreoid in a Full-time Fœtus hardened by Formalin-injection.

involution may result from severe illness, even though complete recovery may have taken place.

During the period of its fuller development the thymus appears as a pinkish mass (yellower in later life), consisting of two laterally compressed, more or less pyramidal, asymmetrical lobes. These are connected with one another, not by any bridge of glandular tissue but by areolar connective tissue.

The surface of the gland, in the young, more actively glandular, condition is finely lobulated.

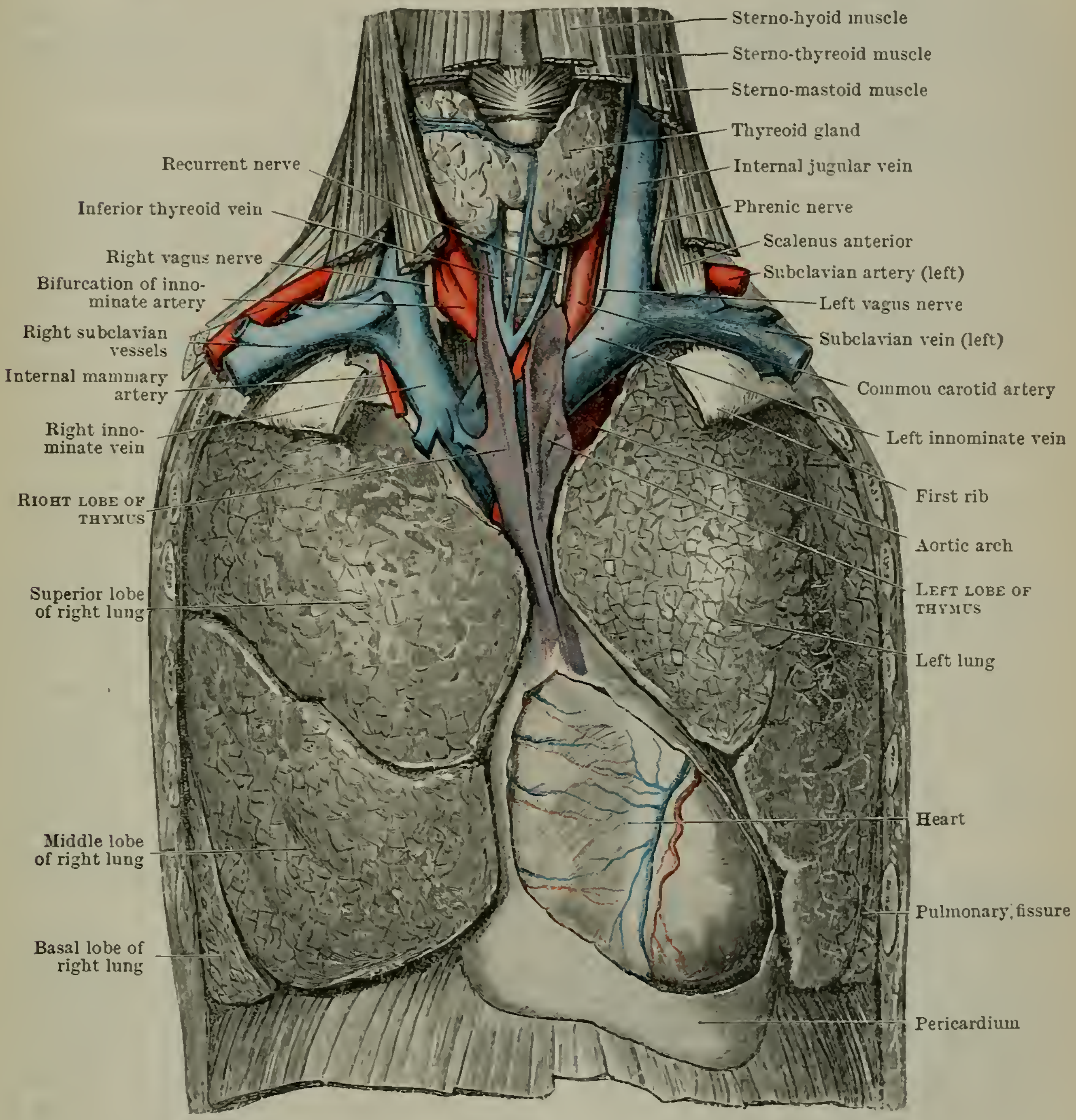

FIG. 1037.—DISSECTION TO SHOW THE THYMUS GLAND IN AN ADULT FEMALE.

The organ, when large, fills all the space available between the pleural sacs laterally, the back of the sternum in front, and the pericardium and great vessels behind; when small it is embedded in fat and fibrous tissue. The shape of the gland varies with its size and the age of the individual. In infants with short thoraces it is broad and squat; in adults with long thoraces it is drawn out into two finger-like strands. It is soft in consistence, and the details of its shape are determined by its size and by the structures upon which it is moulded, viz., the pericardium and the great vessels of the superior mediastinum and the root of the neck. The upper ends of the right and left lobes occasionally extend for some distance into the neck. These "cervical thymus" portions may be elongated and attenuated, and in rare cases may be partially separated from the main mass of the gland or "thoracic thymus." In other cases the upper parts of the thymus may be connected by a strand of fibrous tissue to the tunica propria of the thyreoid gland, representing an atrophic cervical thymus.

Blood and Lymph Vessels.—The blood supply of the thymus is effected through inconstant branches, chiefly of the internal mammary arteries and their branches. Its veins are irregular and mostly join the internal mammary and left innominate veins. Its lymph vessels are abundant. Although they are not related to the organ in the same manner as in a lymph gland, they have been found filled with lymphoid corpuscles derived from the gland. They enter the mediastinal lymph glands.

Nerves.—Its nerves are minute and are derived from the vagus and sympathetic. The branches of the vagus descend directly to the thymus from about the level of the thyreoid cartilage; the sympathetic fibres run with the blood-vessels. The fibrous capsule of the thymus receives small irregular branches from the phrenic nerves, but these do not supply the gland tissue in any way.

Structure.—The thymus is invested by a fibrous capsule which sends septa into its substance to divide it into lobules. The lobules are similarly divided into follicles (secondary lobules) about 1·5 mm. in diameter. Each follicle consists of a medulla not quite completely surrounded by a cortex. In a general way, the structure of the cortex resembles a lymph gland, but the syncytial reticulum is of entodermal epithelial, instead of mesodermal, origin. The spaces of the reticulum are crowded with lymphocytes, but there are no germinal centres nor lymph sinus. The medulla resembles the cortex, but the reticulum is coarser and contains cell nests, the *concentric corpuscles* of Hassall. As age advances the thymus undergoes involution. This process is marked by an increase of fatty and fibrous tissue and a reduction of the lymphoid parenchyma. The number of lymphocytes and of concentric corpuscles varies with nutrition.

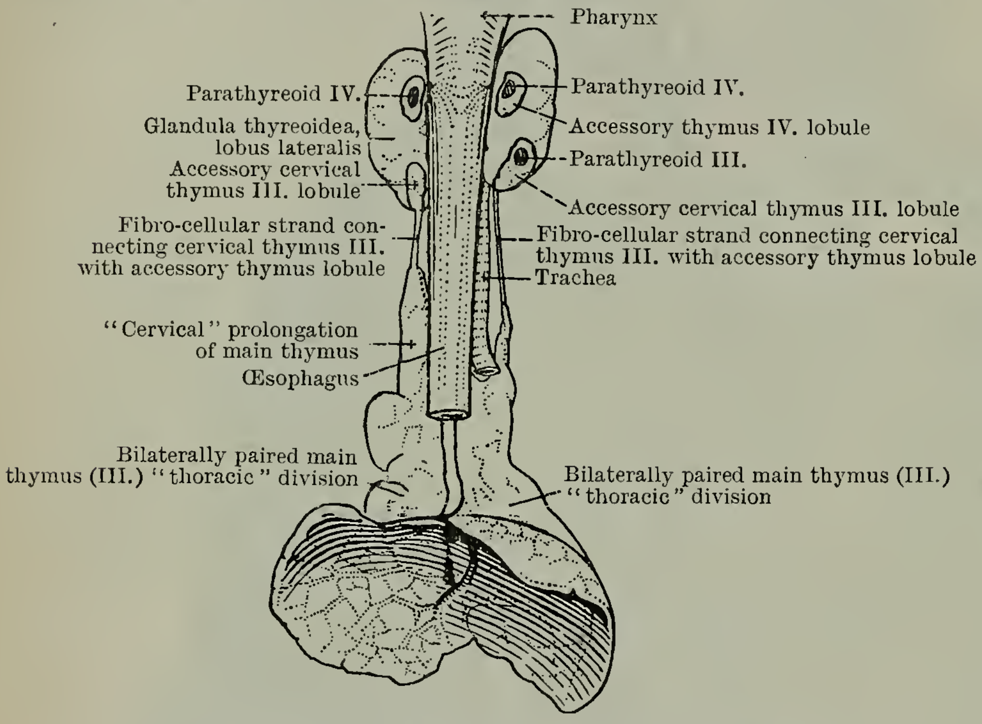
Pharynx
Parathyreoid IV.
Parathyreoid IV.
Glandula thyreoidea, lobus lateralis
Accessory thymus IV. lobule
Parathyreoid III.
Accessory cervical thymus III. lobule
Accessory cervical thymus III. lobule
Fibro-cellular strand connecting cervical thymus III. with accessory thymus lobule
Fibro-cellular strand connecting cervical thymus III. with accessory thymus lobule
Trachea
"Cervical" prolongation of main thymus
Œsophagus
Bilaterally paired main thymus (III.) "thoracic" division
Bilaterally paired main thymus (III.) "thoracic" division

Fig. 1038.—Illustrating the Condition reported by Groschuff in which Accessory Thymus Lobules were present.

Development.—As has been stated, there are in reality two thymus glands, a right and a left; they arise from the ventral diverticula of the third pharyngeal pouches. (In the pig a component derived from the ectodermal "cervical vesicle" has been described as entering into the constitution of the embryonic thymus, *Badertscher*). The first indications of the developing glands, cylindrical elongations of the diverticula, are present in 5-mm. embryos; the walls of the cylinders, more particularly their dorsal parts, soon thicken. Coincidently the necks of the pharyngeal pouches become constricted to form the pharyngo-branchial ducts III. These soon disappear, when the thymus rudiments lose all connexion with the pharynx. At this time the upper parts of the rudiments still have a lumen; the lower parts are solid. Soon the lumen vanishes; the solid parts thicken and the developing thymus migrates caudalwards to reach the pericardium at the 15-mm. stage. As a result of the migration the upper part gets drawn out and finally disappears. It is in this process that parathyreoid III. is involved. It is attached to the upper part of the migrating thymus, the part which disappears. The relative time of this disappearance determines the permanent level of parathyreoid III., for until it happens that gland is dragged in the wake of the thymus (see Parathyreoids, Development of). Sometimes a small detached mass of thymus formative tissue may persist beside parathyreoid III., and may differentiate to form an Accessory Cervical Thymus III.

During migration and after, the cells continue to proliferate and the thymus rudiment increases in mass. At the 40-mm. stage lymphocytes begin to appear in it. Differentiation of cortex and medulla is visible at the 45-mm. stage. The details of the process of thymic histogenesis are undetermined. It is believed that the syncytial reticulum and concentric corpuscles are of entodermal origin, but whether the lymphocytes arise *in situ* by metamorphosis of entodermal epithelial cells or are mesodermal immigrants has been the subject of much controversy. The immigration theory may, however, be said to hold the field.

(iv.) THE THYMUS IV. VESTIGES (*vide* Fig. 1038).

Small accessory masses of thymus tissue are in very rare instances found in close relation to parathyreoids IV. They are developed from the ventral diverticula of the fourth pharyngeal pouches in a manner generally similar to that in which the main thymus gland develops from the third. Although extremely rare in man, such accessory thymic derivatives from the fourth pharyngeal pouch are commonly enough met with in various other mammals. They must not be confused with the accessory thymic lobules referred to in the preceding paragraph, which are to be regarded as detached portions of the cervical part of the main thymus. The accessory thymus IV. may, as in some animals (*e.g.* Cat), be enclosed, along with an "internal" parathyreoid IV., in the substance of the thyreoid gland, thus forming a so-called "internal thymus."

(v.) THE ULTIMO-BRANCHIAL BODIES (OR POST-BRANCHIAL BODIES).

The fifth pharyngeal pouches give rise to a pair of gland rudiments called ultimobranchial bodies. Their fate is not known with certainty; it is possible that they may become the strands of parathyreoid-like tissue occasionally present in the lateral lobes of the thyreoid, but it is believed that more frequently they degenerate and leave no vestiges.

Their chief interest is that, for long, they were regarded as the rudiments of the lateral lobes of the thyreoid gland. This belief has since been generally discredited, but *v. supra*, on development of thyreoid, for further discussion of this question.

4. THE CEREBRO-GLANDULAR GROUP.

(i.) The hypophysis (O.T. pituitary body) is a small glandular body of duplex origin and constitution.

It forms a median basal appendage of the pars optica hypothalami, attached a short distance behind the optic chiasma (Figs. 1039, 1040, and 1041). It is lodged in the fossa hypophyseos, occupying the interval between the cavernous sinuses of opposite sides. The cavity in which it lies is lined by the dura mater covering the bone and forming the sinus walls, and it is roofed over by the centrally perforated fold of dura mater known as the diaphragma sellæ (p. 667). Through the small circular aperture in the latter the stalk of the infundibulum connects the hypophysis with the tuber cinereum of the floor of the third ventricle. It is connected with its shell-like capsule of dura mater by areolar connective tissue and blood-vessels.

The hypophysis is flattened oval in form, elongated transversely, and considerably smaller both antero-posteriorly and vertically. Its average dimensions are about 16 × 10 × 6 mm. It weighs about three-fifths of a gramme.

The hypophysis consists of two morphologically different elements, which are also unequal in size. The larger of these originates from the ectoderm of the primitive mouth cavity, and is therefore often distinguished as the "pars buccalis." It forms the lobus anterior, B.N.A., and is also sometimes known as the "glandular lobe" or "pars glandularis." It must be noted that the term "pars anterior" in use by some English writers is not the exact equivalent of "lobus anterior." The latter term should be taken to include the "pars intermedia" as well as the "pars anterior" of these authors.

The *lobus anterior* forms the main bulk of the hypophysis, including as it does the lateral as well as the anterior portions of the organ. It is deeply indented posteriorly forming a notch which accommodates the much smaller posterior lobe. But it also furnishes inconspicuous laminar extensions around the sides and neck of the posterior lobe, the infundibulum, and even on to the tuber cinereum almost as far as the optic chiasma.

As originally developed the lobus anterior or pars buccalis is a hollow sac. The anterior wall of this sac is represented in the mature organ by the solid glandular mass of the "pars anterior" (Figs. 1039, 1041). But the cavity or lumen of the sac does not entirely disappear although it becomes inconspicuous. It continues to be represented by an imperfect cleft-like cavity which seems to separate the lobus anterior from the lobus posterior but which in reality lies within the lobus anterior, separating its "pars anterior" from its "pars intermedia." The latter forms a cellular lamina of no great thickness clothing the anterior aspect of the lobus posterior and forming the true posterior wall of the cleft-like cavity of the anterior lobe.

This "intra-glandular cleft" is of varying extent in the adult organ and is generally occupied, and more or less interrupted, or even obliterated, by material of colloid character.

The main glandular mass of the anterior lobe is very vascular. In texture it is moderately firm and compact and it is reddish or brownish yellow in tint.

The lobus posterior (Fig. 1039 and Fig. 1041) is much the smaller of the two elements making up the hypophysis. It originates as a diverticulum of the cavity of the forebrain vesicle. The narrow stalk of the diverticulum is preserved as the infundibulum by which the hypophysis is attached to the brain. In accordance with its derivation from the central nervous system the posterior lobe is also known as the "pars nervosa," "pars neuralis," or "cerebral lobe"; the term "pars posterior" has been employed to bring it in line with a "pars anterior" and a "pars intermedia." The term "processus infundibuli cerebri," originally applied to the posterior lobe of the hypophysis by W. Müller, has been adopted by some recent writers but with no very obvious advantage.

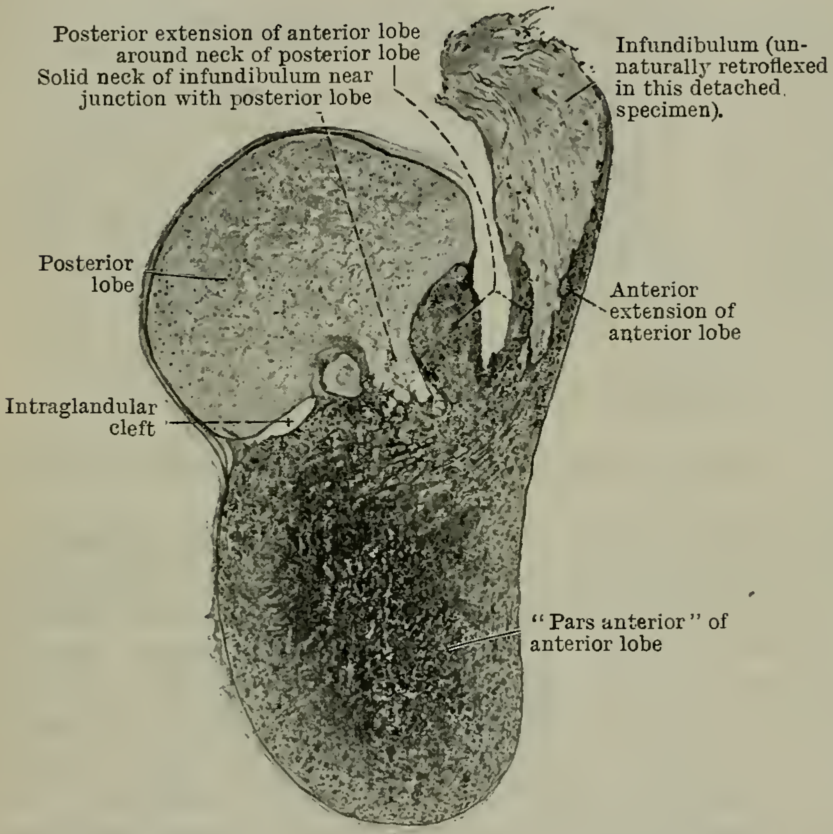
Posterior extension of anterior lobe around neck of posterior lobe
Solid neck of infundibulum near junction with posterior lobe
Infundibulum (unnaturally retroflexed in this detached specimen).
Posterior lobe
Anterior extension of anterior lobe
Intraglandular cleft
"Pars anterior" of anterior lobe

Fig. 1039.—Median Sagittal Section of Adult Human Hypophysis.

The lobus posterior is flask-shaped, the body of the flask fitting into the posterior concavity of the anterior lobe, whilst the tapering neck of the flask is continued as the infundibulum to the tuber cinereum of the brain.

In some mammals the posterior lobe is almost completely enveloped by the laminar expansions of the anterior lobe. In man and various other mammals the posterior aspect of the lobus posterior is largely free from such a covering.

The tissue of the posterior lobe is less dense, more friable, more greyish white, and much less vascular than that of the anterior lobe.

In the human fully-developed hypophysis the lobe is solid, but in various other mammals and in the earlier human fœtal period it contains a prolongation of the tubular cavity of the infundibulum which opens above into the third ventricle. In man even the infundibular canal is obliterated except for a short funnel-shaped recess of the ventricle extending into its base and named the recessus infundibuli (Fig. 1040).

Blood-vessels.—The very vascular glandular part of the anterior lobe is supplied by a circlet of small arteries which converge upon it from the neighbouring anterior part of the arterial circle of Willis. These supply blood to the rich net-work of sinusoidal channels which everywhere permeate the lobe and constitute its sole intrinsic vessels. The veins of the anterior lobe more or less correspond with the arteries in their arrangement, entering a venous circle which is drained by the basilar venous system.

The posterior lobe has a much poorer blood-supply. It is derived from an arterial branch formed by the junction of twigs from each internal carotid artery. The veins enter the circular sinus.

The pars intermedia of the lobus anterior is supplied from both of the above sources and also in part from the contiguous part of the brain.

Lymphatics.—The only lymphatic channels within the organ appear to be minute cleft-like spaces between the walls of the sinusoidal channels and the glandular cell masses. Their strictly lymphatic character is at least doubtful.

Nerves.—The anterior lobe has a rich supply from the carotid plexus by way of the arteries. Their terminals have been described as ending in contact with the gland cells.

The posterior lobe is scantily supplied by fibres which reach it along the stalk of the infundibulum.

Structure.—The glandular anterior lobe is composed of anastomosing columns and quasi-follicular groups of cells. The interstices of this cellular sponge-work are occupied by large thin-walled vascular sinusoidal channels with a small amount of connective tissue.

The glandular cells vary in appearance. Some are clear and chromaphobic, others are granular and chromaphilic, but the difference between them may be physiological rather than morphological. Both basiphilic and oxyphilic forms of the granular cell occur.

Globules and small collections of colloid material may be seen, but mainly in the near neighbourhood of the specialised "pars intermedia."

The "pars intermedia" of the lobus anterior consists of a cellular stratum clothing the anterior and lateral surfaces of the proper lobus posterior. It bounds the intra-glandular cleft posteriorly and represents the persistent posterior wall of the embryonic pars buccalis of the hypophysis (Fig. 1041). The cells of this stratum are smaller than those of the main anterior lobe and the structure is less vascular. Globules of colloid material abound and are regarded as the special elaborated product of this region. From it the colloid may be traced into the adjacent posterior lobe.

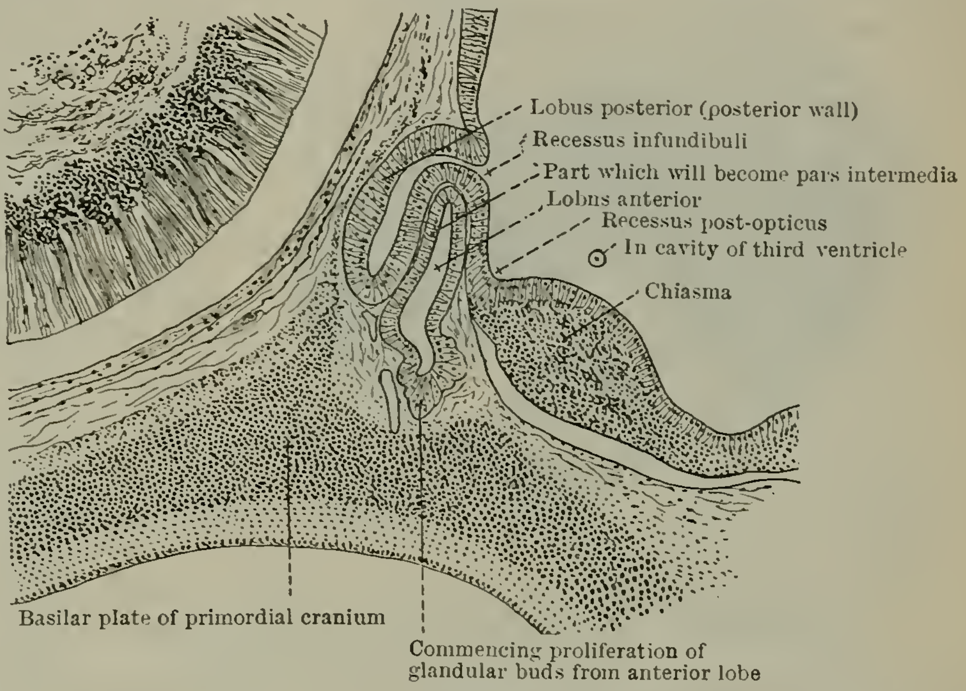
Lobus posterior (posterior wall)
Recessus infundibuli
Part which will become pars intermedia
Lobus anterior
Recessus post-opticus
In cavity of third ventricle
Chiasma
Basilar plate of primordial cranium
Commencing proliferation of glandular buds from anterior lobe

FIG. 1040.—PARAMEDIAN SAGITTAL SECTION OF THE HYPOPHYSEAL REGION OF A HUMAN EMBRYO (20 MM. CR LENGTH).

The posterior lobe consists chiefly of neuroglia tissue, cells, and fibres. There appear to be no nerve cells, and few, if any, nerve fibres. In the vicinity of the pars intermedia the posterior lobe contains groups of immigrant cells derived from the pars intermedia. It also exhibits the colloid masses already referred to. This colloid is believed to reach the cavity of the third ventricle by way of the lobus posterior. It has been shown to be present in the cerebro-spinal fluid.

Development.—As already mentioned, the hypophysis originates from two entirely distinct primordia. Both of these are hollow ectodermal diverticula, one neuro-ectodermal, derived from the floor of the primary forebrain, the other from the surface ectoderm lining the primitive mouth cavity. The latter diverticulum is often known as "Rathke's pouch," and it gives origin to the whole of the lobus anterior or pars buccalis including the pars intermedia. From the former is derived the lobus posterior or pars nervosa (pars neuralis, auct.) together with the infundibulum.

The first trace of the appearance of the hypophysis is met with in embryos of 2-3 mm. in the shape of an angular depression at the bottom of the oral fossa or stomatodaeum immediately in front of the dorsal attachment of the oral (bucco-pharyngeal) membrane. The earliest indication of the infundibular depression from which the neural part of the hypophysis is developed is recognisable in the floor of the primitive forebrain vesicle in embryos of 4-5 mm. In 7-mm. embryos the buccal part of the hypophysis has become a deep diverticulum, but its mouth is still widely open towards the primitive mouth cavity. In the 10-12 mm. stage the deep buccal diverticulum shows some narrowing of its aperture of communication with the exterior. The infundibular recess of the floor of the forebrain vesicle is now more sharply marked, and is somewhat deeper, though still rather insignificant. It is already in contact with the fundus or the posterior wall of the pars buccalis. In 18-20 mm. embryos the diverticulum representing the posterior lobe or pars nervosa has markedly deepened, and is now a rather elongated saccular protrusion of the brain floor, whose anterior wall is in intimate contact with the posterior epithelial wall of the anterior lobe or pars buccalis (Fig. 1040). The previously narrowed duct-like communication of the latter with the buccal cavity has by this time become completely obliterated and the occluded stalk has become interrupted, so that the hypophysial anterior lobe is separated from the epithelium lining the bucco-pharyngeal cavity. Remnants of the obliterated stalk persist, however, not only at this stage, but up to a much later period of fœtal life, and may sometimes be detected in postnatal life. The obliterated remnant of the stalk is not visible in Fig. 1040, because the sagittal paramedian section illustrated does not pass exactly in its plane. The figure shows very well that between the buccal hypophysial sac and the roof of the bucco-pharynx there is a marked condensation of the mesenchyme, and it is to the establishment in this situation of a basilar plate of condensed mesenchyme that we are to attribute the separation of the buccal hypophysis from the site of its origin in the primitive mouth cavity. Nevertheless, in some few cases this basilar plate of skeletogenous tissue is incomplete immediately around the stalk of the hypophysis, so that a cranio-pharyngeal canal is found later perforating the osseous cranial base and surrounding the remains of the epithelial stalk.

At the stage represented in Fig. 1040 the vesicular lobus anterior of the hypophysis is flattened from front to back. But it is rather widely expanded in the transverse direction, extending considerably beyond the lateral limits of the posterior lobe. Indeed the lateral expansions of the anterior lobe grow backwards around the neck of the infundibular diverticulum so as to embrace it in somewhat the same fashion as the outgrowing atria of the embryonic heart embrace the bulbar cardiac region. Ultimately they meet and fuse around the neck of the infundibular sac. But the vesicular anterior lobe also extends forwards towards the region of the optic chiasma as a lingular prolongation in contact with the post-chiasmatic area of the hypothalamic floor.

Up to about the 20 mm. stage the wall of the vesicular lobus anterior has preserved its simple epithelial character. Now, however, the anterior wall of it begins to exhibit a process of proliferative budding resulting in the production of a mass of tubular or quasi-tubular cell strands interpenetrated with highly vascular mesenchyme and forming a well-defined and fairly compact structure in place of the former simple epithelial anterior wall of the pars buccalis. The later result of this process as manifested in an embryo of the third month (71 mm. crown-rump length) is illustrated in Fig. 1041. Here the posterior wall of the anterior lobe is seen closely applied to the anterior surface of the posterior lobe, showing very little, if any, proliferative increase in thickness. It is this epithelial lamina which constitutes the pars intermedia, and the ‘interglandular cavity” in front of it is simply the flattened lumen of the anterior lobe or buccal portion of the hypophysis. Later still it undergoes further relative reduction and partial obliteration, the cleft or clefts representing it becoming more or less occupied by globules and masses of colloid substance. Compare the sagittal section of the adult organ in Fig. 1039 with the horizontal section of the fœtal structure in Fig. 1041 and note that the plane of the latter section is below the level at which the lateral extensions of the anterior lobe could be seen to encircle the neck of the lobus posterior.

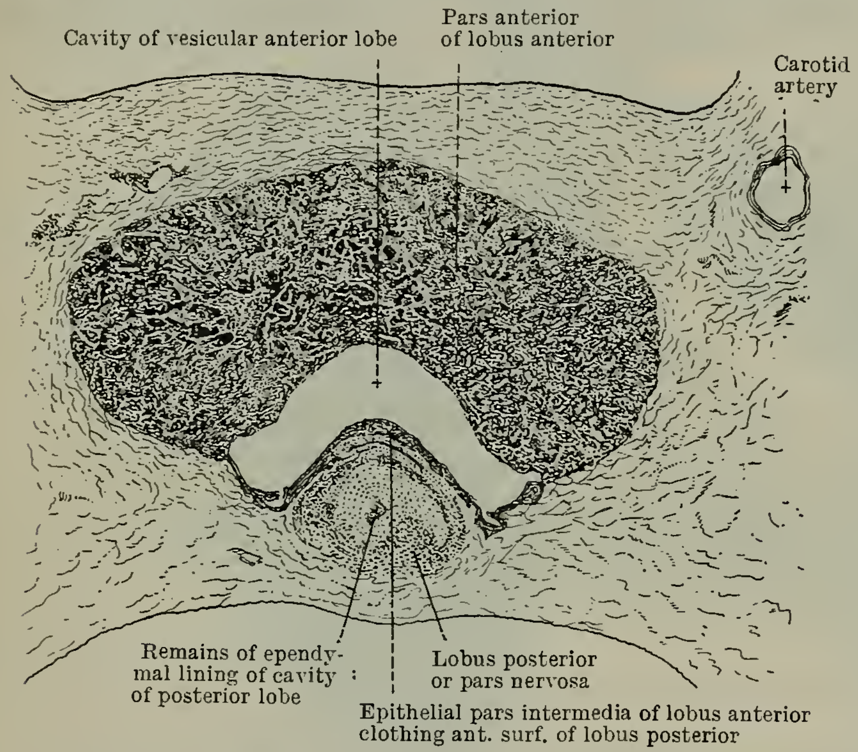
Cavity of vesicular anterior lobe
Pars anterior of lobus anterior
Carotid artery
Remains of ependymal lining of cavity of posterior lobe
Lobus posterior or pars nervosa
Epithelial pars intermedia of lobus anterior clothing ant. surf. of lobus posterior

Fig. 1041.—Horizontal Section of a Human Fœtus (71 mm. CR Length).

During the course of development from the 20 mm. stage onwards the cavity of the lobus posterior in the human hypophysis tends to become obliterated and finally the lobe becomes solid, as does also the stalk of the infundibulum. The lumen persists in the root of the stalk as the recessus infundibuli of the third ventricle. In the fœtal section through the posterior lobe in Fig. 1041 traces of the occluded lumen are still visible in the central part of the lobe, surrounded by a paler neuroglia zone.

(ii.) Corpus Pineale

(Synonyms: *Pineal gland, Conarium, Epiphysis cerebri.*)

This structure originates as a diverticulum of the roof-plate of the diencephalon. Together with the habenulæ and their commissure and the suprapineal recess, it constitutes the *epithalamus*, B.N.A. (Figs. 512, 1042).

The pineal body is shaped somewhat like a fir-cone (hence the terms pineal and conarium), but is actually a somewhat flattened oval structure, attached in front, but with a free rounded or pointed caudal extremity.

It measures about 10 mm. in length and about 5-7 mm. in thickness. It weighs about one-fifth of a gramme. It is moderately firm in consistence and reddish grey in colour. It is attached by a short, wide, hollow stalk to the extreme caudal portion of the roof of the third ventricle whence it projects caudally, overlapping the tectum mesencephali and occupying the shallow median sulcus between the superior colliculi.

The cavity of the stalk of the pineal body is the recessus pinealis of the third ventricle. It separates the dorsal from the ventral portion of the slightly flattened stalk. The dorsal portion is traversed transversely by a fibre-tract, the commissura habenularum, and is superficially continuous on either side with the tænia thalami. The ventral portion of the pineal stalk forms a reflexed medullary lamina of variable extent, intercalated between the pineal body and the posterior commissure which lies just ventral (morphologically caudal) to it.

Immediately dorsal (morphologically rostral) to the pineal body another recess of the third ventricle, the recessus suprapinealis, extends in a caudal direction in the form of a thin-walled, ependyma-lined, saccular evagination of the tela chorioidea of the third ventricle (Fig. 1042). The inferior (morphologically caudal) wall of this sac is adherent to the upper surface of the corpus pineale which it overlies. Both structures are more or less embedded in the tissue of the surrounding pia-arachnoid, whose relations to the tela chorioidea of the third ventricle are most intimate.

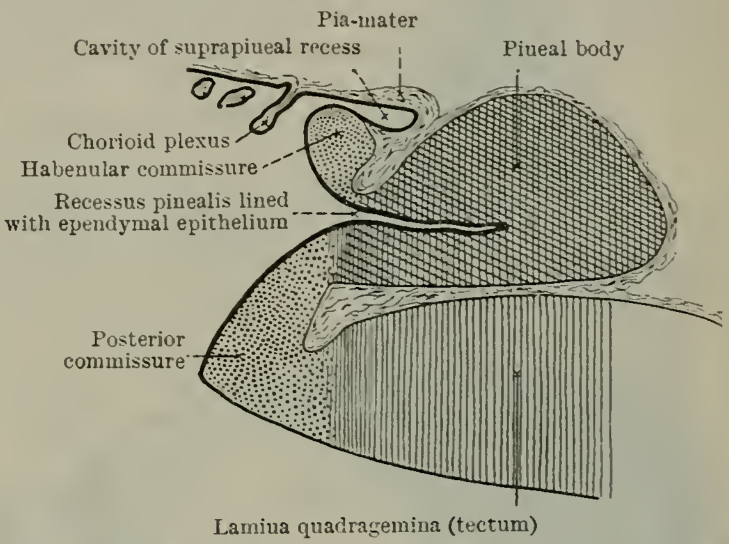
Pia-mater
Cavity of suprapineal recess
Pineal body
Chorioid plexus
Habenular commissure
Recessus pinealis lined with ependymal epithelium
Posterior commissure
Lamina quadragemina (tectum)

FIG. 1042.—DIAGRAM OF A MEDIAN SAGITTAL SECTION THROUGH THE PINEAL BODY AND ITS IMMEDIATE ATTACHMENTS.

Structure.—From the pial investment of the organ delicate fibrovascular processes and septa extend into its substance. These subdivide it in somewhat irregular fashion into lobular areas (more evident in the newborn than later), and also constitute a fairly dense connective tissue stroma. This supports a parenchyma consisting of more or less regular rounded cell groups or masses. The cellular arrangement to some extent simulates an acinous structure, the subcircular cell formations surrounding clearer areas containing amorphous non-cellular material. The aciniform cell groups are also in part marked out by the meshes of the vascular connective tissue stroma.

Several types of cell are recognisable. The most characteristic of them seems to be that of a large cell with granular cytoplasm and deeply staining nucleus. The granules appear to be of a lipoid nature. Neuroglia cells and fibres of ordinary type are also present in abundance and are readily distinguishable from the large "pineal cells" (the "interneuroglial cells" of Jordan). It is nevertheless possible that these latter are derived from ependyma or neuroglia tissue, or, perhaps more correctly, from the spongioblastic tissue which is the common precursor of both.

Pigment cells and melanin granules, scattered or in groups, are also met with, and the occurrence of plain muscle fibres has been recorded in many animal forms. Calcareous concretions (acervulus, B.N.A., corpora amylacea, "brainsand") are present, often in considerable numbers, throughout the body of the organ as well as in its pial investment and in the neighbouring tela chorioidea. They are more numerous in the adult and are stated to make their appearance first in the septal tissue.

Nerve cells proper appear to be absent from the organ. Some nerve fibres are present. Most of them are non-medullated and they are probably mainly destined for the numerous blood-vessels.

Development and Morphology.—The pineal body originates in the form of a pouch-like evagination of the diencephalic roof immediately in front of the mesencephalon. The epithelial wall of the fundus and greater part of the body of this pouch become much thickened by proliferation of its cells, and thus the lumen comes to be confined to the neck of the organ which becomes the short peduncle. Later, the solid cellular mass of the body of the organ becomes invaded by quasi-diverticular cellular sprouts from the ependymal lining of the recess of the gland. These gradually extend throughout the cellular mass, giving rise to the characteristic aciniform groups of large pineal cells. At the same time the exterior surface of the body is invaded by the fibrovascular ingrowths from the pia which form the stroma.

A pineal organ is present throughout the entire vertebrate phylum. The "parietal organ" or "parietal eye" met with in some lower vertebrates, particularly in cyclostomes and some reptilia, is frequently referred to as the "pineal eye." It is probable that this is not the exact homologue of the corpus pineale of other vertebrates, which therefore is not to be regarded as a vestigial eye. In some vertebrates, *e.g.* cyclostomes, embryonic rudiments of both organs coexist, though in intimate relationship with one another. The "parapineal" rudiment of the median eye is situated in front of the true "pineal" rudiment. The latter is better regarded as an independently evolved glandular structure, and its persistence throughout the vertebrate series gives some support to the view that it continues to subserve some persistently recurring functional end, probably as an organ of internal secretion.

5. THE LYMPHOID GROUP.

As already stated, *v. supra*, p. 1322, this group should more or less correspond with that of the "glandulæ vasculares" of the B.N.A. But the only member of the group to receive description in this place is the *spleen*.

(i.) Lien.

The **spleen** (B.N.A., **lien**) is a soft, highly elastic, contractile organ of purplish colour, placed in the upper left posterior part of the abdominal cavity, partly in the epigastrium, mainly in the left hypochondrium. It is moulded by the diaphragm, kidney, stomach, and, sometimes, colon. Its dimensions vary widely, but on the average are approximately: length, 12 cm.; breadth, 7 cm.; thickness, 4 cm. The weight is widely variable with the volume. According to a recent investigation (Neugarten), the average weight of the adult healthy spleen is, in the male, 113 gms., and in the female 140 gms. Its shape is modified by the relaxation, distension, and contraction of the neighbouring hollow viscera; its position and the details of its moulding, by the attitude of the individual. It is also subject to substantial physiological variations in volume due to alterations in its blood content associated with variations in alimentary activity.

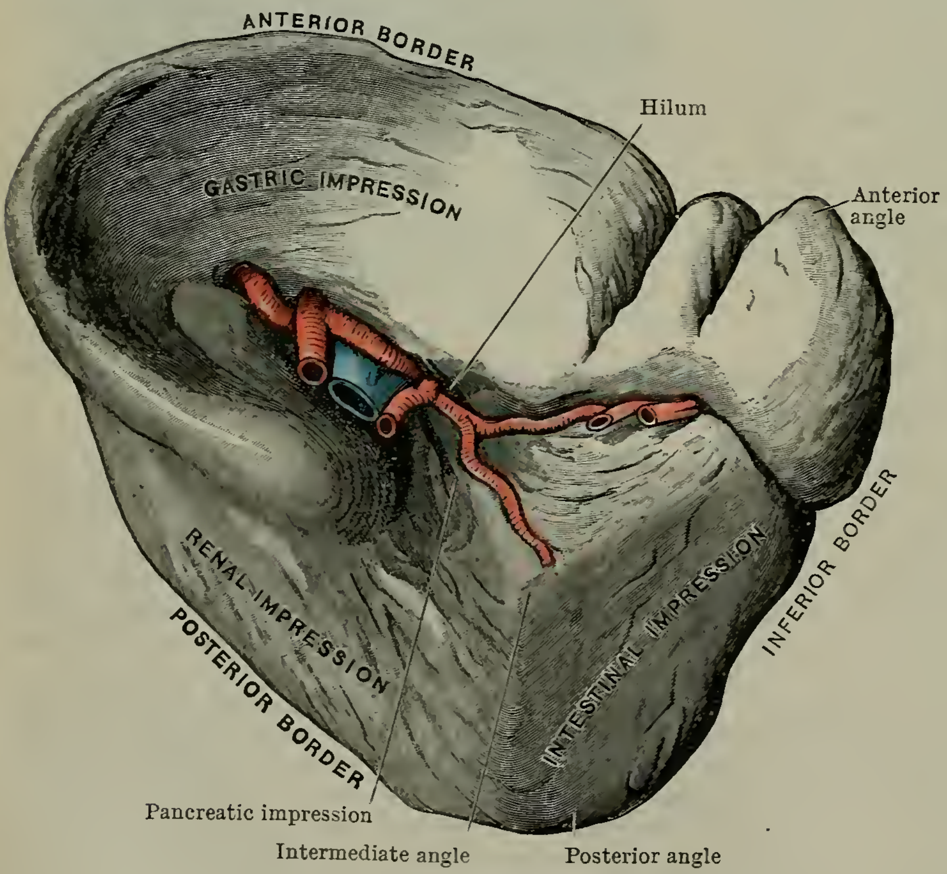

Fig. 1043.—The Spleen—Visceral Aspect.

When the stomach is contracted and the colon distended, the spleen has the form of an irregular tetrahedron; when the conditions of the hollow viscera are reversed, the form of a segment of an orange. These are the extremes of a series of forms which the spleen presents when hardened *in situ*. In the recumbent posture the long axis of the spleen corresponds in direction with the posterior part of the tenth rib; in the erect attitude the long axis is frequently vertical, more especially in adult females.

Surfaces, Borders, and Angles of the Spleen.—The surfaces of the spleen are the facies diaphragmatica, facies renalis, facies gastrica, and, in the tetrahedral form only, facies basalis (colica). Their contour is fairly constant. The **diaphragmatic surface** is convex, moulded to the curve of the diaphragm; the **renal** is slightly concave moulded to the kidney; the **basal** is flat or slightly concave, moulded by the colon; the **gastric**, deeply concave, moulded by the stomach. The gastric surface is interrupted by an irregular, not infrequently divided, slit, the hilum, through which the branches of the splenic artery enter and the tributaries of the splenic vein leave the gland. On the same surface, behind the hilum, there is a depression for the tail of the pancreas.

The borders of the spleen are *margo anterior*, between the gastric and diaphragmatic surfaces; *margo posterior*, between the diaphragmatic and renal surfaces. When present, the basal surface is separated from the diaphragmatic by the *margo inferior*, from the gastric and renal by the *margines intermedii*, *anterior* and *posterior*, whilst another intermediate border also intervenes between the renal and gastric surfaces.

The anterior border of the spleen is almost invariably notched; most frequently there are two notches, but there may be six or seven. Sometimes the posterior border also is notched. Rarely, the notches on the borders are joined by fissures extending across the diaphragmatic surface.

The angles of a tetrahedral spleen are: *superior*, at the junction of the diaphragmatic, gastric, and renal surfaces; *anterior*, at the junction of the diaphragmatic, gastric, and basal surfaces; *posterior*, at the junction of the diaphragmatic, renal, and basal surfaces; *intermediate*, at the junction of the renal, gastric, and basal surfaces. In a spleen of orange-segment form there are but two angles, a superior extremitas superior B.N.A. and an anterior extremitas inferior B.N.A. The superior is bounded in the same way as in the tetrahedral form; the anterior, by the diaphragmatic, gastric, and renal surfaces. In all spleens, but most commonly in those of oblique, irregularly tetrahedral form, the superior angle may curve forward as a blunt hook.

The spleen is entirely covered with peritoneum and is moored by two peritoneal folds, the lieno-renal and gastro-splenic ligaments (pp. 1155 and 1163). Inferiorly it is supported by the peritoneal phrenico-colic ligament (p. 1210).

Small globular accessory spleens are often present. As a rule they are attached to the gastro-splenic ligament near the splenic hilum.

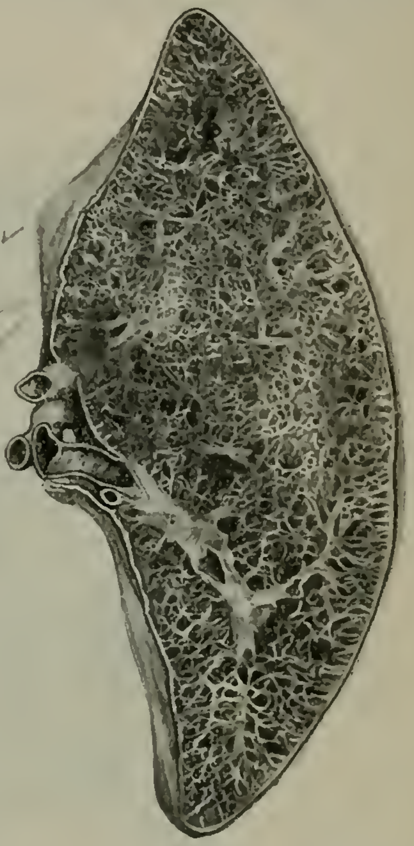

FIG. 1044.—VIEW OF SECTIONAL SURFACE OF ADULT HUMAN SPLEEN, FROM WHICH THE PULP HAD BEEN REMOVED BY WASHING WITH WATER SO AS TO SHOW THE ARRANGEMENT OF THE TRABECULAR AND MAIN VASCULAR STRUCTURES.

Blood and Lymph Vessels.—The spleen receives its blood from the splenic artery, which passes through the lieno-renal ligament. Before reaching the gland it breaks up into six or more branches which enter the hilum independently. Four main branches have been named:—(*a*) art. polaris superior; (*b*) art. gastroepiploica sinistra; (*c*) art. terminalis superior; (*d*) art. terminalis inferior. The vein of the spleen, the splenic vein, is formed in the lieno-renal ligament by the union of several unnamed tributaries which emerge from the hilum. The lymph vessels also leave the spleen at the hilum. They are small and come from the capsule and trabeculæ only, not from the glandular part of the organ. They open into lienal lymph glands placed near the hilum.

Nerves.—The nerves are almost entirely non-medullated and come from the cœliac plexus. They accompany the splenic artery and its branches.

Structure.—The soft and yielding mass of the spleen is encapsuled by peritoneal and fibrous investments and is supported by a fibro-elastic trabecular framework.

The peritoneal covering, tunica serosa, closely invests the organ except where it is reflected on to the lieno-renal and gastro-splenic ligaments and at the hilum. It is very firmly bound to the underlying tunica propria.

The tunica propria (tunica albuginea, B.N.A.) forms a strong fibro-elastic membranous capsule, about 0·1 mm. thick, composed mainly of white fibrous tissue but with a considerable admixture of elastic tissue and also some smooth muscle fibres. From its deep surface rounded or flattened trabeculæ of like constitution pass into the interior of the organ. These are especially strong at the hilum, where they accompany and support the blood-vessels and nerves. The trabecular system appears to be indefinitely and irregularly arranged, but practically its smaller subdivisions outline small areas of splenic pulp which may be regarded as the anatomical units of the organ. These have been termed by Mall the "lobules" of the spleen. They average about 1 mm. in diameter. They are, however, by no means precisely or completely outlined, and they are irregular in both size and shape.

Each of these rather ill-defined lobular areas is permeated by still finer ramifications of the trabecular system and is traversed centrally by a small artery coming from one of the smaller trabecular arteries. It forms a terminal, or end-artery, not anastomosing with the corresponding vessels in its neighbourhood. Each intralobular artery is surrounded by a periarterial sheath of adenoid reticular tissue whose interstices are packed with lymphocytes. This sheath is prolonged over the vessel as a continuation of the adventitia of the trabecular artery, which it replaces. Here and there, more especially at places of bifurcation of the intralobular artery, the sheath of lymphoid tissue swells out abruptly, and usually eccentrically, to form a small ovoid or spindle-shaped mass of lymphoid tissue, *nodulus lymphaticus lienalis* (O.T. Malpighian corpuscle). On account of the eccentricity of the artery which traverses it, the nodule usually has the appearance of being attached to the side of the arterial wall. Many of the nodules are quite small. Others are easily visible to the naked eye and appear in sections of the organ as whitish specks on the red background of the pulp. They average about one-third of a millimetre in diameter. Several of these lymphatic nodules may occur in the course of the same intralobular artery at successive bifurcations. Ultimately the ten or a dozen arterial twigs resulting from these divisions break up into penicillate groups of very numerous fine arterioles which end by supplying the surrounding pulp tissue. The intralobular artery, together with its lymphatic sheath, may be looked on as furnishing a central branching core for the lobule. The interval between this core and the interlobular trabeculæ is occupied by the splenic pulp in which the terminal arterioles end.

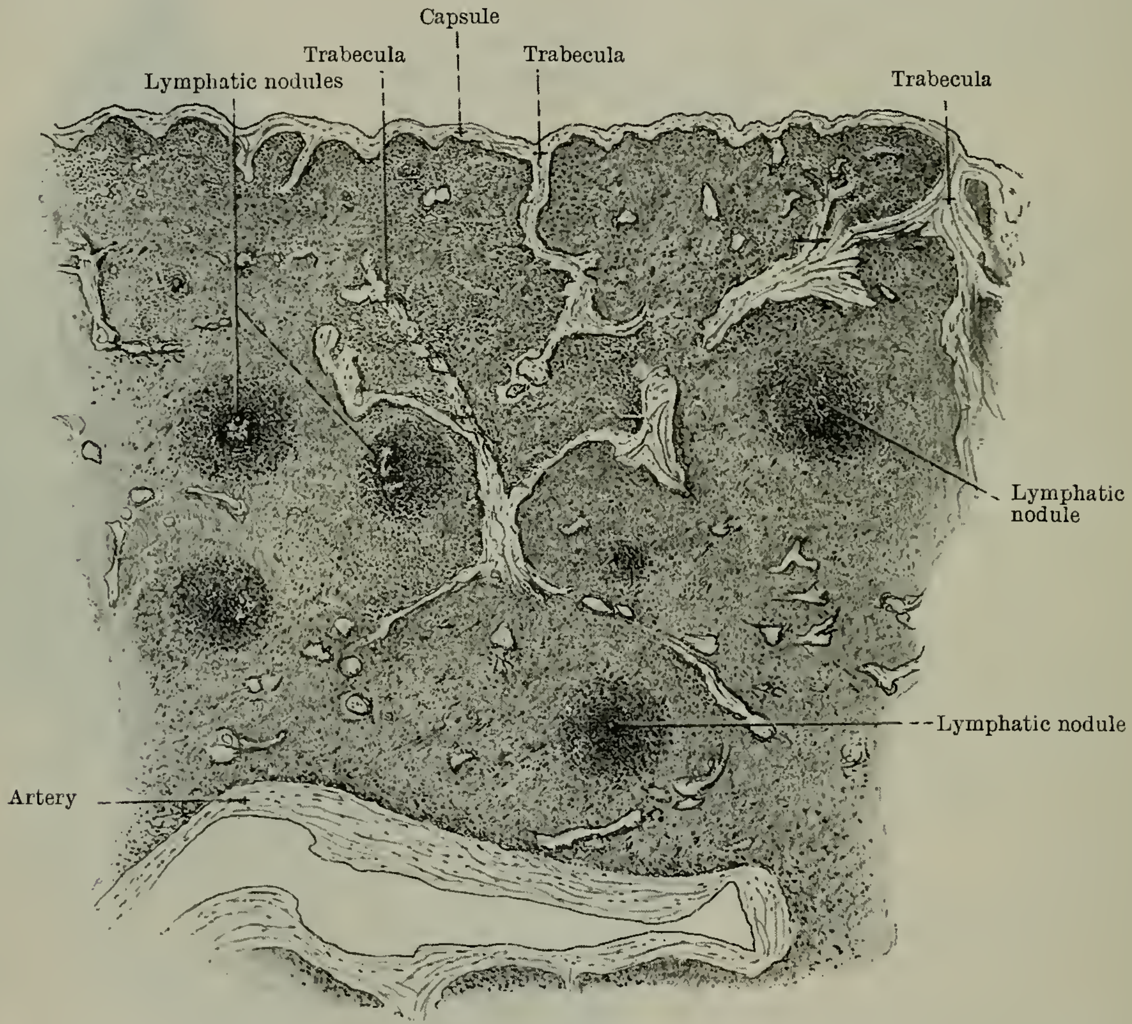

Fig. 1045.—Representation of Low-power Magnification of Section of Human Spleen.

The pulp tissue itself consists of a sponge-like arrangement of splenic cells supported by a fibro-cellular reticulum whose delicate fibres are connected with the ultimate ramifications of the trabecular system.

The cells of the pulp are of various and varying types. These include different varieties of lymphocyte, leucocyte, and erythrocyte. Some are like very large leucocytes and contain the debris of red blood corpuscles. They are to be regarded as splenic phagocytes concerned in the destruction of red blood corpuscles.

Towards their termination the ultimate arterioles of the pulp lose their sheaths entirely and their walls become fenestrated and incomplete. Finally they end in somewhat ampullated channels in the pulp. The veins begin in the same way as the arteries end. The splenic blood therefore flows through a system of "open" intercellular pulp channels which here represent the capillary circulation.

Development.—The spleen is mesodermal in origin. The first indication of its development, in a 9-mm. embryo, is a thickening of the dorsal mesogastrium. In 10-12 mm. embryos the cœlomic epithelium over the splenic rudiment is several layers thick. Soon the deeper layers of the thickening are transformed into mesenchyme and the epithelium is reduced again to a single layer. The first vascularisation of the spleen is effected by a capillary network. Out of this the intra-splenic arteries and veins differentiate. The undifferentiated capillaries between them form capillary tufts or spherules. These become transformed into the pulp. The exact method of this transformation is undetermined, but during its progress great numbers of red blood cells are produced. The lymphatic nodules are developed in the later part of fœtal life, and with their contained lymphocytes differentiate from the tunica adventitia of the arteries.

SURFACE AND SURGICAL ANATOMY.

By Sir Harold J. Stiles, F.R.C.S.

THE HEAD AND NECK.

THE CRANIUM.

Scalp.—The first and third layers of the scalp, namely, the **skin** and the **epicranius muscle**, are firmly united by fibrous processes which pass from the one to the other through the second or subcutaneous **fatty layer**. Intervening between these three layers and the pericranium is a loose **cellular layer** which supports the small vessels passing between the scalp proper and pericranium. The thin **pericranium**, although regarded anatomically as periosteum, possesses limited bone-forming properties; over the vertex it is readily separated from the skull-cap, except along the lines of the sutures, where it gives off intersutural processes to join the external layer of the dura mater.

The free **blood-supply of the scalp** is for the purpose of nourishing its abundant hair follicles and glands. The main vessels lie in the dense subcutaneous tissue, and are superficial, therefore, to the epicranius (Fig. 1046). The arteries supplying the frontal region are derived from the internal carotid, while those for the remainder of the scalp spring from the external carotid. These two sets of vessels anastomose freely with one another, and freely also across the median plane; hence the failure of ligature of the external carotid to cure cirsoid aneurysm of the temporal artery.

Wounds of the scalp bleed freely, and the vessels are difficult to ligature on account of the adhesion of their walls to the dense subcutaneous tissue. In extensive flap wounds and in diffuse suppuration beneath the epicranius there is little danger of sloughing of the scalp. **Abscesses** and **hæmorrhages** superficial to the epicranius are usually limited on account of the density of the subcutaneous tissue. Hæmorrhage beneath the epicranius is seldom extensive on account of the small size of the vessels, but suppuration in that situation may rapidly undermine the whole muscle and its aponeurosis—the galea aponeurotica; incisions to evacuate the pus should be made early, and parallel to the main vessels of the scalp. Extravasation of blood beneath the pericranium leads to a hæmatoma which is limited by the sutures.

The **veins** of the scalp communicate with the intra-cranial venous sinuses—(1) directly through their anastomoses with the large emissary veins, namely, the parietal, which open into the superior sagittal sinus, and the mastoid and condyloid, which open into the transverse sinus; (2) through the anastomoses of the frontal and supra-orbital veins with the ophthalmic vein, which opens into the cavernous sinus; (3) through the veins of the diplöe, which connect the veins of the scalp and the pericranium on the one hand with those of the dura mater and the venous sinuses on the other; (4) through small veins which pass from the pericranium through the bones and the intersutural membranes to the dura mater. It is along these various channels that pyogenic infection may extend, from the scalp and pericranium, through the bone to the dura mater and venous sinuses, and from the latter to the cerebral veins, the pia-arachnoid, and the substance of the brain. More rarely the infection spreads from the cranial cavity along the emissary veins to the scalp.

The **lymph vessels** of the anterior part of the scalp join the external maxillary lymph vessels; those of the temporal and parietal regions open into the pre-auricular and parotid lymph glands, situated in front of and below the ear, and into the post-auricular or mastoid glands, situated upon the insertion of the sterno-mastoid muscle. The lymph vessels of the occipital region open into the occipital glands, which lie close to the occipital artery and the greater occipital nerve where they become superficial in the scalp. Occipital neuralgia may result from pressure on the nerve by enlargement of one of these glands.

Bony Landmarks of the Cranium.—At the root of the nose is the fronto-nasal suture (**nasion**); a little above it is the **glabella**, a slight prominence which connects the superciliary arches. About 1 in. below the posterior pole of the cranium, and 2 in. above the spine of the epistropheus, is the external occipital protuberance (**inion**). In the child the protuberance is not developed; its position may be defined by taking a point at the junction of the upper and middle thirds of a line extending from the posterior pole of the skull to the spine of the epistropheus. About a third of the distance from the nasion to the inion is the **bregma** or junction of the coronal and sagittal sutures; with the head in the natural erect posture the bregma corresponds to the middle of a line carried across the vertex between the pre-auricular points of the zygomatic arches.

At birth the position of the bregma is occupied by the **fonticulus frontalis**, a rhomboidal membranous area which generally becomes ossified at about the eighteenth month. The size and date of closure of the fontanelle, as well as its tension and pulsation, are all points to be carefully noted in the clinical examination of children.

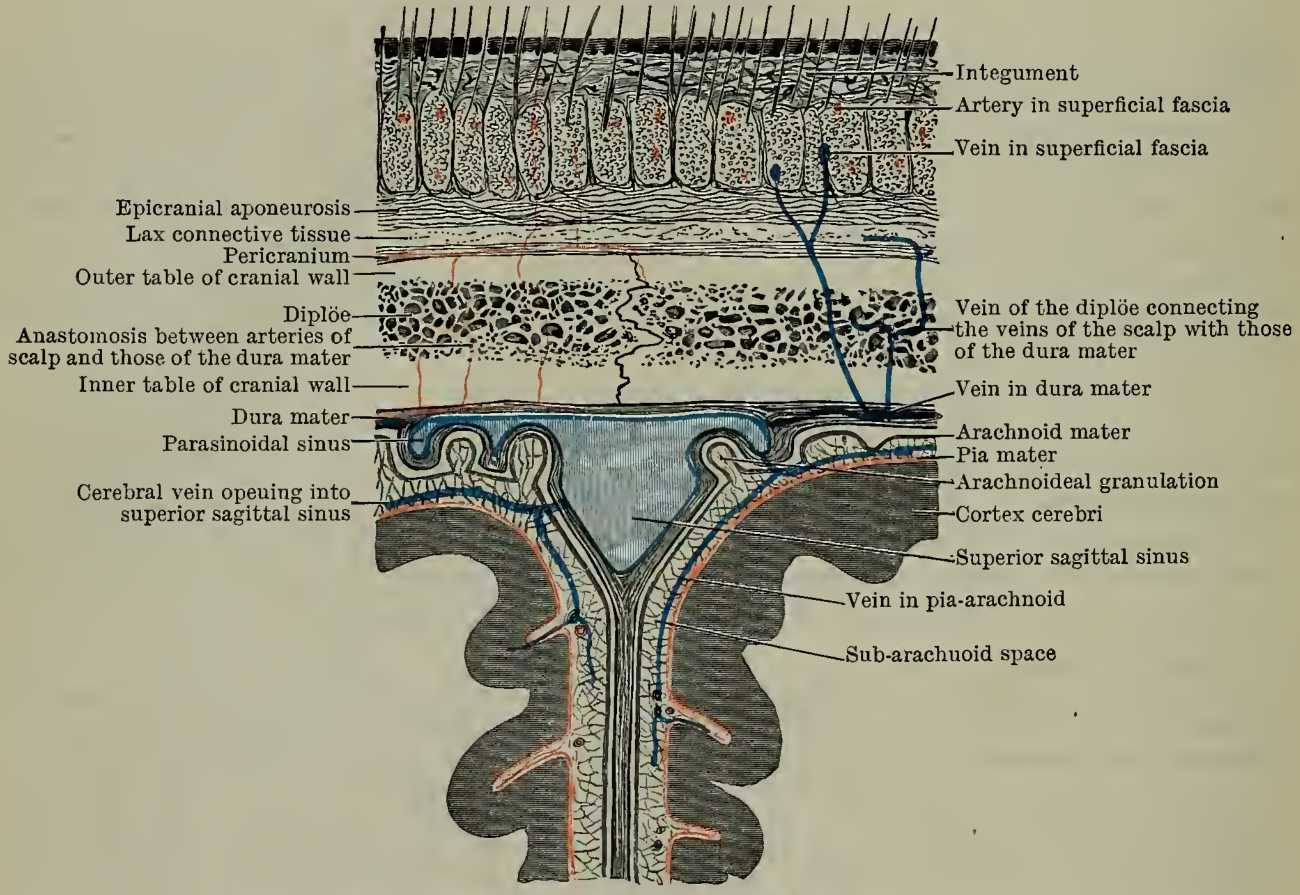
Integument
Artery in superficial fascia
Vein in superficial fascia
Epicranial aponeurosis
Lax connective tissue
Pericranium
Outer table of cranial wall
Diplöe
Anastomosis between arteries of scalp and those of the dura mater
Inner table of cranial wall
Vein of the diplöe connecting the veins of the scalp with those of the dura mater
Vein in dura mater
Dura mater
Parasinoidal sinus
Arachnoid mater
Pia mater
Arachnoideal granulation
Cerebral vein opening into superior sagittal sinus
Cortex cerebri
Superior sagittal sinus
Vein in pia-arachnoid
Sub-arachnoid space

FIG. 1046.—DIAGRAMMATIC REPRESENTATION OF A FRONTAL SECTION THROUGH THE SCALP, CRANIUM, MENINGES, AND CORTEX CEREBRI. (Modified from Cunningham.)

The **lambda**, or junction of the sagittal and lambdoidal sutures, situated 2½ in. above the inion, can generally be felt through the scalp; a line drawn from it to the posterior border of the root of the mastoid process corresponds to the **lambdoidal suture**. In the adult the *parieto-occipital fissure* of the brain lies opposite, or a few millimetres in front of, the lambda; in the child, however, the fissure may be as much as 1 in. in front of it.

Crossing the supra-orbital margin close to its medial angle, a finger's-breadth from the medial line, are the **supra-trochlear nerve** and the **frontal branch of the ophthalmic artery**; the latter nourishes the flap in the operation of rhinoplasty. At the junction of the medial and intermediate thirds of the supra-orbital margin, 1 in. from the medial line, is the **supra-orbital notch** or **foramen**, the guide to the **supra-orbital vessels** and **nerves**. A little above the level of the lateral canthus of the eyelid is the **fronto-zygomatic suture**, immediately above which is the **zygomatic process** of the frontal bone. At the posterior end of the suture the

zygomatico-temporal branch of the **orbital nerve** pierces the temporal fascia to reach the scalp. Half an inch above the suture is the **lower margin** of the **cerebral hemisphere**; while half an inch below the suture is a small *tubercle* on the posterior border of the zygomatic bone; a line drawn from this tubercle to the lambda gives the line of the **superior temporal sulcus** and of the **inferior cornu** of the **lateral ventricle.**

The **zygomatic arch**, an important landmark, is horizontal when the head is in the natural position, and is on the same level as the inferior margin of the orbit and the inion; its superior border is at, or not infrequently a little above, the level of the lower lateral margin of the hemisphere. The superior border of the zygoma may be traced backwards immediately above the tragus and the external acoustic meatus to become continuous with the ridge formed by the **supra-mastoid portion** of the **temporal crest.** The part of the posterior root of the zygoma which lies immediately in front of the superior end of the tragus constitutes a valuable landmark which may with advantage be termed the **pre-auricular point** of the zygoma, while by the term **post-auricular point** is understood that point upon the supra-mastoid crest which lies immediately behind, and a finger's-breadth below, the upper attachment of the auricle. The **temporal vessels** and the **auriculo-temporal nerve** cross the zygoma at the pre-auricular point, and it is there that the pulsations of the temporal artery may be felt during the administration of an anæsthetic, or the vessel compressed for the purpose of checking bleeding from the temporal region of the scalp. The termination of the auriculo-temporal nerve in the neighbourhood of the parietal tuber is often the seat of a neuralgic pain in irritative conditions about the external acoustic meatus, the latter being supplied by this nerve.

Two inches vertically above the pre-auricular point is the **inferior end** of the **central sulcus of Rolando.** Two inches vertically above the middle of the zygomatic arch is the **pterion** (spheno-parietal suture), a point which cannot be felt, but which is nevertheless of topographical importance, as it overlies the **lateral point** (the point where the lateral fissure of the brain breaks up into its three branches) and the **anterior branch** of the **middle meningeal artery.**

The **frontal tuber** (better marked in the child) overlies the **middle frontal convolution.** The **parietal tuber**, which varies considerably in the definiteness with which it can be recognised, overlies the **termination of the posterior horizontal limb** of the **lateral fissure of the brain**, and therefore also the **supra-marginal convolution**, which is named by Turner the *convolution of the parietal tuber*. The part of the **temporal crest** which intervenes between the zygomatic process of the frontal bone and the coronal suture lies a little above the level of the inferior frontal sulcus. The highest part of the temporal crest crosses the anterior central gyrus at the junction of its middle and lower thirds, that is to say, at the **junction of the motor areas for the arm and face.** In the child the temporal muscle, which is relatively much smaller than in the adult, reaches only a short distance above the squamous suture, and, therefore, only as far as the level of the inferior end of the central sulcus of Rolando.

The thickness of the skull-cap varies at different parts and in different individuals. The inner table is only half the thickness of the outer table, but both possess the same degree of elasticity. When the vault is fractured from direct violence, the inner table is more extensively fissured than the outer table, because the elements of the latter are compressed, while those of the former are stretched apart. The weak areas at the base of the skull through which fractures are liable to extend are: in the anterior cranial fossa, the orbital parts of the frontal bone, and the cribriform plate of the ethmoid; in the middle cranial fossa, the region of the glenoid cavity of the temporal bone, and of the foramen ovale of the sphenoid; in the posterior fossa, the fossæ of the occipital bone. The strong petrous part of the temporal is weakened by the tympanic cavity and by the deep jugular fossa.

Cranio-Cerebral Topography.—Of the many methods which have been devised for mapping out the relations of the cranial contents to the scalp, that introduced by Professor Chiene is, probably, the most useful from a clinical point of view; no figures or angles have to be remembered, and the primary surface lines are drawn from bony points which are not variable, whilst the secondary lines are drawn, for the most part, between mid-points of the primary lines. The method is as follows (Figs. 1047 and 1049):—

"The head being shaved, find in the median line of the skull between the glabella (G) and the external occipital protuberance (O) the following points:—

"First, the *mid-point* (M); second, the *three-quarter point* (T); third, the *seven-eighth point* (S).

"Find also the *zygomatic process* (E), and the *root of the zygoma* (preauricular point) (P), immediately above and in front of the external acoustic meatus. Having found these five points, join EP, PS, and ET. Bisect EP and PS at N and R. Join MN and MR. Bisect also AB at C, and draw CD parallel to AM."

The line MA corresponds to the **superior** and **inferior pre-central sulci**, and may therefore be termed the *pre-central line.* The *origins* of the **superior** and **inferior frontal sulci** may be indicated by the points of union of the upper and middle and the middle and lower thirds of the line MA, the lower point being at the level of the temporal crest.

The line ET, termed the *oblique* or *lateral line,* intersects the pre-central line at the point A, which overlies the *pterion,* and corresponds therefore to the **lateral point** of the **lateral cerebral fissure** and to the **anterior division** of the **middle meningeal artery.** AC overlies the **posterior horizontal limb** of the **lateral fissure of the brain,** which terminates at the level of the temporal crest, in the inferior part of the triangle HCB. This triangle contains the parietal tuber, and may, therefore, be termed the *supra-marginal triangle.* The termination of the lateral line, at the three-quarter sagittal point T, overlies the **parieto-occipital fissure.**

By joining TR, RO, a triangle is mapped out which delimits the surface of the **occipital lobe**; the line TR corresponds to the **lambdoidal suture,** while RO corresponds to, or lies a little above, the **tentorium** and the upper border of the **transverse sinus.**

CD, the *post-central line,* corresponds to the **superior post-central sulcus,** and lies a little behind the **inferior post-central sulcus.**

The line MA which corresponds to the superior and inferior pre-central sulci affords a ready guide to the Rolandic motor centres.

The pentagon ABRPN maps out the **temporal lobe,** with the exception of its apex, which is directed downwards, forwards, and inwards, a finger's-breadth in front of the point N.

A finger's-breadth below AB is the **superior temporal sulcus,** the posterior extremity of which turns upwards to terminate at B, the point which indicates, therefore, the position of the **angular gyrus.**

The **central sulcus of Rolando** may be mapped out upon the scalp by drawing a line downwards and forwards for a distance of 3⅜ in. from a point half an inch behind the mid-sagittal point M at an angle of 67° to the sagittal line (Hare). This angle may readily be found by Chiene's plan of folding a sheet of paper first to half a right angle and again to a quarter of a right angle ($45° + 22{\cdot}5° = 67{\cdot}5°$). According to Cunningham, the average angle which the fissure makes with the sagittal line is 70°.

Krönlein's scheme for projecting the more important cerebral areas on the surface of the cranium is as follows:—A base line, the same as that advocated by Reid, is drawn from the infra-orbital margin backwards through the upper border of the external acoustic meatus to the occipital region, which it strikes a little below the inion, Fig. 1048. A second line is drawn backwards parallel to it from the supra-orbital margin. Three vertical lines are now projected between these two parallels: the anterior from the centre of the zygomatic arch (C), the middle from the pre-auricular point (D), the posterior from the posterior border of the base of the mastoid process (E). The latter is prolonged upwards to the sagittal line on the cranial vault, and the direction of the central sulcus of Rolando is obtained by drawing a line from this point obliquely downwards and forwards to the point where the anterior vertical meets the superior horizontal line (Sylvian point). The inferior extremity of the sulcus corresponds to the point where the middle vertical line, prolonged upwards, meets the Rolandic line. The lateral fissure line is obtained by bisecting the angle formed by the Rolandic line and the superior horizontal line.

The topographical distribution of function in the cerebral cortex is shown in Figs. 1047 and 1048, in which the areas worked out by Grünbaum and Sherrington in the anthropoid apes have been transferred to the human brain. The above observers have shown that, while the *motor area* occupies the whole length of the anterior central convolution and of the central sulcus of Rolando (with the exception of its very extremities), it nowhere extends on to the exposed surface of the posterior central convolution; nor does it extend as far down on the medial surface of the hemisphere as the sulcus cinguli. Extirpation of the hand area, for example, is followed by severe paralysis of the hand, but the use and power of the hand is regained in a few weeks; ablations, on the other hand, of even large portions of the posterior central gyrus do not give rise even to transient paralysis.

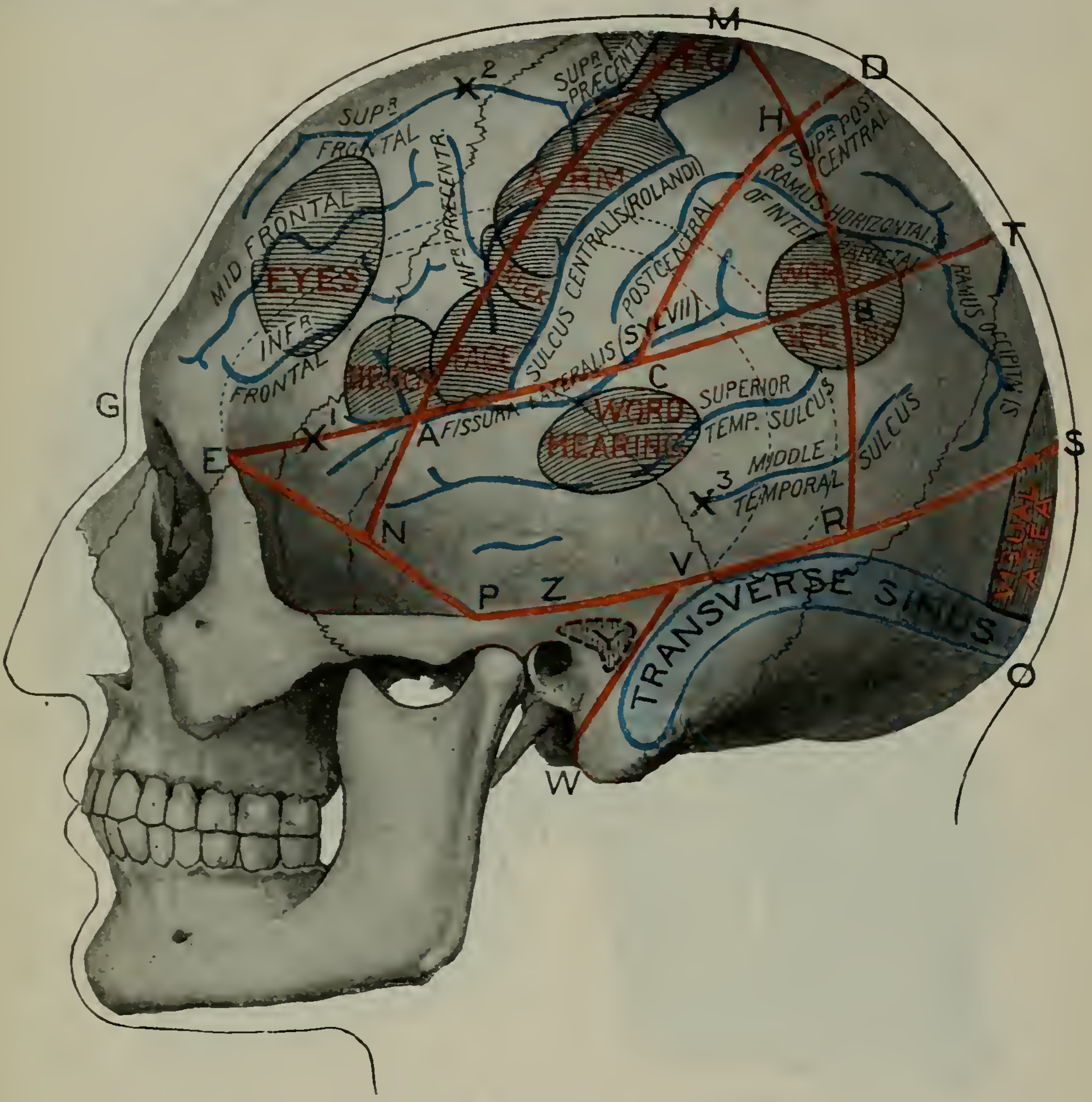

Fig. 1047.—Cranio-Cerebral Topography.

Shows relations of the motor and sensory areas to the gyri, and to Chiene's lines.

G.	Glabella.
O.	External occipital protuberance (inion).
M.	Mid-point between G and O.
T.	Mid-point between M and O.
S.	Mid-point between T and O.
E.	Zygomatic process of frontal.
P.	Root of zygoma (pre-auricular point).
N.	Mid-point of EP.
R.	Mid-point of PS.
C.	Mid-point of AB.
CD	is drawn parallel to AM.
Z.	Post-auricular point.
VW.	Guide to anterior limit of transverse sinus.
Y.	Tympanic antrum.
X^1.	Site at which subarachnoid space may be opened.
X^2.	Site for draining lateral ventricle (Kocher).
X^3.	Site for draining lateral ventricle (Keen).

In some of the animals experimented on, the motor area was found to extend to the deeper part of the posterior wall of the central sulcus of Rolando. Anteriorly it extended into the pre-central sulci as well as into the occasional sulci which cross the anterior central gyrus; indeed the hidden part of the motor area fully equals in extent that contributing to the free surface of the hemisphere. The motor areas extend a little in front of the superior and inferior pre-central sulci, which cannot therefore be regarded as physiological boundaries.

Reference to Fig. 1047 shows that, of the main areas, that for the lower extremity occupies the upper third of the motor region, that for the upper extremity the middle third, while the face occupies the inferior third. The relative topography of the chief subdivisions of these main areas is shown in Fig. 1048. It must be remembered, however, that there exists much overlapping of the adjacent areas.

The body of the lateral ventricle, which is equal in length to the posterior horizontal ramus of the lateral cerebral fissure, occupies a level midway between it and the temporal line. The anterior horn of the ventricle is opposite the lower part of the coronal suture while the posterior horn is opposite the posterior part of the temporal line. The inferior horn corresponds to the second temporal gyrus.

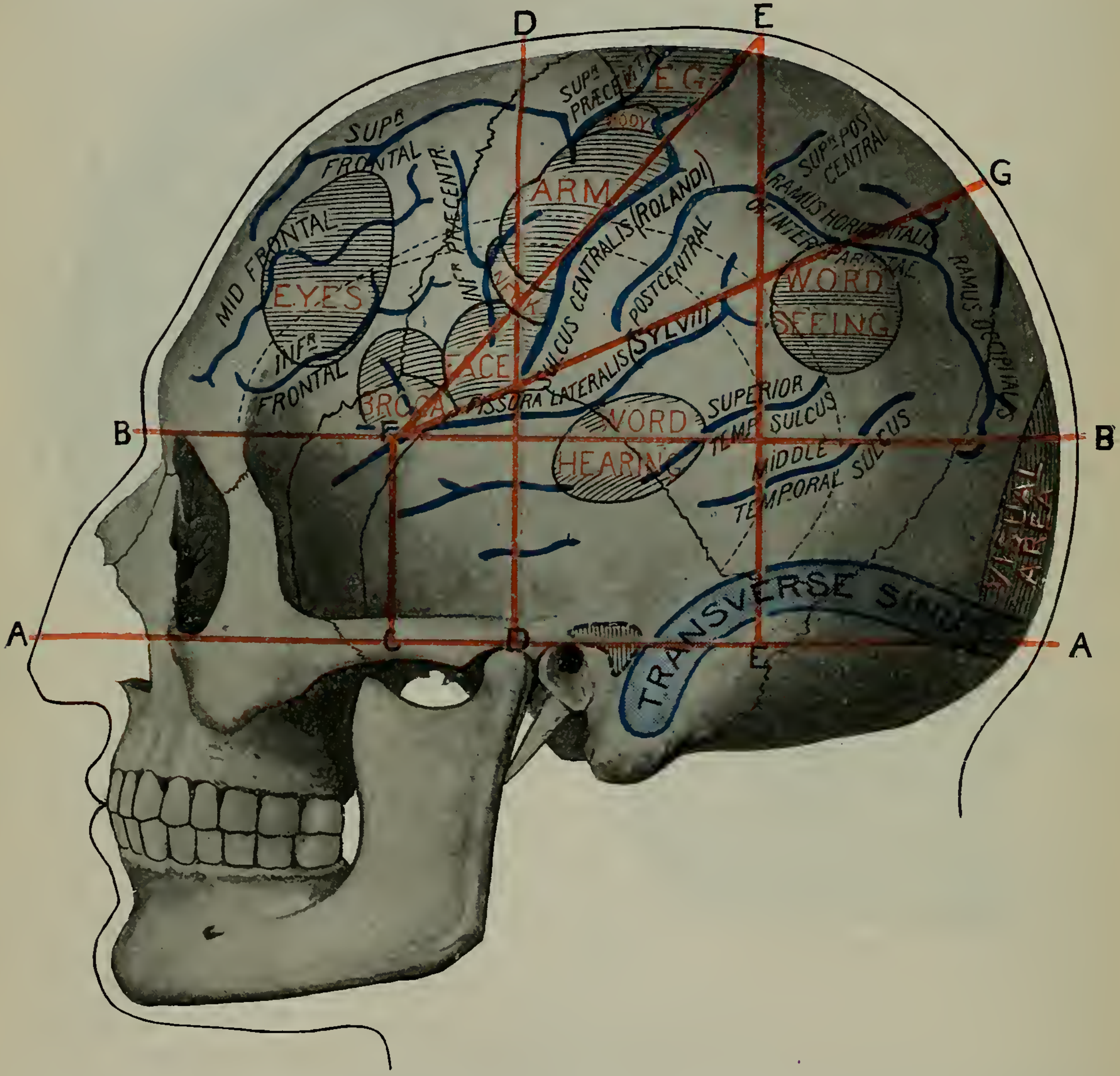

FIG. 1048.—CRANIO-CEREBRAL TOPOGRAPHY ACCORDING TO KRÖNLEIN (motor centres adapted from Grünbaum and Sherrington). Guiding lines, red ; sulci, blue.

The lateral **ventricle** may be tapped or drained from above, by traversing brain tissue for a depth of 4 to 5 cm. through the superior frontal sulcus, 1¼ in. (two fingers'-breadth) in front of the point X^2, Fig. 1047, the instrument being directed downwards and backwards (Kocher).

Keen drains the ventricles through an opening 1¼ in. behind the external acoustic meatus and the same distance above Reid's base-line (a line drawn backwards from the inferior margin of the orbit through the centre of the external acoustic meatus, X^3, Fig. 1047), the instrument being passed into the brain towards the summit of the opposite auricle. If the ventricle is not distended it will be reached at a depth of two inches from the surface.

To open the **subarachnoid space**, the pin of a small trephine is placed over the mid-point of the line EA, Fig. 1047 ; the dura is incised as it crosses the stem of the lateral fissure of the brain from the frontal lobe to the anterior extremity of the temporal lobe. Care must be taken to keep in front of the middle meningeal artery.

The **cisterna cerebello-medullaris**, situated between the under surface of the cerebellum and the medulla oblongata, may be tapped by turning down a flap of soft parts, and removing a circle of bone immediately above the foramen magnum ; the **fourth ventricle** may be opened up by making a larger opening and separating the posterior extremities of the tonsillar lobes of the cerebellum.

To expose a **hemisphere** of the **cerebellum**, trephine over the centre of a line drawn from the tip of the mastoid process to the external occipital protuberance.

To expose both hemispheres of the cerebellum two flaps are reflected by an anchor-shaped incision. The curved horizontal limb is made a little above and parallel to the superior nuchal line of the occipital bone, and, if possible, the extremities of the incision are kept medial to the mastoid emissary vein, which may give rise to troublesome bleeding. The occipital arteries are divided. The vertical limb of the incision descends medially. As the flap contains the sub-occipital muscles the bone itself may be removed. If more room is required, the opening in the bone may reach above the level of the transverse sinuses without wounding them, as they can be displaced along with the dura. The occipital sinus is divided between two ligatures. After dividing the dura a hemisphere of the cerebellum may be displaced towards the median plane to enable the finger to be passed between it and the posterior surface of the petrous portion of the temporal bone so as to reach a tumour of the acoustic nerve, which occupies the angle between the cerebellum and the pons.

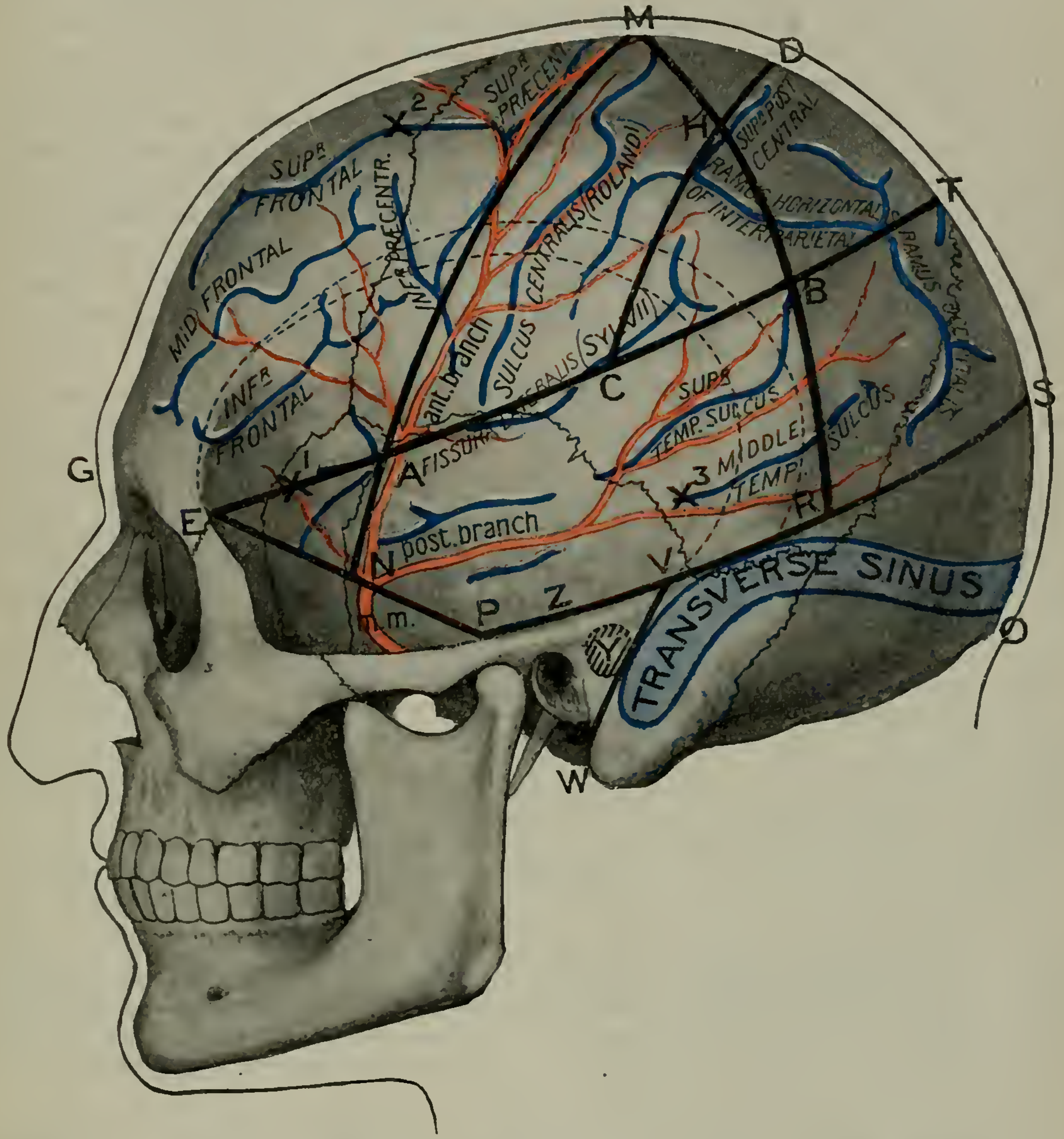

FIG. 1049.—CRANIO-CEREBRAL TOPOGRAPHY.

Guiding lines (Chiene's), deep black ; sutures, fine black ; meningeal arteries, red ; sulci, blue.

G.	Glabella.
O.	External occipital protuberance (inion).
M.	Mid-point between G and O.
T.	Mid-point between M and O.
S.	Mid-point between T and O.
E.	Zygomatic process of frontal.
P.	Root of zygoma (pre-auricular point).
N.	Mid-point of EP.
R.	Mid-point of PS.
C.	Mid-point of AB.
CD	is drawn parallel to AM.
Z.	Post-auricular point.
VW.	Guide to anterior limit of transverse sinus.
Y.	Tympanic antrum.
X^1.	Site at which subarachnoid space may be opened.
X^2.	Site for draining lateral ventricle (Kocher).
X^3.	Site for draining lateral ventricle (Keen).

Meningeal Arteries.—When the calvaria is removed the **meningeal arteries** are found to adhere firmly to the dura mater. Of these vessels the middle meningeal artery is the only one of surgical importance. It is frequently lacerated in fractures of the skull; the blood is generally extravasated between the dura and the bone, and the bleeding point lies beneath the clot. After entering the cranial cavity through the foramen spinosum, the *main trunk*, which is usually about 1½ in. in length, runs laterally and slightly forwards to bifurcate into anterior and posterior divisions at a point a finger's-breadth above the middle of the zygomatic arch, viz., at or close behind the point N, Fig. 1049. When the main trunk is short the bifurcation takes place opposite the middle of the zygomatic arch.

The *anterior and larger division* passes upwards, with a slight forward convexity, a little behind the spheno-squamosal suture and across the pterion to the sphenoid angle of the parietal bone. From that point the vessel is continued upwards and slightly backwards, behind the coronal suture; it gives off branches which ascend over the motor area. The position and general direction of the anterior branch may be said to correspond to the line MN; it follows, therefore, that the artery will be encountered in trephining over the lower and anterior part of the Rolandic area, especially over the motor centres for the tongue and face.

The *posterior division* passes almost horizontally backwards, towards the mastoid angle of the parietal bone.

To expose the *trunk* of the vessel and its bifurcation, the trephine is applied immediately above the middle of the zygomatic arch. To expose the *anterior division* the pin of the trephine may be applied at the point A, which strikes the artery as it crosses the pterion and grooves the sphenoidal angle of the parietal bone. The inferior segment of the disc of bone removed is much thicker than the superior, as it involves the prominent ridge which passes from the tip of the great wing of the sphenoid on to the sphenoidal angle of the parietal bone. At the sphenoidal angle of the parietal bone, the artery frequently runs in a canal for a distance of half an inch. It follows, therefore, that a considerable thickness of bone has to be sawn through at the inferior segment of the circle before the disc can be removed, and during the removal bleeding may occur from the artery as it lies in the canal.

Vogt localises the *anterior division* at a point a thumb's-breadth behind the tubercle on the posterior border of the zygomatic bone and two fingers'-breadth above the zygoma. Krönlein trephines at a point 1¼ in. behind the zygomatic process of the frontal, on a line drawn from the supra-orbital margin backwards parallel to Reid's base-line. If the centre of the trephine be placed at the mid-point of the lower third of the line MA, the anterior division will be reached above the canal and the ridge at the sphenoidal angle of the parietal; if the bleeding-point is lower down, the trephine opening may be enlarged downwards along the line AN.

The course of the *posterior division* may be indicated upon the surface by drawing a line backwards from the point N parallel to PR, that is to say, a finger's-breadth above the zygoma and the supra-mastoid crest.

When the **frontal branch** of the anterior division is injured, the clot is in the fronto-temporal region, and involves more especially the motor area for the face, and, on the left side, Broca's convolution; when the **anterior division** is wounded, the clot, which is larger, involves the parieto-temporal region, and the motor symptoms are due to pressure upon the centres for the arm and face; in injuries to the **posterior division** the clot overlies the parieto-occipital region, and the localising symptoms are sensory (Krönlein). In more extensive meningeal hæmorrhage the clot may cover the greater part of the hemisphere.

The **superior sagittal sinus**, which enlarges as it extends backwards, occupies the median plane of the vertex from the glabella to the internal occipital protuberance, where it opens into the confluens sinuum, and becomes continuous usually with the right transverse sinus. Opening into the sinus, especially in the posterior part of the parietal region, are the **para-sinoidal sinuses**, into which arachnoideal granulations project.

In opening the skull over the posterior part of the vertex, the edge of the trephine should be kept at least three-quarters of an inch from the median plane.

The **transverse sinus** may be mapped out on the surface by drawing a line, slightly convex upwards, through a point a little above the inion to the asterion (1½ in. behind and 1 in. above the centre of the external acoustic meatus) at, or a little in front of, the point R, Fig. 1049, and thence in a downward and forward direction to a point ¾ in. inferior and posterior to the centre of the external acoustic meatus, where it finally curves medially and forwards to open into the jugular bulb, which occupies the jugular foramen. According to Moorhead the highest part of the sinus lies a finger's-breadth above the middle of a line extending from the inion to the middle of the external acoustic meatus. The *anterior border* of the *descending* or *mastoid portion* of the sinus may be mapped out by drawing a line VW from a point a finger's-breadth behind the post-auricular point of the temporal crest to the anterior border of the tip of the mastoid process. In wounds of the sinus the hæmorrhage is very free, owing to the inability of its walls to collapse, but the bleeding is easily controlled by plugging.

Of the **cerebral arteries**, the *middle* supplies almost the whole of the motor area, and one of its lenticulo-striate branches, which enters the brain at the anterior perforated substance, is called "*the artery of cerebral hæmorrhage*" from the frequency of its rupture in apoplexy. The extravasated blood involves the motor part of the internal capsule. The postero-medial central branches of the *posterior cerebral* artery, which enter the brain at the posterior perforated substance, supply the thalamus and walls of the third ventricle; hæmorrhage from one of these branches is apt to rupture into the ventricle. The postero-lateral central branches of the posterior cerebral artery supply the thalamus, and when one of these vessels ruptures the hæmorrhage is apt to invade the posterior or sensory part of the internal capsule.

Semilunar Ganglion.—The topography of the semilunar ganglion is important in relation to the operation of division of its sensory root for the cure of trigeminal neuralgia. The ganglion is situated between two layers of the dura at the apex of the petrous portion of the temporal bone, at the medial part of the middle fossa of the base of the skull.

The surgeon reaches it by an extra-dural route through an opening immediately above the zygomatic arch. The bone is removed down to the level of the infra-temporal crest, which forms the boundary line between the lateral and basal portions of the middle cranial fossa. The dura mater is separated from the fossa so as to admit of the ligature of the middle meningeal artery immediately after its entrance into the cranium through the foramen spinosum. By separating the dura mater still further in a medial direction the posterior-lateral border of the ganglion is exposed. The raising of the dura is now continued more deeply and at the same time in a slightly backward direction until the dura propria (arachnoid) which covers the sensory trunk of the trigeminal nerve is exposed. By incising this membrane horizontally the cavum Meckelii will be opened into and the nerve will be seen after the cerebro-spinal fluid has escaped; it may then be followed back to its exit from the aperture in the dura mater, which is situated immediately below the attachment of the tentorium cerebelli, between it and the superior margin of the petrous temporal bone. The sensory trunk is now gently raised on a hook and all its bundles must be carefully divided without injury to the small motor root; the latter lies beneath the sensory root. The ganglion has a grayish-red colour and a felted surface, while the portio major or trunk of the trigeminal nerve is almost white, and striated longitudinally.

Ear.—The skin covering the lateral surface of the **auricle** is tightly bound down to the perichondrium, hence inflammations of it are attended with little swelling but much pain. The **posterior auricular artery**, which ascends along the groove at the posterior attachment of the auricle, is immediately anterior to the incision for opening the tympanic antrum.

The cartilaginous portion of the **external acoustic canal**, the general direction of which is medially, forwards, and downwards, possesses various curves of practical importance. The highest part of the upward convexity, which is also the narrowest part of the canal, is situated at the centre of its osseous portion; beyond this the floor sinks to form a recess in which foreign bodies are liable to be imprisoned. Of the two horizontal curves the lateral is convex forwards, the medial concave forwards. The skin of the osseous portion of the canal is thin and fused with the periosteum. Boils in the canal are extremely painful; when situated on the posterior wall and associated with cellulitis the condition may be difficult to distinguish from mastoiditis.

The relations of the osseous walls of the canal are of importance to the surgeon. The whole of the upper wall and the upper half of the posterior wall, developed from the squamous portion of the temporal bone, consist of two layers of compact bone, a superior and an inferior, which are continuous, the former with the inner table, the latter with the outer table of the skull. The superior plate passes medially to the petro-squamosal suture, where it becomes continuous with the lateral edge of the tegmen tympani, which roofs over the epitympanic recess and the tympanic antrum; the lower plate bends downwards and medially at its deepest part to form the lower and lateral wall of the recess and the anterior part of the lateral wall of the antrum (Trautmann). Upon the upper and posterior segment of the external acoustic margin is the **suprameatal spine**; this small but important process, developed from the squamous portion, can usually be distinctly made out in the living subject by pressing upwards and backwards with the forefinger placed in the external acoustic meatus.

The lower half of the posterior wall of the osseous canal (posterior part of the tympanic plate) is fused with the anterior part of the mastoid process, and closes the lower and anterior set of mastoid cells (border cells).

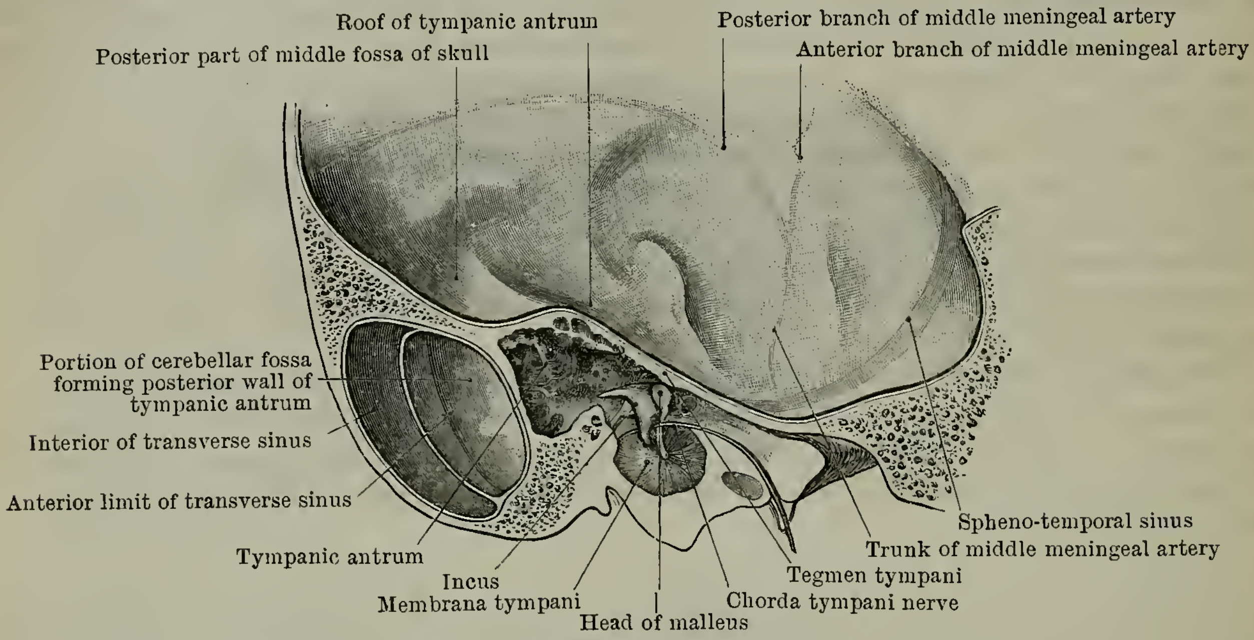
Roof of tympanic antrum
Posterior part of middle fossa of skull
Posterior branch of middle meningeal artery
Anterior branch of middle meningeal artery
Portion of cerebellar fossa forming posterior wall of tympanic antrum
Interior of transverse sinus
Anterior limit of transverse sinus
Tympanic antrum
Incus
Membrana tympani
Head of malleus
Chorda tympani nerve
Tegmen tympani
Trunk of middle meningeal artery
Spheno-temporal sinus

FIG. 1050.—VIEW OF THE LATERAL WALL OF THE MIDDLE EAR.
Section through the left temporal bone of a child, to show the relations of the tympanum and tympanic antrum to the middle and posterior fossæ of the skull.

Anteriorly and inferiorly the osseous canal is related respectively to the **mandibular articulation** and the **parotid gland**; hence it follows that blows upon the chin may fracture the tympanic plate as well as the base of the skull, that pain on mastication is usually complained of in acute inflammatory affections of the meatus and middle ear, and that in young children, in whom the tympanic plate is incompletely ossified, suppurative inflammation is liable to extend from the parotid region into the external acoustic canal.

Clinically, to obtain a view of the **membrana tympani** a speculum and a reflecting mirror are employed; the auricle is pulled upwards, backwards, and laterally in order to straighten the cartilaginous part of the canal. The healthy membrane is pearly gray, semi-opaque, slightly concave, and obliquely placed, the upper and posterior portion being nearer to the observer than the anterior and inferior part.

The handle and lateral process of the malleus, both embedded in the membrana tympani, are the only objects distinctly seen when the healthy ear is examined with the speculum. The lateral process of the malleus projects laterally, and presents itself, therefore, as a distinct knob-like projection at the superior part of the membrane; passing forwards and backwards from this process are the **anterior** and **posterior malleolar folds** of the membrana; they form the lower limit of the pars flaccida of the membrane, and correspond to the line of the chorda tympani nerve. The handle of the malleus, situated at the junction of the two upper quadrants, is seen passing downwards and backwards to the point of maximum concavity of the

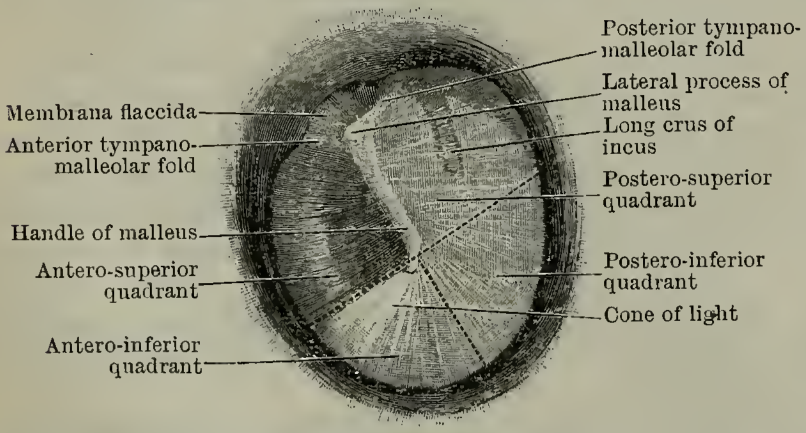
Posterior tympano-malleolar fold
Lateral process of malleus
Long crus of incus
Postero-superior quadrant
Postero-inferior quadrant
Cone of light
Membrana flaccida
Anterior tympano-malleolar fold
Handle of malleus
Antero-superior quadrant
Antero-inferior quadrant

FIG. 1051.—LEFT TYMPANIC MEMBRANE (as viewed from the external acoustic meatus). × 3. (From Howden.)

membrane (umbo), situated a little below its centre (Fig. 1051); passing downwards and forwards from the umbo is the *triangular cone of reflected light*, to which too much importance must not be attached, since its appearances vary considerably in healthy ears. Normally, the long crus of the incus is but faintly visible, and still less so are the promontory and fenestra cochleæ; in the condition of obstruction of the auditory tube (Eustachian), however, in which the membrane is indrawn, these structures, along with the folds of the drum-head, become more distinct.

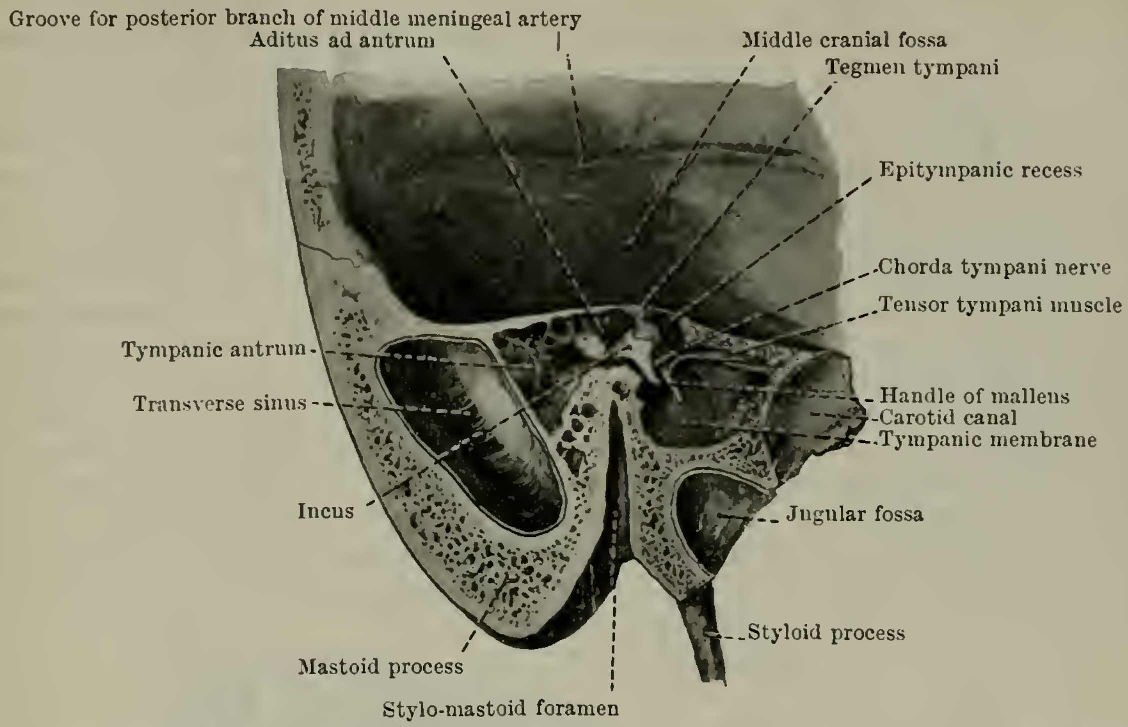

FIG. 1052.—SECTION THROUGH LEFT TEMPORAL BONE, SHOWING TYMPANIC WALL OF TYMPANIC CAVITY, ETC.

In performing the operation of *paracentesis of the tympanic membrane* the incision is made through the two posterior quadrants, as, in addition to providing good drainage, it is farthest removed from important structures, especially the chorda tympani nerve.

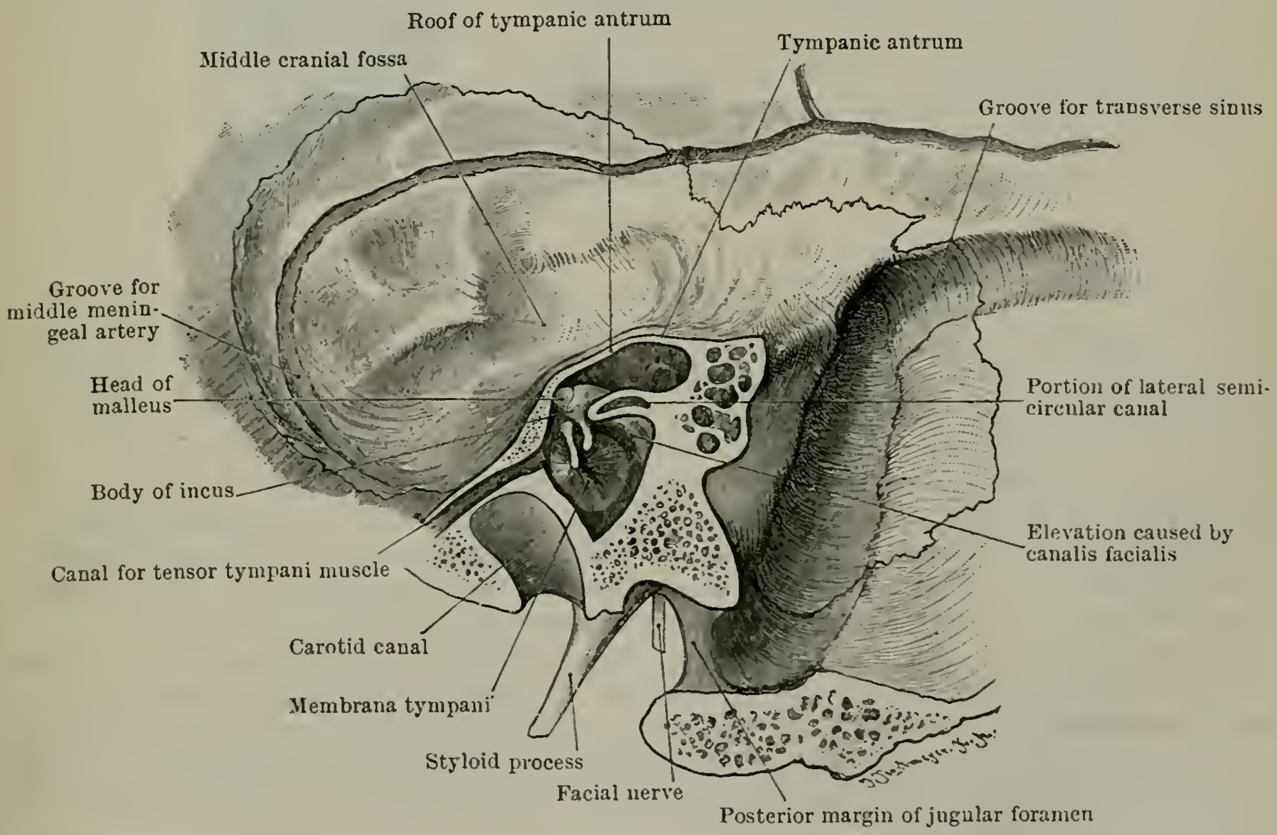
Roof of tympanic antrum
Middle cranial fossa
Tympanic antrum
Groove for transverse sinus
Groove for middle meningeal artery
Head of malleus
Portion of lateral semicircular canal
Body of incus
Elevation caused by canalis facialis
Canal for tensor tympani muscle
Carotid canal
Membrana tympani
Styloid process
Facial nerve
Posterior margin of jugular foramen

FIG. 1053.—SECTION THROUGH PETROUS PORTION OF TEMPORAL BONE OF ADULT.
Showing the relation of the tympanum to the middle and posterior fossæ of the skull.

In order to understand the clinical importance of the parts seen through the translucent membrane, it is necessary to study the relative position of the structure of the "*mesotympanum*," that is to say, that part of the tympanum which lies opposite the tympanic membrane. If the tympanic plate and the tympanic membrane be carefully removed so as to leave the ossicles and chorda tympani nerve in position, it will be seen that the head of the malleus and the body and short crus of the incus are altogether above the tympanic membrane, and that they occupy the **tympanic attic** or **epitympanic recess** (Fig. 1054). At the junction of the two upper quadrants of the membrane is the **handle** of the **malleus**, which is directed downwards, forwards, and medially; the tendon of the tensor tympani muscle crosses the tympanic cavity from its inner wall to be attached to the upper part of the handle. The **lateral process** of the **malleus** is directed laterally a little below the deepest part of the roof of the osseous external acoustic canal. Opposite the postero-superior quadrant are the **long crus** of the **incus**, which descends behind and almost parallel to the handle of the malleus, and the **stapes**, which is directed medially as well as slightly upwards and backwards to the fenestra vestibuli. The **chorda tympani nerve** runs from behind forwards between the lateral surface of the superior part of the long crus of the incus and the medial surface of the neck of the malleus. At the deepest part of the roof of the osseous canal, above the chorda tympani nerve and the lateral process of the malleus, is a notch (*notch of Rivinus*), which is occupied by the flaccid and highest portion of the membrana tympani (*Shrapnell's membrane*); the notch is due to a deficiency in the tympanic ring which only forms about five-sixths of a circle. Opposite the postero-inferior quadrant of the drum-head is the **promontory** caused by the first part of the **cochlea**, below and behind which is the **fenestra cochleæ**. Opposite the antero-superior quadrant are the **processus cochleariformis**, the **tendon** of the **tensor tympani**, and the passage leading towards the **auditory tube**.

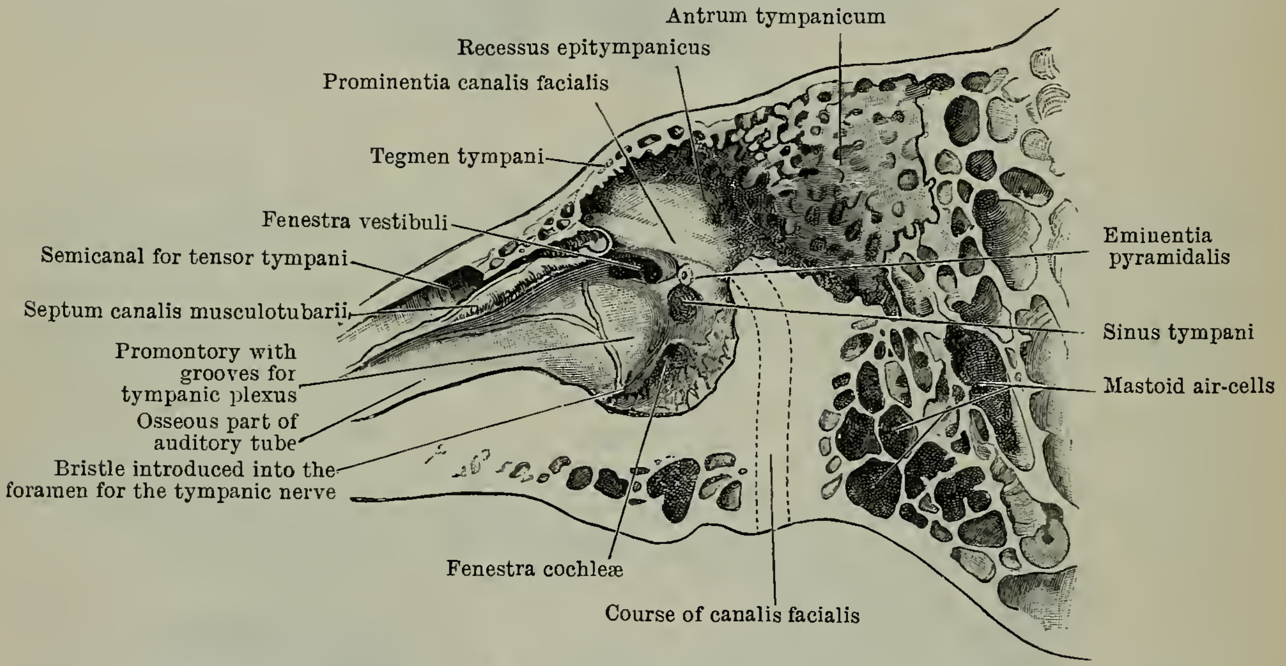
Antrum tympanicum
Recessus epitympanicus
Prominentia canalis facialis
Tegmen tympani
Fenestra vestibuli
Semicanal for tensor tympani
Septum canalis musculotubarii
Promontory with grooves for tympanic plexus
Osseous part of auditory tube
Bristle introduced into the foramen for the tympanic nerve
Fenestra cochleæ
Course of canalis facialis
Eminentia pyramidalis
Sinus tympani
Mastoid air-cells

FIG. 1054.—SECTION THROUGH LEFT TEMPORAL BONE, showing labyrinthic wall of tympanic cavity, etc.

The *labyrinthine wall* of the tympanic cavity is related to the internal ear. The *tegmental wall* separated the tympanic cavity from the middle fossa of the skull and the under surface of the temporal lobe of the brain. It is formed by the **tegmen tympani**—a thin plate of bone, which is continued anteriorly to form the roof of the osseous portion of the auditory tube, while posteriorly it roofs over the tympanic antrum. Laterally the tegmen is limited by the **petro-squamous suture**, which may remain unossified for some years after birth, thus affording a channel along which pyogenic infection may spread from the middle ear to the meninges and brain. Infection may also spread along the small veins which convey blood from the tympanum to the superior petrosal and transverse sinuses, and to the posterior fossa of the skull along the vessels which pass from the inner wall of the mastoid antrum through the fossa subarcuata, beneath the dome of the superior semicircular canal.

The *jugular wall* of the tympanum is formed mainly by the bone forming the **jugular fossa**, which is occupied by the bulb of the internal jugular vein. When the transverse sinus is large and unusually far forward the bulb is likewise large, and the fossa, which is consequently deeper, may arch up into the jugular wall of the tympanic cavity, from which it may be separated merely by a thin and translucent plate of bone which occasionally shows an osseous deficiency. In cases where this condition existed the jugular bulb has been wounded in the operation of paracentesis of the tympanic membrane.

Anteriorly the tympanic cavity leads into the **auditory tube**, which brings it into communication with the nasal part of the pharynx. In the child the auditory tube is shorter, wider, and more horizontal than in the adult, hence inflammations are more liable to spread along it to the tympanum.

Above the level of the membrana tympani is the **epitympanic recess**, which communicates posteriorly by means of a triangular opening (*aditus ad antrum*) with the tympanic antrum; the base of the triangle, directed upwards, is formed by the tegmen tympani; its apex, directed downwards, is formed by the meeting of the medial and lateral walls. The opening will admit an instrument half a cm. in diameter. The epitympanic recess contains from before backwards the head of the malleus, the body and short crus of the incus, the latter being attached by a ligament to the floor of the aditus. When these structures are covered with inflamed mucous membrane or granulations, drainage from the tympanic antrum into the tympanum proper is interfered with. The *boundaries of the aditus*, important surgically, are as follows: superiorly, the tegmen tympani; medially, an eminence of compact bone, containing the lateral semicircular canal, inferior and anterior to which is a second smaller prominence, corresponding to that portion of the facial canal which curves immediately above and behind the fenestra vestibuli. The wall of the facial canal is here thin and not infrequently deficient, in which case inflammation may readily spread from the tympanum to the facial nerve. The lateral wall of the aditus is formed by the deepest part of the upper and lateral wall of the osseous external acoustic meatus.

The *posterior wall* of the tympanum, below the aditus ad antrum, is formed by diplöic bone which contains the descending portion of the facial canal. Just below the floor of the aditus, on the posterior wall of the tympanum, is the pyramid, through which the tendon of the stapedius muscle emerges to be attached to the head of the stapes.

The **tympanic antrum** is to be considered, developmentally as well as anatomically, as a backwards and upwards extension of the tympanum (Fig. 1052). Its anatomy and relations will be best understood by studying it in the child, in whom it is relatively larger than in the adult. Situated above and posterior to the tympanic cavity proper, its *lateral wall* is formed by a triangular plate of bone which descends, behind the external acoustic process, from the squamous portion. Posteriorly, this triangular plate is separated from the petro-mastoid element by the **squamo-mastoid suture**, which overlies the posterior part of the antrum and transmits small veins to the surface. The suture does not become completely ossified until a year or two after birth, and remains of it may frequently be detected in the adult bone. The anterior and superior portion of the triangular plate turns medially at an angle to form the upper and posterior wall of the rudimentary osseous canal, as well as the floor of the epitympanic recess.

In the adult the lateral wall of the tympanic antrum is formed by a plate of bone from $\frac{1}{2}$ to $\frac{3}{4}$ in. in thickness, which occupies the triangular and somewhat depressed area between the ridge extending, posteriorly and slightly upwards, from the posterior root of the zygoma (supra-mastoid portion of temporal crest), and the superior and posterior quadrant of the osseous external acoustic meatus; upon the latter is the **supra-meatal spine**, immediately posterior to which, upon the floor of the above triangle, is a crescentic depression, the **fossa mastoidea**. The lateral wall of the antrum is felt through the skin as a slight depression immediately behind the auricle, and immediately inferior to the ridge formed by the supra-mastoid crest; below the depression is the prominence corresponding to the insertion of the sterno-mastoid muscle. Trautmann has pointed out, however, that the supra-mastoid crest, which varies considerably in its obliquity, is sometimes situated a little above the level of the roof of the antrum, and that it is safer, therefore, to take the level of the superior border of the osseous meatus as the guide in order to avoid opening the middle fossa of the skull. In children the supra-mastoid crest is not developed, so that if the operator mistake the posterior root of the zygoma for the crest, he will open into the middle fossa of the skull immediately in front of the epitympanic recess. The upper and posterior quadrant of the osseous meatus is therefore the only reliable guide to the antrum in the child.

The *medial wall* is formed by a thick plate of spongy bone which separates the antrum from that portion of the posterior fossa lying between the aqueduct of the vestibule and the groove for the sigmoid portion of the transverse sinus, and which contains the posterior semicircular canal.

The *roof*, which slopes downwards and forwards, is formed by the posterior and thinnest part of the tegmen tympani.

The *floor* is on a lower level than the aditus, and is therefore unfavourably placed for natural drainage.

The **mastoid process** begins to develop in the second year. As development advances the diplöe surrounding the antrum in the child becomes excavated to form the **mastoid cells**, which radiate from the antrum, and either directly or indirectly communicate with it by small openings. In the pneumatic type of mastoid the whole of the process is excavated by these cells, which extend upwards into the squamous portion, forwards to the posterior wall of the osseous meatus (border-cells), and backwards into the occipital bone. Pus retained within the *"border-cells"* may bulge into, and rupture through, the posterior wall of the osseous meatus. Less frequently the mastoid cells are absent, the bone consisting either of osseous tissue similar to that of the diploë, or of dense bone (sclerosed type).

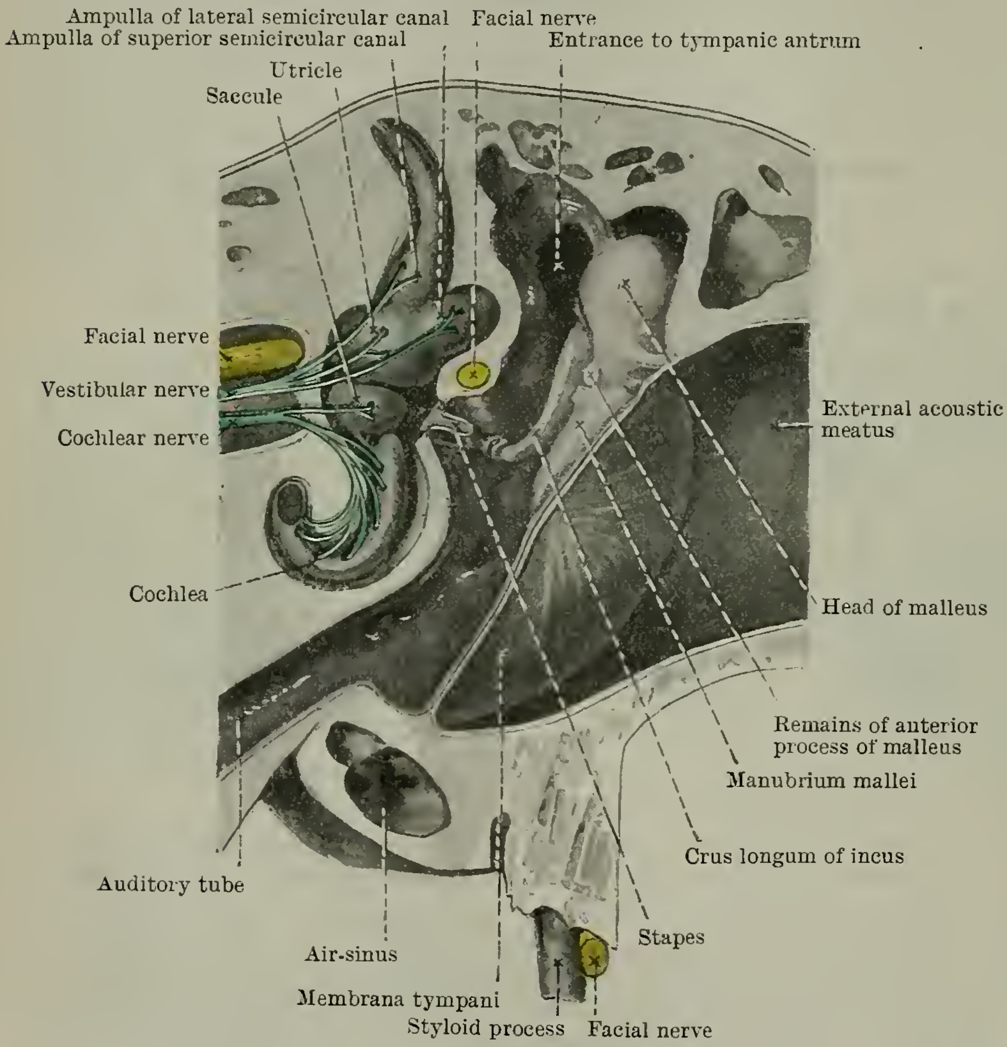

Fig. 1055.—The Tympanic Cavity and Adjacent Parts (semi-diagrammatic).

Arthur Cheatle has shown that in the infant the mastoid is composed of sclerotic or sclero-diploëtic bone. The mastoid antrum is always present and there are a few small air cells in its outer wall. In the adult the sclerotic or sclero-diploëtic type of bone persists in about 20 per cent of skulls; that is to say that the outer wall of the antrum is formed of dense bone, or at least dense bone containing marrow spaces. In the remaining 80 per cent the mastoid process is cellular or pneumatic, owing to the extension of the air cells from the antrum into the rest of the mastoid process. This difference in anatomical structure is of great importance in cases of mastoiditis because, if a patient with a pneumatic mastoid suffers from severe otitis media and mastoiditis, the inflammatory process extends to all these air cells and usually comes to the surface on the outer aspect of the mastoid, giving rise to a subperiosteal abscess. On the other hand, if the patient has a sclerotic or sclero-diploëtic mastoid—the so-called "persistent infantile" form of mastoid—the inflammatory process is confined to the mastoid antrum and does not come to the surface and so become manifest. It is in these cases that an attack of acute suppurative otitis media, with infection of the mastoid antrum, is specially liable to become chronic or to result in infection of the labyrinth or an intracranial complication. In operating on cases of chronic middle ear suppuration the surgeon almost invariably meets with the persistent infantile type of mastoid process, for the reason given above. Formerly it was erroneously supposed that the chronic infection of the mastoid resulted in sclerosis of the bone. We now know, however, that cause and effect have been transposed and that it is the sclerotic type of mastoid which has resulted in the chronic inflammatory condition and not the chronic inflammatory condition which has resulted in sclerosis of the mastoid.

The **labyrinth** may become infected in cases of suppurative otitis media. In acute cases the infective process may pass into the inner ear through the fenestra ovalis or fenestra rotunda. In the former case the annular ligament is infiltrated by pus cells, while in the latter the secondary tympanic membrane is similarly affected. In chronic cases, on the other hand, the route of infection is by way of the prominence of the lateral semicircular canal, which not infrequently becomes eroded in cases of chronic purulent otitis media associated with accumulation of cast off epithelium in the tympanic antrum—a condition known as cholesteatoma. If the labyrinth contains pus it is unsafe to operate on the mastoid unless the inner ear be opened up at the same time. If this is not done the mastoid operation in such cases is likely to be followed by purulent meningitis, owing to the passage of infective material from the labyrinth to the subarachnoid space. The hollow spaces of the labyrinth may be drained by removal of the promontory (see Fig. 1054) by means of a small gouge and two or three blows of the hammer. The gouge is applied just below and in front of the fenestra ovalis, so as to remove the bone between the two windows. In addition, the prominence of the lateral semicircular canal on the inner wall and floor of the aditus is usually removed and the canal opened up (Hinsberg's operation). A more radical method is that described by Neumann, in which the sigmoid portion of the lateral sinus is first of all exposed with the large gouge and hammer. A small, blunt periosteum elevator is then passed in between the sigmoid sinus and its bony wall, in an inward and forward direction, so as to separate the dura from the bone in the region of the saccus endolymphaticus. Stacke's protector is then introduced between the dura and the bone and thereafter the bone is removed with the gouge in the direction of the internal auditory meatus. In this way the posterior semicircular canal is first opened up and later the lateral canal is reached. The smooth end of the lateral canal is then followed up to the vestibule, so that the latter cavity is freely drained from behind. In addition, the outer wall of the promontory is chipped off according to the method described above in Hinsberg's operation.

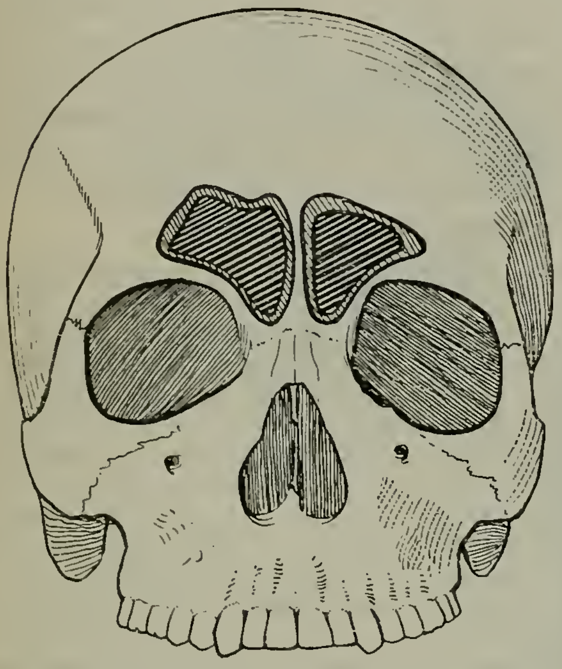

Fig. 1056.—Frontal Sinuses of Average Dimensions, with a Median Septum. (Logan Turner.)

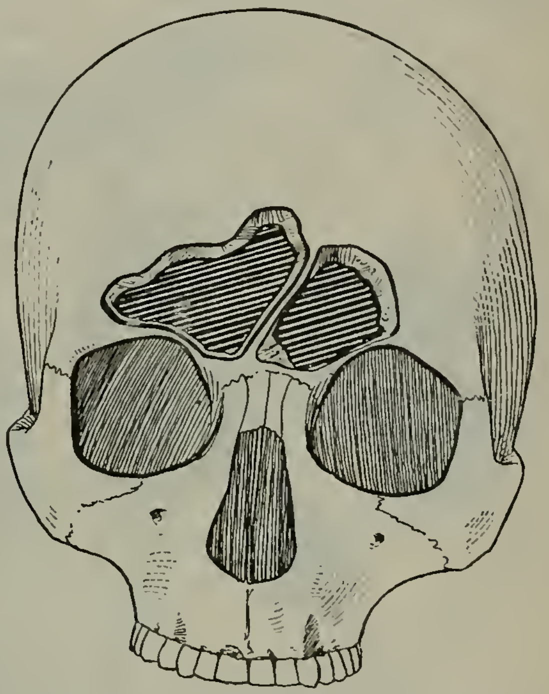

Fig. 1057. — A Large Right Frontal Sinus with Septum oblique to the Left. (Logan Turner.)

The mastoid portion of the temporal bone is grooved, upon its medial surface, by the sigmoid portion of the **transverse sinus**. The average distance of the foremost part of the sinus from the supra-meatal spine is 1 cm. The right sinus usually receives the superior sagittal sinus, and when this is the case it is larger and farther forward than the left; in extreme cases it may reach to within 2 or 3 mm. of the meatus. The average minimum distance of the transverse sinus from the *outer* surface of the mastoid is about 1 cm., but when the sinus is large and far forward the thickness may be reduced to 1 or 2 mm.

The **facial nerve**, after entering the facial canal at the bottom of the internal acoustic meatus, lies immediately above and behind the fenestra vestibuli, between it and the prominence of the lateral semicircular canal; thence it descends almost vertically in the mastoid wall of the tympanum $\frac{1}{8}$ in. posterior and medial to the inferior half of the deepest part of the posterior wall of the external osseous canal and emerges through the stylo-mastoid foramen (Fig. 1052).

In the infant, in consequence of the absence of the mastoid process, the exit of the facial nerve from the stylo-mastoid foramen is unprotected and exposed upon the lateral rather than upon the basal surface of the skull, at a point immediately behind the posterior segment of the tympanic horse-shoe. It follows, therefore, that, in infancy, the incision to expose the antrum should not be curved too far downwards and forwards, otherwise the facial nerve may be divided. In the infant the position of the tympanic antrum is relatively higher than in the adult, because in the former the upper wall of the osseous canal inclines towards the vertical plane instead of being horizontal.

The lymph vessels from the auricle and external meatus open into the posterior and anterior auricular lymph glands, the latter receiving also the lymph from the middle ear. The efferent vessels from those glands open into the superior substernomastoid glands; hence it is that those groups of glands are so frequently found to be diseased secondary to tuberculosis of the middle ear; and care must be taken not to mistake an abscess in one of the mastoid glands for subperiosteal mastoid suppuration associated with middle-ear disease.

To open the **tympanic antrum** the surgeon makes a curved incision a little behind the attachment of the auricle, and removes, with a hammer and gouge, the bone immediately above and behind the postero-superior quadrant of the external osseous meatus. In this operation the *middle fossa* of the *skull* is avoided by keeping below the supra-mastoid crest; the *transverse sinus*, by keeping close to the external acoustic canal and by chiselling obliquely to the surface in opening the mastoid cells; the descending portion of the *facial nerve* is avoided by not encroaching upon the inferior half of the deepest part of the posterior wall of the osseous canal. In extending the operation from the tympanic antrum through the aditus into the epitympanic recess care must be taken not to injure either the *lateral semicircular canal* or the curve of the *facial nerve*, both of which lie in relation to the medial wall of the aditus.

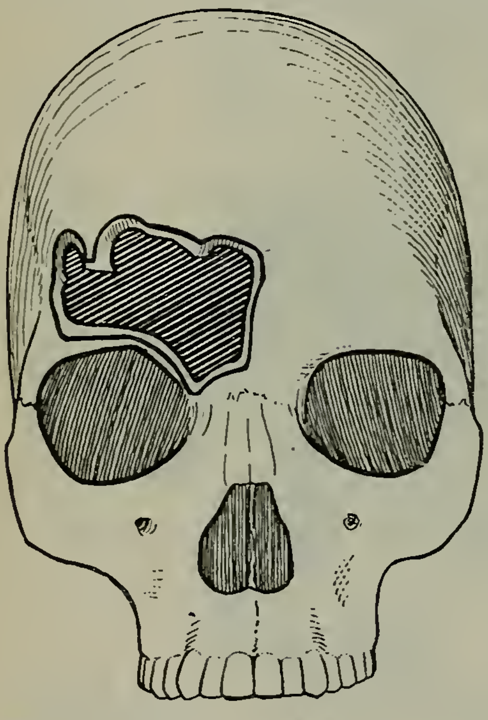

Fig. 1058.—Right Frontal Sinus of very large Dimensions; left Sinus unopened. (Logan Turner.)

The **frontal air sinuses** are two cavities situated immediately above the root of the nose between the two tables of the frontal bone. Each sinus at its most dependent part communicates, by means of the naso-frontal duct, either directly with the middle meatus of the nose, or indirectly with that channel through its infundibulum. A bony septum, rarely incomplete, separates the two sinuses; it is usually median in position below, but it may deviate to one or other side above (Figs. 1056 and 1057).

The sinuses vary considerably in their size and shape, independently of the degree of development of the glabella and superciliary arches (Fig. 1058). According to Logan Turner, the dimensions of an average-sized sinus are: *height,* $1\frac{1}{4}$ in., from the lower end of the fronto-maxillary suture vertically upwards; *breadth,* 1 in., from the median septum horizontally laterally; *depth,* $\frac{3}{4}$ in., from the anterior wall backwards along the orbital roof. The sinus may exist merely as a recess limited to a small area of bone above the nose, or it may extend upwards on to the forehead for more than two inches; laterally it may be limited by the bony wall of the temporal fossa, while posteriorly it may reach as far back as the optic foramen. The anterior wall is thickest, but the thickness may vary from 1 to 5 mm. The floor is the thinnest wall, hence when pus is retained within the cavity it tends to point at the superior and medial angle of the orbit. Intra-cranial suppuration may arise in connexion with sinus disease by extension through the cerebral wall. The muco-periosteal lining, which readily strips from the bone, is thin and pale, and provided with mucus-secreting glands.

In many individuals, by the aid of *trans-illumination*, the extent of the sinuses and the position of the intervening septum may be mapped out upon the forehead. For this purpose a small electric lamp is placed against the floor of the sinus, beneath the inner third of the supra-orbital margin.

The skiagraphic appearances of the frontal sinuses are of importance clinically and give more information than trans-illumination. Antero-posterior skiagrams show the vertical extent of the sinus, the degree of asymmetry, and the presence or absence of recesses, with their intervening septum. An orbital expansion is indicated by a well-defined shadow with a sharply-defined upper margin, extending laterally parallel to and immediately above the medial half or more of the supra-orbital margin. A profile skiagram shows not only the height of the sinuses but also their antero-posterior diameter, as well as the degree to which they extend backwards between the roof of the orbit and the floor of the anterior fossa of the skull, and the relation of the sinus to the underlying ethmoid cells. While it is exceptional to meet with frontal sinuses before the age of five years, they are almost invariably present by the seventh or eighth year.

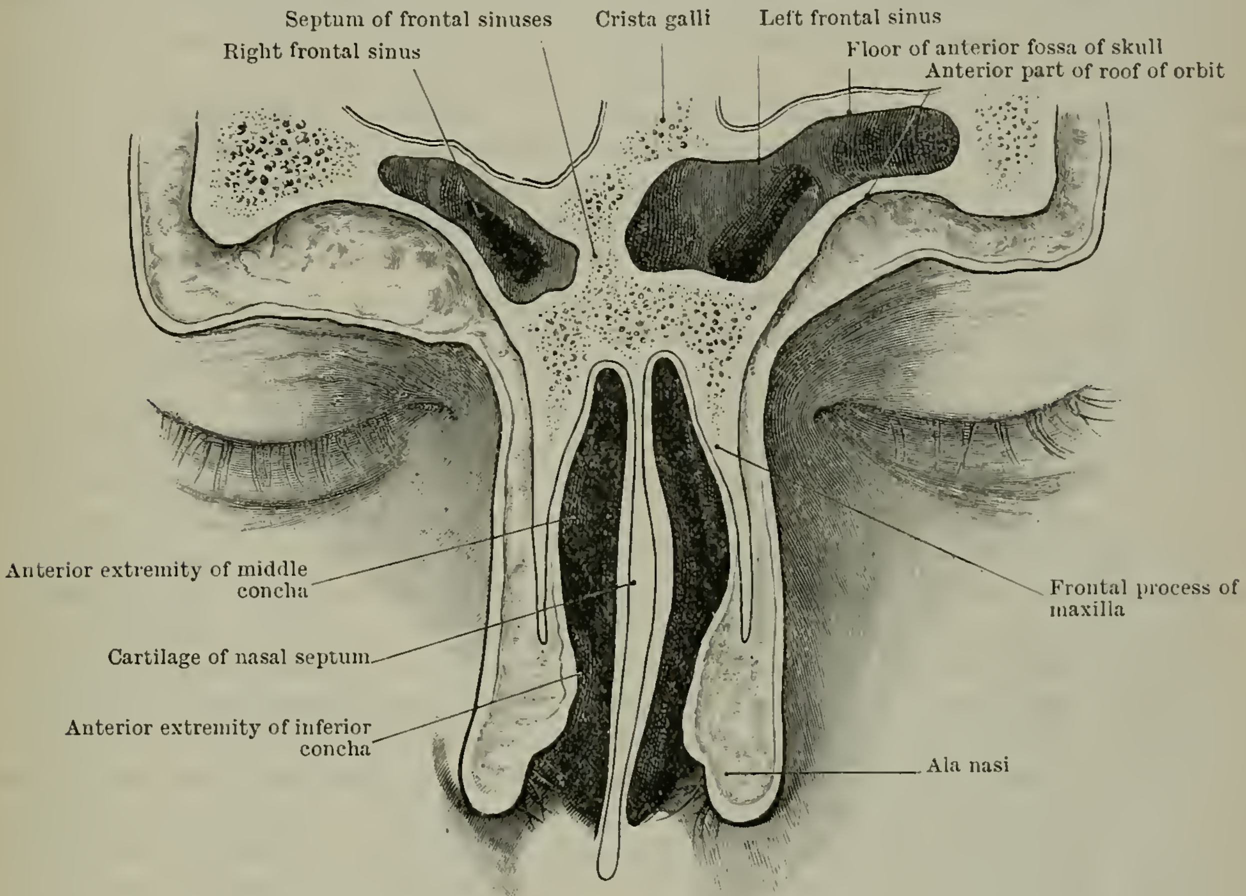
Septum of frontal sinuses
Crista galli
Left frontal sinus
Right frontal sinus
Floor of anterior fossa of skull
Anterior part of roof of orbit
Anterior extremity of middle concha
Cartilage of nasal septum
Anterior extremity of inferior concha
Frontal process of maxilla
Ala nasi

FIG. 1059.—VERTICAL FRONTAL SECTION THROUGH THE NOSE AND FRONTAL SINUSES.

In exploring the sinus, the opening in the bone should be made close to the median plane, immediately above the root of the nose. In marked cases of deviation of the septum one sinus may extend so far across the median plane of the forehead as to reduce the other to a mere slit; in such cases the surgeon may fail to open the diseased sinus when the operation is performed through the anterior wall. The sinus frequently contains incomplete partitions, which give rise to the formation of pockets and recesses usually found towards the lateral angle of the sinus; when dealing with chronic suppuration of the sinuses, special attention should be paid to these recesses as well as to the backward extension of the cavity along the orbital roof. The **anterior ethmoidal cells** are closely related to the thin medial or nasal portion of the floor of the sinus and its duct of exit; hence suppuration very frequently coexists in both cavities. In some cases pus may flow from the frontal sinus along the infundibulum into the maxillary sinus, which opens at its inferior extremity. Killian's operation for the cure of chronic suppuration in the sinus consists in the removal of its anterior and inferior walls, the supra-orbital margin being left to prevent the falling in of the eyebrow. By removing the frontal process of the maxilla good access may at the same time be obtained to the ethmoidal cells and free drainage established between the frontal sinus and the nasal cavity. (Skiagraphs of Frontal Sinuses, see Plates I. and II.)

In an antero-posterior skiagram of the skull, the light shadows formed by the ethmoidal cells are seen to occupy the well-defined area bounded on either side by the still lighter shadow of the orbital cavities and above by the dense horizontal shadow of the cribriform plate, which occupies the frontier line between these sinuses and the frontal sinuses. Anteriorly the ethmoidal area is overlapped by the vertical shadow caused by the frontal processes of the maxillæ and by the ridges of the lacrimals. Not infrequently the ethmoidal cells will be seen to extend into the roof of the orbit, while inferiorly and laterally they come into close relation to the superior and medial angle of the shadow formed by the maxillary sinus. The comparative transparency of the area of the ethmoidal cells is accounted for by the fact that it is superimposed upon that of the sphenoidal sinuses.

In a profile skiagram the ethmoidal area is seen to extend from the frontal process of the maxilla backwards across the orbits to the sphenoidal sinuses, with which they are contiguous. This area is crossed about its middle by the vertical shadow caused by the lateral margin of the orbit. In front of this, and occupying, therefore, the light area of the orbital cavity, are the anterior ethmoidal cells; while behind it are the posterior ethmoidal cells. In a profile view of the skull, the posterior ethmoidal cells, the sphenoidal sinuses, and the hypophyseal fossa all lie from before backwards in the axis of those rays which pass through the thinnest portion of the cranial box, namely, the anterior part of the temporal fossa; hence the possibility of being able to identify them even in a skiagram taken from a living subject.

The sphenoidal sinuses are so deeply placed behind the upper half of the piriform aperture of the nose that their outlines cannot be identified in an antero-posterior skiagram. If the sinuses be filled with bismuth before the skiagram is taken, it will be seen that they produce a well-defined and slightly oval black shadow, about the size of a shilling, situated opposite the superior half of the piriform aperture, the superior limit of the shadow reaching just up to the transverse curvilinear line already referred to, while laterally the shadow reaches ½ cm. medial to the inferior half of the medial margin of the orbit (Logan Turner).

In a profile skiagram of the skull the light shadow produced by the sphenoidal sinus is seen immediately inferior to and in front of the characteristic well-defined cup-shaped shadow formed by the concave floor of the hypophyseal fossa. Inferiorly the sinus area is bounded and to some extent overlapped and obliterated by the dense shadow which corresponds from latero-medially to the tuberculum articulare and the horizontal portion of the great wing of the sphenoid, that is to say, to the floor of the middle fossa of the base of the skull. This dark shadow is continuous, posteriorly, with that which is caused by the dense petrous portion of the temporal bone. Anteriorly is the shadow of the posterior ethmoidal cells (blurred by that produced by the vertical portion of the great wing of the sphenoid), while posteriorly it is limited by the shadow produced by that portion of the body of the sphenoid which lies inferior to the dorsum sellæ.

HYPOPHYSIS CEREBRI.

The topography of the sella turcica, which lodges the hypophysis cerebri, is of importance now that surgery has succeeded in dealing with certain tumours and enlargements of this organ. The fossa hypophyseos lies immediately behind the superior part of the sphenoidal sinuses, and, in a median sagittal section of the skull, the anterior half of the fossa is seen to project into what would correspond to the supero-posterior angle of the sinuses (Fig. 146). The more the sphenoidal sinuses project backwards, beneath the sella turcica, the thinner is the plate of bone which separates the sinus from that part of the posterior fossa of the base of the skull which supports the pons. When, on the other hand, the sphenoidal sinuses are small and do not extend backwards below the sella turcica, the latter may be difficult to identify.

The sphenoidal sinuses constitute the surgeon's guide to the hypophysis. To reach them he traverses the upper portions of both nasal cavities, removing, from before backwards, the upper portion of the septum nasi, the superior and middle conchæ, and, if necessary, the anterior and posterior ethmoidal cells. The rostrum sphenoidale, situated at the superior and most posterior part of the nasal septum, serves as a guide to the anterior wall of the sphenoidal sinuses; after removing it the sinuses are opened up by removing their anterior and inferior walls and the septum. The hypophysis is then exposed by breaking down the anterior portion of the floor of the sella turcica, which forms a bullous-like projection into the superior and posterior part of the sinuses. In making the opening from the sphenoidal sinuses into the hypophyseal fossa, the surgeon must keep strictly to the median plane, so as to avoid opening into the cavernous sinus; if the roof of the sinus be penetrated in front of the fossa the optic chiasma would be injured and the cranial cavity opened, while if the posterior wall of the sinus be penetrated below the level of the fossa hypophyseos the spongy tissue of the body of the sphenoid would be opened into, and if the sinus happened to extend unusually far back, the anterior part of the posterior fossa of the base of the skull would be opened into the basilar artery, adjacent to the ventral surface of the pons, and the cerebral peduncles.

According to Stanley Gibson, the average distance from the nasion to the anterior superior margin of the sphenoidal sinus is 1¾ inches, while the distance from the anterior superior boundary of the sinus to the anterior superior margin of the sella turcica is a little more than ½ inch, so that the total distance from the nasion to the hypophysis is from 2¼ to 2½ inches. The average distance from the anterior nasal spine to the hypophysis is 7·8 cm. (practically 3 in.), while that from the temporal fossa to the hypophysis is 2 inches. The floor of the hypophyseal fossa occupies a plane ½ inch above the upper border of the zygoma, and is on a level also with a plane projected backwards from the nasion to the inion. The normal fossa varies considerably in size. The antero-posterior and transverse diameters are practically the same, and average 11 mm. (Cope), that is to say, they vary from 1 cm. to ½ inch.

In a profile skiagram of the skull, the outline of the cup-shaped sella turcica is marked out by a crescentic linear shadow, the anterior and posterior horns of the crescent being represented by the shadows of the anterior and posterior clinoid processes. Below and in front of the fossa the outlines of the sphenoidal sinuses may be distinctly traced. In front of the fossa hypophyseos the shadow which outlines the roof of the sphenoidal sinus is formed from before backwards by (1) the tuberculum sellæ, (2) the sulcus chiasmaticus, (3) the plane of the lesser wing of the sphenoid. Above the latter is a second horizontal shadow caused by the roof of the orbit. Below the sphenoidal sinus is a curved shadow produced by the floor of the middle cranial fossa, while behind the dorsum sellæ is the dense triangular shadow corresponding to the petrous portion of the temporal bone. (Plate I.)

Enlargements of the hypophysis cerebri can often be clearly demonstrated by an increase in the depth and antero-posterior diameter of the skiagraphic outline of the sella turcica, by the unusual extent to which the fossa encroaches upon the sphenoidal sinus, by pressure atrophy of the anterior and posterior clinoid processes, and by the thinning and backward inclination of the dorsum sellæ.

Adenomata and cysts of the anterior (glandular) lobe of the hypophysis frequently enlarge upward through the diaphragma sellæ towards the brain. After emerging from the sella the tumour projects through the diamond-shaped space bounded in front by the anterior segment of the arterial circle (Willis), and behind by the optic nerves and the chiasma. The resulting temporal hemianopsia, or complete blindness, is due to the pressure of the growth on the above nerves.

In cases of this kind the tumour must be removed by an intra-cranial operation, which consists in elevating the frontal lobe of the brain after the removal of a portion of the frontal bone. (1) The floor of the anterior cranial fossa, (2) the posterior margin of the lesser wing of the sphenoid, (3) the anterior clinoid process, (4) the optic nerve, (5) the internal carotid artery, (6) the chiasma, and (7) the opposite optic nerve, are, in the order mentioned, the structures encountered successively as the tumour is approached. When, on the other hand, the enlargement of the hypophysis is confined to the hypophyseal fossa, partial removal (decompression) of the growth is carried out by the naso-sphenoidal route.

THE FACE.

The skin of the face is thin, vascular, and rich in sebaceous and sweat glands; it is intimately connected with the subcutaneous tissue, in which are embedded the facial muscles as well as the main blood-vessels. Owing to its elasticity and to the presence of the main blood-vessels in the lax subcutaneous tissue, the face is an admirable site for plastic operations, as the flaps do not necrose in spite of considerable tension. The laxity of the tissues accounts for the marked swelling which attends œdematous and inflammatory conditions about the face. Whenever possible, incisions should be made along the line of the natural furrows and creases of the skin, so as to render the resulting cicatrix less noticeable.

The bony landmarks of the face which may be readily palpated are: the **superciliary ridges** and the **glabella**, the **nasion** (fronto-nasal junction), the **bridge of the nose**, the **osseous piriform opening** and the **anterior nasal spine**, the **supra- and infra-orbital margins**, the **zygomatic process** of the **frontal bone**, the **medial angular process**, the anterior part of the **temporal crest**, the **zygomatic bone**, the **zygomatic arch**, and the region of the **canine fossa** of the maxilla.

Immediately inferior to the root of the zygoma, and in front of the superior part of the tragus, is the **condyle of the mandible.** By pressing with the point of the finger upon the condyle while the mouth is being widely opened, the bone will be felt to glide forwards, while the finger sinks deeply into the hollow corresponding to the **mandibular fossa.** The close relation of the first part of the **internal maxillary artery** to the medial aspect of the neck of the mandible must be kept in mind in operations calling for disarticulation or excision of the condyle. The **ramus of the mandible** is sandwiched between the masseter and the pterygoid muscles, and can be removed without opening into the mouth. Passing downwards from the condyle, one can palpate the anterior and posterior borders of the ramus and the **angle** and **body of the mandible.** The anterior border of the **coronoid process** is felt in front of the upper part of the anterior border of the masseter, immediately below the anterior part of the zygomatic arch.

The pulsation of the **external maxillary artery** may be felt as the vessel crosses the inferior margin of the mandible at the anterior border of the masseter, 1¼ in. in front of the angle of the mandible. To map out the course of the artery upon the face, draw a line from this point to a point ½ in. lateral to the angle of the mouth, and thence to a point a little behind the ala nasi and along the side of the nose to the medial angle of the orbit. The **anterior facial vein** lies posterior to the external maxillary artery, and takes a straighter course from the medial palpebral commissure to the anterior inferior angle of the masseter. The vessel is devoid of valves, hence infective phlebitis and thrombosis are liable to spread along it to the cavernous sinus by way of the ophthalmic and pterygoid veins.

A line dropped vertically downwards from the supra-orbital notch (junction of medial and intermediate thirds of the supra-orbital margin) to the inferior border of the mandible opposite the interval between the two lower premolar teeth, will cross the **infra-orbital** and **mental foramina**, the former ¼ in. below the infra-orbital margin, the latter midway between the superior and inferior borders of the mandible. In performing the operation of neurectomy for the relief of trigeminal neuralgia, these foramina furnish the guides to the correspondingly-named branches of the fifth nerve. It should be remembered that the nerves in question, after emerging from their respective foramina, lie, in the first instance, beneath the facial muscles. The supra-orbital and infra-orbital nerves are not infrequently represented each by two branches, one of which passes through an accessory foramen situated lateral to the normal opening. Neurectomy of the **inferior alveolar nerve** is performed by trephining the ramus of the mandible midway between its anterior and posterior borders, on a level with the crown of the last molar tooth, the nerve being reached as it enters the inferior alveolar canal: the **lingual nerve**, which lies a little anterior to the inferior alveolar, can be exposed through the same opening.

The relations of the maxillary and mandibular divisions of the trigeminal nerve have become of increased importance to the surgeon since the introduction of the treatment of trifacial neuralgia by the injection of alcohol into these nerves immediately after their exit from the cranial cavity. According to Symington, in order to reach the maxillary nerve as it lies in the pterygo-palatine fossa, the skin should be punctured immediately below the zygomatic arch, about 4 cm. in front of the anterior wall of the external acoustic meatus. The needle should be directed medially with a slight inclination upwards and backwards. After perforating the masseter and temporal muscles, the instrument enters the fatty tissue of the infra-temporal fossa, embedded in which is the internal maxillary artery and some veins. By passing the needle still more deeply, it is made to penetrate between the two heads of the external pterygoid muscle through the pterygo-maxillary fissure into the pterygo-palatine fossa. If the instrument be passed too far forwards it will strike the maxillary tuberosity; if too far backwards, the lateral pterygoid lamina. The œdema of the eyelids which not infrequently follows the operation is due to some of the fluid passing upwards into the orbit through the inferior orbital fissure. The distance from the skin to the nerve, as it lies in the pterygo-palatine fossa, is practically 2 in. Should the needle, after perforating the masseter, strike the coronoid process of the mandible, the latter may be depressed by opening the mouth.

The mandibular nerve is injected immediately beyond its exit from the foramen ovale, which lies 4 cm. from the skin in the same vertical frontal plane as the tuberculum articulare. When the mouth is opened widely the condyle of the mandible travels forwards and can be distinctly felt immediately below the tubercle. To avoid entering the mandibular joint the needle is introduced through the skin immediately below the zygoma, a little in front of the eminence. It is pushed medially and slightly backwards through the mandibular notch of the mandible, and thence through, or immediately above, the external pterygoid muscle, into the nerve. Symington points out that "the chief dangers connected with this operation are dependent upon the needle being passed in too far. Thus, if it be directed straight inwards beyond the depth of the nerve (4 cm.) it would penetrate the tensor veli palatini and the auditory tube and open on the lateral wall of the naso-pharynx; or, if directed somewhat upwards, it might pass through the foramen ovale, and even reach the cavernous sinus and the internal carotid artery, as the medial boundary of the foramen slopes upwards and inwards."

The **facial nerve**, after emerging from the stylo-mastoid foramen, enters the substance of the parotid gland, nearly an inch deep to the middle of the anterior border of the mastoid process. It is superficial to the external carotid artery. The nerve can be rolled under the finger as it crosses the posterior border of the ramus of the jaw at the level of the lower margin of the tragus; incisions continued along the ramus above this point should be only skin deep if the nerve is to be avoided. To expose the trunk of the nerve an incision is made from the anterior border of the mastoid process to the angle of the mandible. Incisions upon the cheek should, whenever possible, be planned so as to run parallel with the branches of the nerve; these radiate from the inferior end of the tragus. The nerve may be paralysed by wounds of the cheek and by malignant tumours of the parotid, as also by intra-cranial and middle-ear lesions.

The **parotid gland** is surrounded by a fascial envelope, the strongest portion of which is continued from the deep cervical fascia over its superficial aspect to become attached to the zygoma (Fig. 1066); hence abscesses in the parotid tend to burrow deeply towards the pterygo-palatine fossa and the superior part of the pharynx (Fig. 1066); the pus should therefore be evacuated early by Hilton's method, through an oblique incision a little behind and below the angle of the mandible. A study of the relations of the gland explains the surgical difficulties which attend its complete removal.

The **parotid duct** can be rolled beneath the finger as it crosses the masseter, rather less than a finger's-breadth below the zygoma. After winding round the anterior border of the muscle it soon pierces the buccinator, and opens into the mouth opposite to the second molar tooth of the maxilla. The duct corresponds to the intermediate third of a line drawn from the inferior margin of the concha to a point midway between the ala nasi and the margin of the upper lip.

Superficial to the parotid and a little in front of the tragus is the **pre-auricular lymph gland**, which is frequently found to be inflamed in children suffering from eczematous conditions of the eyelids, face, scalp, and external ear. In opening an abscess connected with this gland care must be taken to make the incision as low down as possible, so as to avoid the parotid duct.

The deep parotid lymph glands which lie partly in the substance of, and partly deep to, the inferior part of the parotid, form the highest group of the medial superior deep cervical lymph glands. They are especially liable to become infected secondary to tuberculous disease of the middle ear and to malignant affections about the root of the tongue, the fauces, and the naso-pharynx. In removing them it is generally impossible to avoid dividing the cervical branch of the facial nerve, which pierces the cervical fascia immediately below and behind the angle of the mandible. This nerve supplies the platysma and the depressor labii inferioris muscles, so that its division gives rise to inability to depress the lower lip on the affected side. At the same operation some trouble may be caused by bleeding from the posterior facial vein and its divisions, which traverse the substance of the gland.

Eyelids.—The skin of the **eyelids**, more especially of the upper, is very thin and connected with the orbicularis oculi muscle by delicate and lax subcutaneous tissue destitute of fat; hence the marked swelling which occurs in a "black eye" and in œdema of the lids. Along the anterior edge of the free margins of the lids are the eyelashes and the orifices of the sebaceous glands, suppurative inflammation of which gives rise to a "*stye*"; along the sharp posterior edge of the free margins are the minute orifices of the **tarsal glands**. These glands, embedded in the deep surface of the tarsi, are seen through the palpebral conjunctiva as a row of parallel, yellowish, granular-looking streaks. From the deep position of the glands it follows that the skin over a Meibomian cyst is freely movable, and that to reach the cyst an incision should be made through the conjunctival surface of the lid.

The **palpebral conjunctiva** is closely adherent to the ocular surface of the tarsi; at the fornix it is loose and contains small lymph follicles, which become hypertrophied in the condition known as granular conjunctivitis. The **ocular conjunctiva** is thin, transparent, and loosely attached to the sclera, so that in operating upon the eye a fold of the membrane can be picked up with forceps to steady the eyeball.

In inflammatory affections of the eye the state of those vessels which are visible gives important information as to the seat of the mischief. For example, in inflammation of the *conjunctiva* the posterior conjunctival vessels (derived from the palpebral arteries), scarcely visible normally, appear as a close network which fades away towards the corneal margin; these vessels move freely with the conjunctiva, and do not disappear under pressure. In superficial inflammations of the *cornea* the anterior conjunctival vessels (the most superficial of the terminal branches of the anterior ciliary arteries) are seen to spread in a freely branching manner into its superficial layers. In *iritis* and deep inflammations of the cornea there is a pink circumcorneal zone of vascular dilatation consisting of delicate straight vessels which disappear under pressure and do not move with the conjunctiva; they are the subconjunctival (episcleral) terminations of the anterior ciliary arteries; in health they are invisible.

Lacrimal Apparatus.—The **lacrimal gland**, situated behind the lateral part of the supra-orbital margin, cannot be felt unless enlarged. By everting and raising the upper eyelid, the accessory (palpebral) portion of the gland is seen to project beneath the lateral third of the fornix, in which situation also the minute orifices of the lacrimal ducts may be detected. By gently drawing downwards the lower lid, the small **punctum lacrimale** is seen situated upon a slight papillary elevation of its margin about 4 mm. from the medial palpebral commissure; the corresponding orifice of the upper lid is placed a little nearer the commissure. Normally the puncta are directed towards, and accurately applied to, the ocular conjunctiva immediately lateral to the lacrimal caruncle. By drawing the lids laterally the **medial palpebral ligament** is put upon the stretch, and can be felt as a narrow tense band passing transversely medially to be attached to the frontal process of the maxilla. The ligament is a guide to the position of the **lacrimal sac**, which it crosses a little above its centre. Continuous with the inferior end of the lacrimal sac is the **naso-lacrimal duct**, which passes downwards and slightly backwards and laterally, to open into the inferior meatus of the nose, under cover of the anterior end of the inferior concha. The lacrimal sac and naso-lacrimal duct each measure about $\frac{1}{2}$ in. in length; the latter is slightly contracted at its commencement and termination, and it is in these situations that pathological strictures of the duct are commonest. Spontaneous rupture of an abscess of the lacrimal sac almost invariably occurs just below the medial palpebral ligament; it is in this situation that the abscess should be opened, the incision being made a little lateral to the angular termination of the external maxillary artery.

The **canaliculi lacrimales**, which convey the tears from the puncta to the lacrimal sac, run for the first 1-2 mm. almost vertically to the free margins of the lids, and thence parallel to them. Between the canaliculi is the **lacrimal caruncle.** In the various morbid conditions which give rise either to misdirection of the puncta or to stricture at any part of the lacrimal drainage apparatus, overflow of the tears (*epiphora*) is the chief symptom. In passing a probe along a canaliculus the instrument, in consequence of the bend upon the duct, is passed at first vertically to the margin of the lid, and afterwards parallel to it, until the point is felt to strike against the medial wall of the lacrimal sac; to pass the instrument onwards along the naso-lacrimal duct the handle is rotated forwards and upwards through a quarter of a circle, and then pushed gently downwards and slightly backwards and laterally into the inferior meatus of the nose.

The **tarsi** are attached to the periosteum of the orbital margins by the **superior** and **inferior palpebral ligaments** which shut off the communication between the subcutaneous tissue of the eyelids and the fatty tissue of the orbital cavity. In fracture of the anterior fossa of the base of the skull involving the orbital part, the blood extends forwards between the periosteum and the musculo-fascial envelope of the orbit and appears under the conjunctiva.

To obtain free access to the cavity of the orbit, the surgeon first enlarges the palpebral fissure by making a horizontal incision from the lateral palpebral commissure to the lateral margin of the orbit, and then, after everting the eyelid, divides the conjunctiva along the fornix of the upper or lower lid, or of both, as may be desired.

Nose.—To examine the anterior nares (*anterior rhinoscopy*) a strong light is reflected into the nostril, which is dilated by means of a nasal speculum. The **anterior extremity of the inferior concha** appears as a rounded body projecting from the lateral wall of the nose; in turgescence of its erectile tissue it is liable to come in contact with the nasal septum and so occlude the nostril. The **inferior meatus**, situated between the inferior concha and the floor of the nasal cavity, is brought into view by tilting forwards the head. The **inferior aperture of the naso-lacrimal duct** is concealed from view by the anterior part of the inferior concha. The **floor** of the nose is horizontal and placed on a slightly lower level than the anterior nares. The **septum**, generally more or less deviated to one or other side, is seen when the head is slightly rotated away from the side to be examined. The **anterior extremity of the middle concha**, which lies a little behind and medial to the lower-medial angle of the orbital margin, is seen when the patient's head is thrown well back; between it and the septum is a slit-like interval (*olfactory cleft*). By rotating the patient's head towards the corresponding shoulder the **anterior part of the middle meatus** is brought into view; pus in that situation may originate from the frontal, the anterior ethmoidal, or the maxillary sinuses, all of which open into the middle meatus.

To make a satisfactory *digital exploration* of the anterior part of the nasal cavities, it is necessary to divide the columella and the cartilaginous septum with a strong pair of scissors, one blade being introduced into each nostril (Kocher); blood spurts from the small arteries of the septum, but the bleeding soon ceases. When these vessels, which are derived from the superior labial arteries, are the source of the hæmorrhage in epistaxis, the bleeding can be arrested either by compressing the superior labial arteries, by plugging the anterior nares, or by grasping the cartilaginous part of the nose firmly between the finger and thumb.

The **maxillary sinus** (O.T. **antrum of Highmore**), situated in the maxilla, is a pyramidal cavity with its base formed by the lateral wall of the nose and its apex directed towards the zygomatic bone. The cavity is lined by a thin muco-periosteal membrane, easily separable from the bone; in the mucous layer are numerous mucous glands from which cysts may develop. The floor of the sinus, which is at or a little below the level of the floor of the nose, is separated from the roots of the premolar and molar teeth by a plate of bone of varying thickness. When this plate is thin and devoid of spongy bone, the floor of the sinus sinks below the level of the floor of the nose, and suppuration at the roots of one of the teeth above mentioned is, in these circumstances, very liable to extend to the sinus. In a sinus of average dimensions the line of union of the nasal and facial walls of the cavity corresponds externally to the lateral edge of the canine ridge (Logan

Turner). The *nasal orifice* is situated at the highest part of the sinus, and is therefore unfavourably placed for natural drainage; it opens into the posterior and lower part of the infundibulum, which in its turn communicates with the middle meatus of the nose through the *hiatus semilunaris.* In a varying percentage of heads a second communication exists between the sinus and middle meatus, the opening being situated posterior to and below the normal orifice; when this accessory aperture exists, pus from the sinus may drain backwards into the nasal part of the pharynx (Logan Turner).

In *empyema of the sinus* the opening to evacuate and drain the cavity may be made—(1) Through the alveolus of the second premolar or of the first or second molar tooth, the first molar being the site of election; this route is now seldom made use of. (2) Through the canine fossa, lateral to the prominence caused by the root of the canine tooth. (3) Through the lateral wall of the inferior meatus of the nose.

In an antero-posterior skiagram of the skull, the shadow of the maxillary sinus presents a pyramidal outline, the base corresponding to the floor of the orbit and the rounded apex to the alveolar recess of the sinus. Sometimes the floor of the sinus extends medially, below the floor of the nose, into the palatine process of the maxilla so as to form a distinct palatine recess. The medial outline of the sinus area is formed by the foreshortened shadow of the nasal wall of the sinus and the lateral pterygoid lamina, while laterally it is outlined by the zygomatic bone. The petrous portion of the temporal bone throws a deep shadow across the superior half of the sinus. In taking the skiagram, therefore, the head should be placed in such a position that this shadow is raised as much as possible into the orbits. In the living subject the inferior and medial portion of the outline of the maxillary sinus is considerably obscured by that caused by the cervical portion of the vertebral column (Killian).

In a profile skiagram of the facial region of the dried skull, the shadow of the outline of the maxillary sinus is well defined. It is represented below by the dense horizontal shadow of the hard palate which crosses the tips of the roots of the molar teeth. Above it is limited anteriorly by the dark curved shadow of the floor of the orbit, while above and posteriorly is the shadow of the posterior ethmoidal-cell area. Behind the maxillary area are the vertical linear shadows of the pterygoid laminæ overlapped by that of the coronoid process of the mandible. The anterior part of the sinus area is overlapped and, to a considerable extent, obscured by the shadow caused by the denser and somewhat triangular shadow of the zygomatic bone.

Lips. — In compressing the **labial arteries**, it must be remembered that they run under cover of the mucous surface, a short distance from the free margins of the lips. The lips are abundantly supplied with **mucous glands** which can be felt immediately beneath the mucous membrane nearer their attached than their free borders; the glands are a frequent source of mucous cysts; occasionally they are enlarged congenitally, giving rise to one form of hypertrophy of the lip.

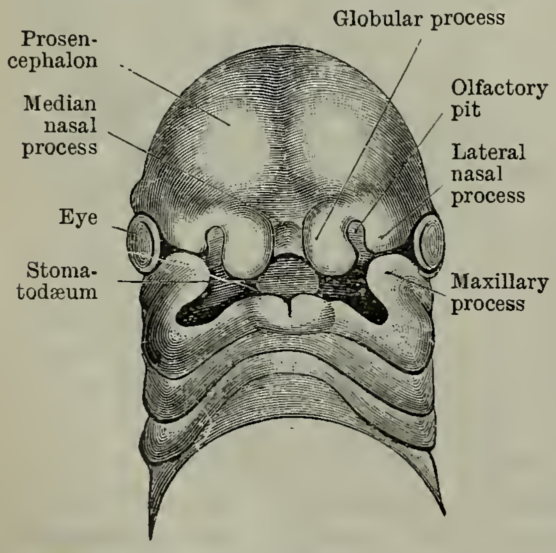

FIG. 1060.—HEAD OF HUMAN EMBRYO ABOUT 29 DAYS OLD, showing the division of the lower part of the median nasal process into the two globular processes, the intervention of the olfactory pits between the median and lateral nasal processes, and the approximation of the maxillary and lateral nasal processes, which, however, are separated by the oculo-nasal sulcus. (From His.)

Hare-lip is due to failure of the union of the superficial parts of the median nasal subdivision of the fronto-nasal process with the maxillary process (Fig. 1060). The deformity is spoken of as complete or incomplete according as the cleft extends into the nostril or merely involves a portion of the lip. The fissure may involve the lip only, or it may include the alveolar process of the maxilla; in the latter case the cleft may or may not be associated with a cleft of the palate

Lastly, the hare-lip may be single or double, according as the deficiency has occurred on one (usually the left) or both sides.

Fig. 1061, taken from a coronal section through the head of a human embryo at the seventh week, shows how the mouth is shut off from the nasal cavities by the growth inwards from the deep aspect of the maxillary process of two horizontal plates (palatine processes) which unite in the median line with each other and with the inferior border of the septum of the nose; the latter, which develops as a downgrowth from the primitive basis cranii, is continuous anteriorly with the two medial nasal processes which form the premaxillæ and the median portion of the upper lip. The various degrees of *cleft palate* are due to the more or less complete failure of union of the palatine processes with each other and with the premaxillary part of the median nasal processes. The cleft in the soft palate, which is always median, may be either partial or complete, and may or may not extend forwards into the hard palate. The cleft in the latter is spoken of as single or double according to whether the palatal processes have failed to unite with the lower edge of the nasal septum on one, or on both, sides. When the cleft extends forwards through the alveolar process to become continuous with a cleft of the lip, the medial (premaxillary) edge of the cleft is usually projected forwards in advance of the lateral (maxillary) edge. Before proceeding to repair the cleft in the lip, the projecting premaxillary edge is forced back into line with the maxillary edge.

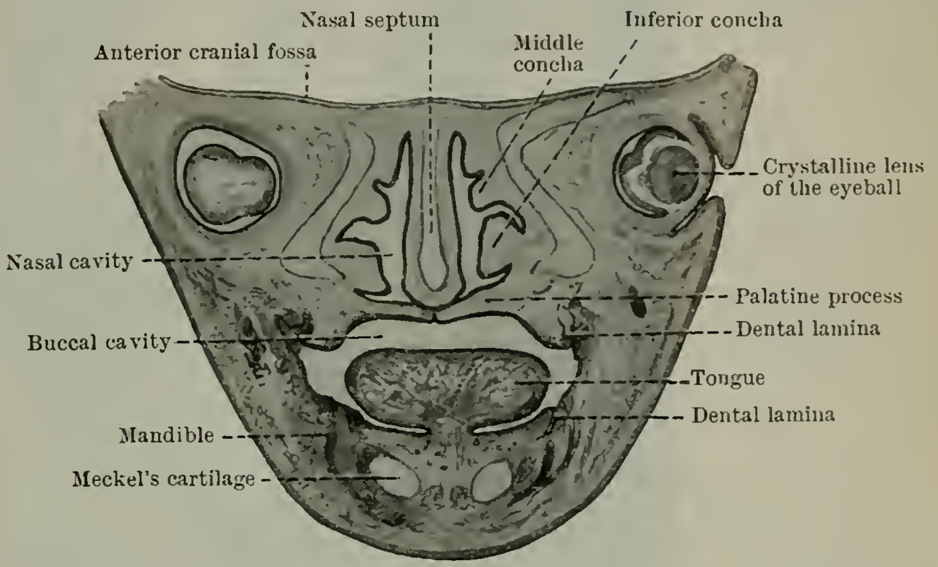

Fig. 1061.—Frontal Section through the Face of a Human Embryo at the Seventh Week.

In what is known as a complete double cleft palate, the palatine processes fail to join the nasal septum and the premaxillæ on both sides; the result is a wide median cleft which communicates with both nasal cavities. The free inferior border of the vomer extends along the middle of the cleft to be continuous anteriorly with the rounded premaxillary mass; the latter, along with the central portion of the upper lip, is projected forwards between the two labial clefts, often to such an extent that it appears to spring from the tip of the nose (Fig. 1062). In operating on such a double hare-lip the first step is to get rid of the premaxillary projection. This is done, not by removing it altogether, but by removing a triangular portion of the septum of the nose behind it, so as to allow of its being bent back into line with the alveolar processes of the maxillæ. The base of the triangular piece of bone should not be taken from the constricted portion of neck of the premaxillary projection, but should consist of the olive-shaped thickening situated immediately behind the neck. This thickening is crossed by the transverse suture uniting the premaxilla with the anterior extremity of the vomer (Fig. 1063). If the premaxillary projection be removed altogether, there is nothing left to support the upper lip, and the result is an ugly deformity, due to the comparative protrusion and redundancy of the lower lip.

Teeth.—The **milk teeth** begin to appear from the sixth to the eighth month, the first to emerge being the lower central incisors. The first dentition is completed about the thirtieth month. Delayed dentition is generally due to rickets. Of the **permanent set** the first to erupt are the first molars, which appear at the end of the sixth or seventh year; the third molars, the last to appear, may erupt any time between the eighteenth and the twenty-fifth year, or even later. As the permanent teeth push their way towards the surface, absorption of the roots of the first set takes place, and the first set either fall out of their own accord or are easily removed. Loss of the permanent teeth is followed by absorption of the alveolar margin of the jaw. The tooth sockets are lined by a thin periosteum, which is anatomically continuous with the pulp tissue of the teeth on the one hand and the dense fibrous tissue of the deep layer of the gum on the other.

The upper incisors and canines and the lower premolars have *cylindrical* roots, hence in extracting those teeth they should be first loosened by a slight rotatory movement; the roots of the lower incisors and canines and of the upper premolars are *flattened*, so that they must be loosened by a lateral movement. The roots of the third molars are *convergent*, generally welded together and curved backwards, especially in the mandible. The first and second upper molars have three roots which are often *divergent.*

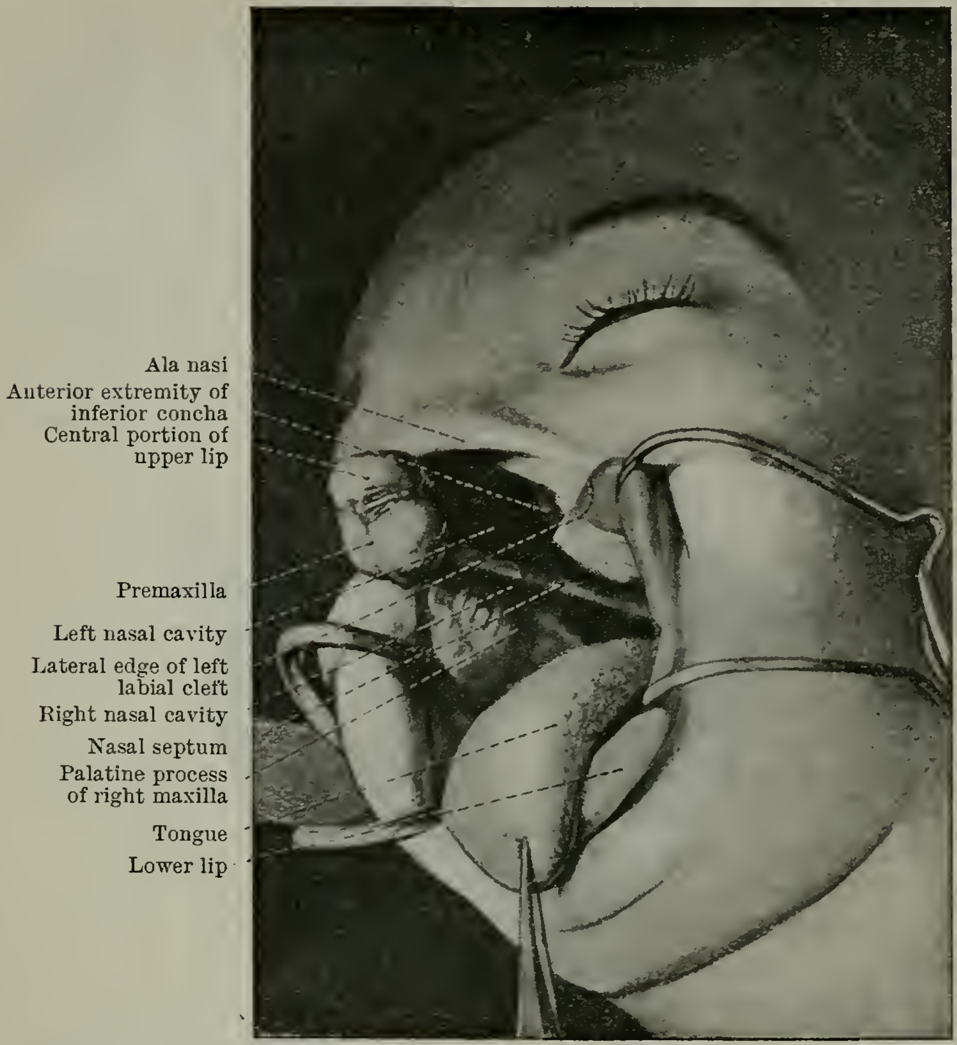
Ala nasi
Anterior extremity of inferior concha
Central portion of upper lip
Premaxilla
Left nasal cavity
Lateral edge of left labial cleft
Right nasal cavity
Nasal septum
Palatine process of right maxilla
Tongue
Lower lip

Fig. 1062.—From a Photograph showing Double Complete Hare-lip and Cleft Palate.

Tongue.—For practical purposes, as well as on developmental and structural grounds, it is convenient to divide the tongue into an anterior two-thirds—the **oral part**, and a posterior third—the **pharyngeal part** (Fig. 1066). At the junction of the two portions, immediately behind the median vallate papilla, is the **foramen cæcum**, which represents the remains of the upper or pharyngeal extremity of the **thyreo-glossal duct.** *Congenital cysts* and *fistulæ* which develop from persistent remains of this tract are always median; those arising from the upper or lingual portion of the tract are situated above the hyoid bone, whereas those developed from the lower or thyreoid portion are situated below the hyoid bone. The liability of these cysts and fistulæ to recur after operation is due to the fact that part of the epithelial tract lies in the substance of the hyoid bone.

The mucous membrane covering the pharyngeal part is much more sensitive than that covering the oral, hence in using a tongue depressor the instrument should, except under special circumstances, rest only upon the latter region, otherwise a reflex arching of the tongue will be set up, which prevents the operator from obtaining a satisfactory view of the throat. Scattered over the pharyngeal part are clusters of **lymph follicles** (lingual tonsils), which appear on the surface as a number of nodular umbilicated elevations provided with little crypts into which mucous glands open (Fig. 1066). The lingual tonsils are liable to chronic inflammation and hypertrophy, conditions which are often accompanied by a varicose condition of the veins which lie immediately beneath the mucous membrane containing the palatoglossus muscle. To obtain a satisfactory view of the lingual tonsils in the living subject the laryngoscopic mirror must be employed.

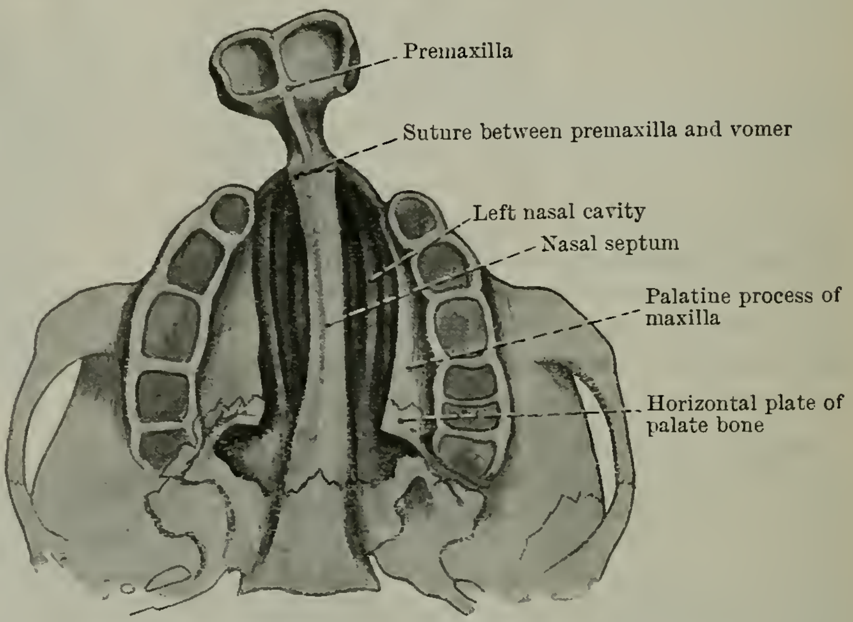
Premaxilla
Suture between premaxilla and vomer
Left nasal cavity
Nasal septum
Palatine process of maxilla
Horizontal plate of palate bone

Fig. 1063.—Shows Arrangement of Bones in Double Cleft Palate. (*Handbook of Practical Surgery*, Bergmann, Bruns, and Mikulicz.)

The pair of mucous glands situated on the inferior surface of the tongue a little behind its tip, and known as the **anterior lingual glands**, are of interest in that they occasionally give rise to mucous cysts similar to those which develop in connexion with the labial glands (Fig. 1065).

The **muscular bundles** of the tongue are separated by a quantity of loose connective tissue, rich in blood- and lymph-vessels (Fig. 1064); hence acute inflammatory œdema of the substance of the tongue may be attended with a degree of swelling sufficient to obstruct the respiratory passage.

The main **blood-vessels** of the tongue run from behind forwards, nearer its inferior than its superior surface (Fig. 1064); incisions into the substance of the tongue to reduce swelling and tension should therefore be made longitudinally upon the dorsum. Bleeding from the lingual artery, divided in the substance of the tongue, is temporarily arrested by passing the finger behind the base of the tongue and hooking it well forward, so as to compress the vessel against the lingual surface of the mandible. On account of the very slender anastomosis between the vessels of the two halves of the tongue, scarcely any bleeding occurs when the organ is split in the median plane.

According to Poirier, the collecting trunks which arise from the lymph networks in the mucous membrane and muscular substance of the tongue may be divided into four groups:—(1) **Apical trunks** which open partly into the submental glands and partly into a gland of the medial deep cervical group lying immediately above the anterior belly of the omo-hyoid muscle. (2) **Marginal trunks** which pass, some lateral to the sublingual gland and through the mylo-hyoid muscle, to join the most anterior of the submaxillary lymph glands; others pass medial to the sublingual gland, in front of and behind the hyoglossus muscle, to join the glands of the medial deep cervical group. The more *anterior* their lingual origin the *lower* in the chain is the gland to which they pass. (3) The **basal trunks**, from the posterior third of the tongue, pass from before backwards towards the inferior extremity of the tonsils, where they pierce the superior and middle constrictors of the pharynx, and, after surrounding the lingual artery, open into a gland placed on the internal jugular vein immediately below the posterior belly of the digastric. (4) The **central trunks**, which descend in the middle line between the genio-glossi, pass beneath the hyoglossus and mylo-hyoid muscles into the submaxillary space, and thence in front of the hyoid bone (having embraced the tendon of the digastric) to join the glands of the medial deep cervical group.

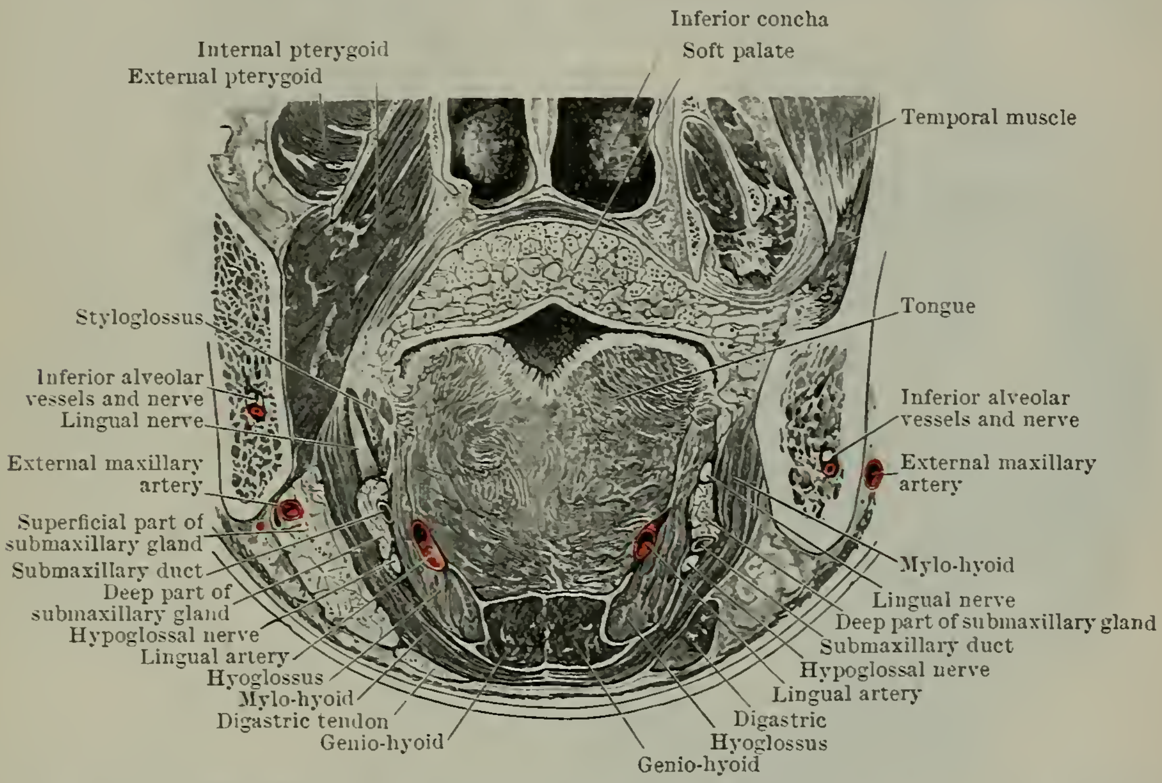

FIG. 1064.—FRONTAL SECTION THROUGH THE TONGUE AND SUBMAXILLARY REGION IN A PLANE BEHIND THE MOLAR TEETH. (From Cunningham.)

Between the tongue and the lingual surface of the gums is the **alveolo-glossal sulcus**, crossed in the median plane by the **frenulum linguæ**, which passes upwards to the inferior surface of the tongue (Fig. 1065). Immediately on either side of the lower part of the frenulum is the **orifice of the submaxillary duct.** A little external to the frenulum the **profunda veins** are seen lying immediately under the thin mucous membrane; to the lateral side of the veins are the profunda arteries and the lingual nerves, both of which lie deeper than the veins, and are therefore not visible.

The mucous membrane at the anterior part of the floor of each alveolo-glossal sulcus is thrown into a slight elevation, which overlies, and is caused by, the corresponding **sublingual salivary gland.** The duct of the submaxillary gland and the lingual nerve lie beneath and to the medial side of the sublingual gland.

In dividing a shortened frenulum for "tongue-tie" the deep lingual vessels and the orifices of the submaxillary ducts must be avoided. Behind the frenulum linguæ are the anterior borders of the **genio-glossi,** which descend to the superior genial tubercles. In operations necessitating the removal of the region of the symphysis of the mandible, or the separation of the origins of the genio-glossi, the tongue must be kept forward, otherwise the patient will be suffocated by the organ falling backwards over the entrance to the larynx. In removing a small salivary calculus from the floor of the mouth the calculus should be fixed with the finger against the lingual surface of the mandible before cutting down upon it.

When the teeth are clenched the vestibule of the mouth communicates behind the last molars with the oral cavity proper through an opening which barely admits a medium-sized catheter. Hence, when the jaws cannot be separated it is generally necessary to feed the patient through a tube passed along the floor of the nose.

When the mouth is opened widely and a deep inspiration is taken, the soft palate is elevated, and the glosso-palatine and pharyngo-palatine arches are rendered prominent. The **glosso-palatine arches** spring from the anterior surface of the soft palate, close to the base of the uvula, and arch downwards and laterally, in front of the palatine tonsils, to end at the posterior end of the side of the tongue. The **pharyngo-palatine arches** are really the continuation of the lower free border of the soft palate downwards behind the palatine tonsils to become attached to, and lost upon, the side wall of the pharynx. Together with the lower edge of the soft palate and the base of the tongue they bound a hemispherical opening (**pharyngo-nasal isthmus**), through which the mucous membrane covering the posterior wall of the nasal portion of the pharynx is visible.

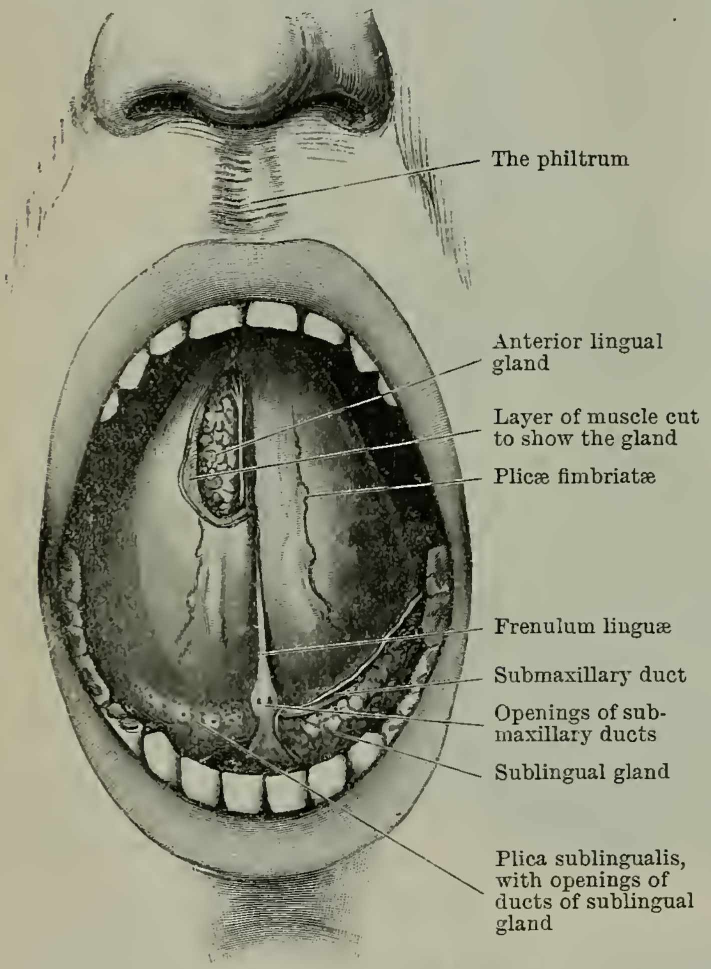
The philtrum
Anterior lingual gland
Layer of muscle cut to show the gland
Plicæ fimbriatæ
Frenulum linguæ
Submaxillary duct
Openings of submaxillary ducts
Sublingual gland
Plica sublingualis, with openings of ducts of sublingual gland

Fig. 1065.—Open Mouth with Tongue raised and the Sublingual and Anterior Lingual Glands exposed.

The sublingual gland of the left side has been laid bare by removing the mucous membrane; to expose the anterior lingual gland of the right side a thin layer of muscle, in addition to the mucous membrane, has been removed. A branch of the lingual nerve is seen running on the medial aspect of the gland. The profunda vein is faintly indicated on this side also. (From Birmingham.)

The **palatine tonsils** (Fig. 1066) lie one on each side of the isthmus, between the palatine arches; they are situated opposite the angle of the mandible, but they cannot be felt from the outside. Each tonsil is covered, on its free surface, by mucous membrane upon which are seen the orifices of the tonsillar crypts; the lateral or deep surface is covered by a layer of fibrous tissue which forms an imperfect capsule to the organ. According to Merkel, the internal carotid artery is situated

1·5 cm. behind the lateral margin of the tonsil, which is separated from the superior constrictor by a quantity of loose cellular tissue and fat, so that the gland can be grasped with a volsellum and pulled forwards without dragging the vessel with it. The tonsil receives its *blood-supply* mainly from a small vessel derived from the anterior palatine artery; when this branch is larger than usual and adherent to the capsule of the tonsil the bleeding which attends the operation of removal of the tonsils may be considerable. The hæmorrhage can be arrested by pressing the bleeding point outwards against the internal pterygoid and the ramus of the mandible. If the bleeding be from a spurting vessel of larger size, its source, according to Merkel, is probably the *external maxillary artery,* which has been wounded as it arches upwards beneath the digastric and stylo-hyoid muscles to within a short distance from the lateral surface of the tonsil. In children and adolescents the tonsils are frequently hypertrophied; the enlargement may be either general, more towards the median line, downwards along the pharynx, or upwards behind the soft palate; to expose and thoroughly remove the last-mentioned variety of enlargement the upper part of the glosso-palatine arch must be divided.

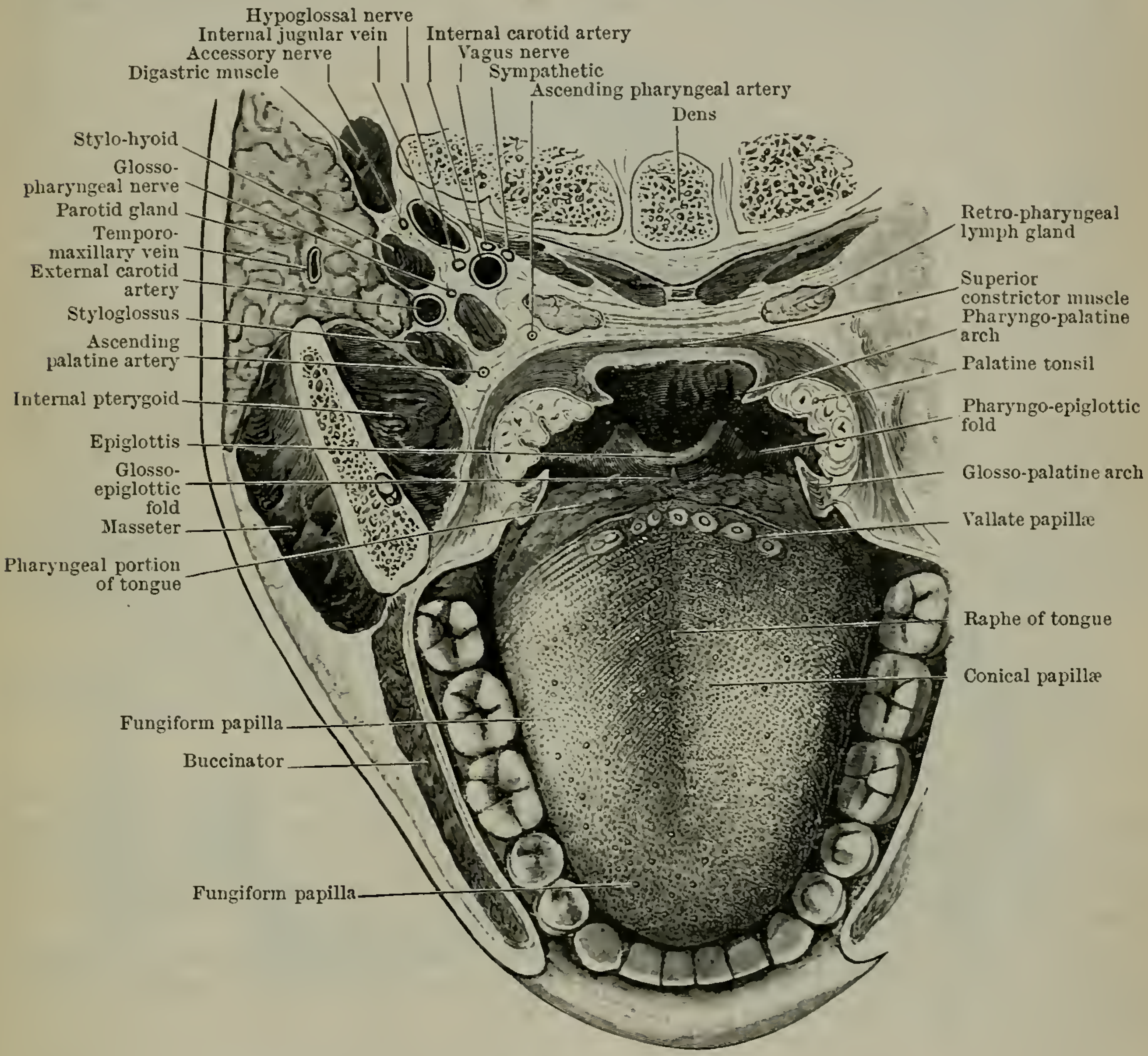

FIG. 1066.—HORIZONTAL SECTION THROUGH MOUTH AND PHARYNX AT THE LEVEL OF THE TONSILS.

The stylopharyngeus, which is shown immediately to the inner side of the external carotid artery, and the prevertebral muscles, are not indicated by reference lines. (From Birmingham.)

The mucous membrane and the periosteum of the **hard palate** are so closely united as to form practically one membrane. The **greater palatine arteries,** after leaving the greater palatine foramina, run forwards in shallow grooves in the hard palate, close to its alveolar margin. In the operation for cleft palate (*staphylorrhaphy*), in order to secure nourishment for the muco-periosteal flaps, the lateral incisions should be made *lateral* to those vessels.

Secondary hæmorrhage after the operation for cleft palate is treated by plugging the **greater palatine foramen**, which lies a little medial to the last molar tooth about $\frac{1}{3}$ in. in front of the hamular process, which can be felt at the superior extremity of the fold of mucous membrane containing the pterygo-maxillary ligament. In the closure of a wide cleft of the soft palate the tension of the **tensor veli palatini muscle** is got rid of by chipping off the **hamulus** with a small chisel introduced at the posterior extremity of the lateral relief incisions.

Nasal Part of the Pharynx.—To explore the superior or nasal part of the pharynx the finger should be hooked upwards behind the soft palate. *Anteriorly*, the finger readily detects the sharp posterior border of the vomer, the choanae, and the posterior extremity of the middle and inferior conchæ. The *roof* of the space is formed by the basilar part of the occipital bone, while upon the *posterior wall* is a transverse bony ridge caused by the projection of the anterior arch of the atlas. Upon the *side walls* of the nasal part of the pharynx are the openings of the **auditory tubes**, situated $\frac{1}{2}$ in. behind the posterior extremities of the inferior conchæ. The orifices, bounded superiorly and posteriorly by a prominent margin, are directed downwards and forwards, and therefore in a direction favourable to the passage of the Eustachian catheter. Behind the prominent posterior margin of the orifice is the *lateral recess of the pharynx* (O.T. **fossa of Rosenmüller**), in which the point of the Eustachian catheter is apt to become engaged. Upon the roof and posterior wall of the pharynx, down to the level of the anterior arch of the atlas, and extending laterally as far as the orifices of the auditory tubes, is a collection of adenoid tissue, the **pharyngeal tonsil**. Hypertrophy of this tissue constitutes the condition known as "*adenoids*," the harmful effects of which are due to their interference with nasal respiration. Upon the centre of the pharyngeal tonsil is an orifice leading into a small recess into which numerous mucous glands open. The structures felt in the post-nasal space may be rendered visible by reflecting the light upon a small mirror placed immediately behind and below the soft palate (*posterior rhinoscopy*). The inferior part of the inferior concha is obscured from view by the bulging of the superior surface of the soft palate.

In *plugging the posterior nares*, it is important to remember that those openings measure nearly one inch in the vertical and half an inch in the transverse direction. In the child, owing to the small size of the face, the vertical diameter of the naso-pharynx is relatively much smaller than in the adult.

The **lymph vessels** from the nasal cavities and pharynx, including the palatine and pharyngeal tonsils, join the sub-parotid and superior deep cervical glands, one of which lies medial to the carotid vessels between the lateral recess of the pharynx and the prevertebral fascia. In children suppuration originating in this gland is the commonest cause of a retro-pharyngeal abscess.

In the *adult* the four upper cervical vertebræ can be explored from the mouth, while in the *child* the finger can also reach as far down as the sixth vertebra and the back of the cricoid cartilage.

THE NECK.

The general envelope of **deep cervical fascia**, along with the processes and partitions which proceed from its deep surface, subdivides the neck into compartments which limit and determine the spread of pus. The most important compartment is the **central** or **visceral compartment**, bounded *anteriorly* by the pretracheal fascia, *posteriorly* by the prevertebral fascia, and *laterally* by the fascia forming the vascular compartment. Posteriorly, this compartment extends from the base of the skull downwards into the posterior mediastinum; anteriorly, it extends from the hyoid bone into the anterior part of the superior mediastinum. *Abscesses* in the visceral compartment are either secondary to disease of the lymph glands or organs it contains, or the result of a primary suppurative cellulitis. A tubercular abscess originating in one of the retropharyngeal lymph glands (Fig. 1066) lies *in front of* the prevertebral fascia, and points towards the posterior wall of the pharynx; abscesses secondary to disease of the cervical vertebræ lie *behind* the prevertebral fascia, and spread laterally behind the vascular compartment; they point behind the sterno-mastoid, and should be opened through an incision at the posterior border of the muscle, the surgeon keeping to the anterior aspect of the transverse processes in order to avoid the structures in the vascular compartment (Chiene).

In front of the visceral compartment is a **small muscular compartment** containing the infra-hyoid muscles; anterior to it again, in the region of the supra-sternal notch, is the small **supra-sternal compartment**, containing the lower part of the anterior jugular veins, along with their transverse communicating branch, a little fat, and one or two lymph glands.

The vascular compartment contains the carotid vessels, and the internal jugular vein, and the following nerves, viz.: the vagus, the first part of the hypoglossal, the descendens hypoglossi, and the superior part of the accessory. These structures are enveloped in a thin fascial tube, the carotid sheath. The sheath is surrounded by cellular tissue in which are embedded the carotid chain of lymph glands; normally they may be readily separated from the sheath of the internal jugular vein, to which, however, they become adherent when inflamed. A few small lymph glands lie within the sheath. The cervical sympathetic trunk and the inferior thyreoid artery lie in the cellular space between the posterior wall of the carotid sheath and the prevertebral fascia; they can be reached through an incision along the posterior border of the sterno-mastoid muscle, this muscle, along with the carotid sheath and its contents, being pulled well forwards. In approaching the trunk of the inferior thyreoid artery from the front the sterno-mastoid and carotid sheath are retracted and the dissection is continued through the cellular interval between the carotid sheath and the sheath (outer capsule) of the thyreoid gland, which is formed by the splitting of the pretracheal fascia.

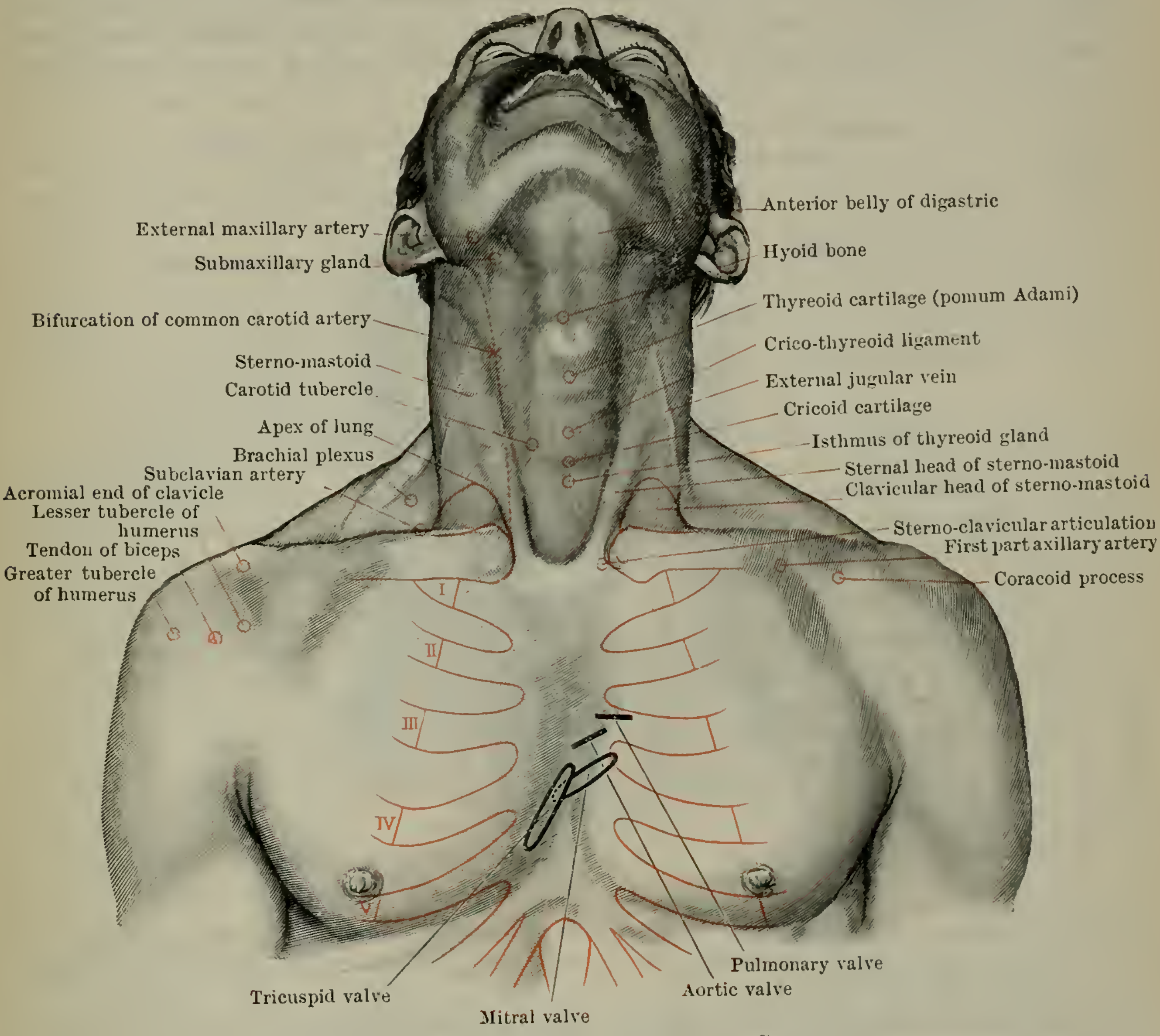
Anterior belly of digastric
External maxillary artery
Hyoid bone
Submaxillary gland
Thyreoid cartilage (pomum Adami)
Bifurcation of common carotid artery
Crico-thyreoid ligament
Sterno-mastoid
External jugular vein
Carotid tubercle
Cricoid cartilage
Apex of lung
Isthmus of thyreoid gland
Brachial plexus
Sternal head of sterno-mastoid
Subclavian artery
Clavicular head of sterno-mastoid
Acromial end of clavicle
Lesser tubercle of humerus
Sterno-clavicular articulation
Tendon of biceps
First part axillary artery
Greater tubercle of humerus
Coracoid process
I
II
III
IV
V
Pulmonary valve
Aortic valve
Tricuspid valve
Mitral valve

FIG. 1067.—ANTERIOR ASPECT OF NECK AND SHOULDERS.

A glandular abscess in this compartment usually points upon the surface, adhesions being formed, first, between the gland and the fascia, and, subsequently, between the latter and the cutaneous structures. In diffuse suppurative cellulitis of this compartment the pus burrows towards the root of the neck, and may reach either the mediastinum or the axilla.

Median Line of the Neck.—The body of the **hyoid bone** divides the median plane of the neck into **supra-** and **infra-hyoid portions.** Above the hyoid bone is the **submental triangle**, with its apex at the inferior border of the symphysis menti and its sides formed by the anterior bellies of the digastrics. In the floor of the triangle are the anterior portions of the mylo-hyoid muscles, separated by the median raphe (Fig. 1068). The most important structures in the triangle are the **submental lymph glands**, which can usually be felt a little above the body of the hyoid bone. In children they are a frequent seat of abscess secondary to impetigo of the lower lip and chin. About 1 in. below the hyoid bone is the **pomum Adami**, more prominent in the male than in the female. On either side of the pomum Adami are the laminæ of the thyreoid cartilage, while between the latter and the hyoid bone is the **thyreo-hyoid membrane.** In the operation of *sub-hyoid pharyngotomy* the epiglottis and the superior opening of the larynx are reached by passing through the anterior wall of the pharynx at the level of the thyreo-hyoid membrane. The structures divided from without inwards are: the integuments, the sterno-hyoid, omo-hyoid, and thyreo-hyoid muscles, the median portion of the thyreo-hyoid membrane, along with a layer of fat between it and the lower part of the epiglottis, and, finally, the glosso-epiglottic ligament and fold of mucous membrane. The incision must not be extended too far on either side of the median plane for fear of wounding the **superior laryngeal vessels** and **nerve** which pierce the thin lateral portions of the thyreo-hyoid membrane.

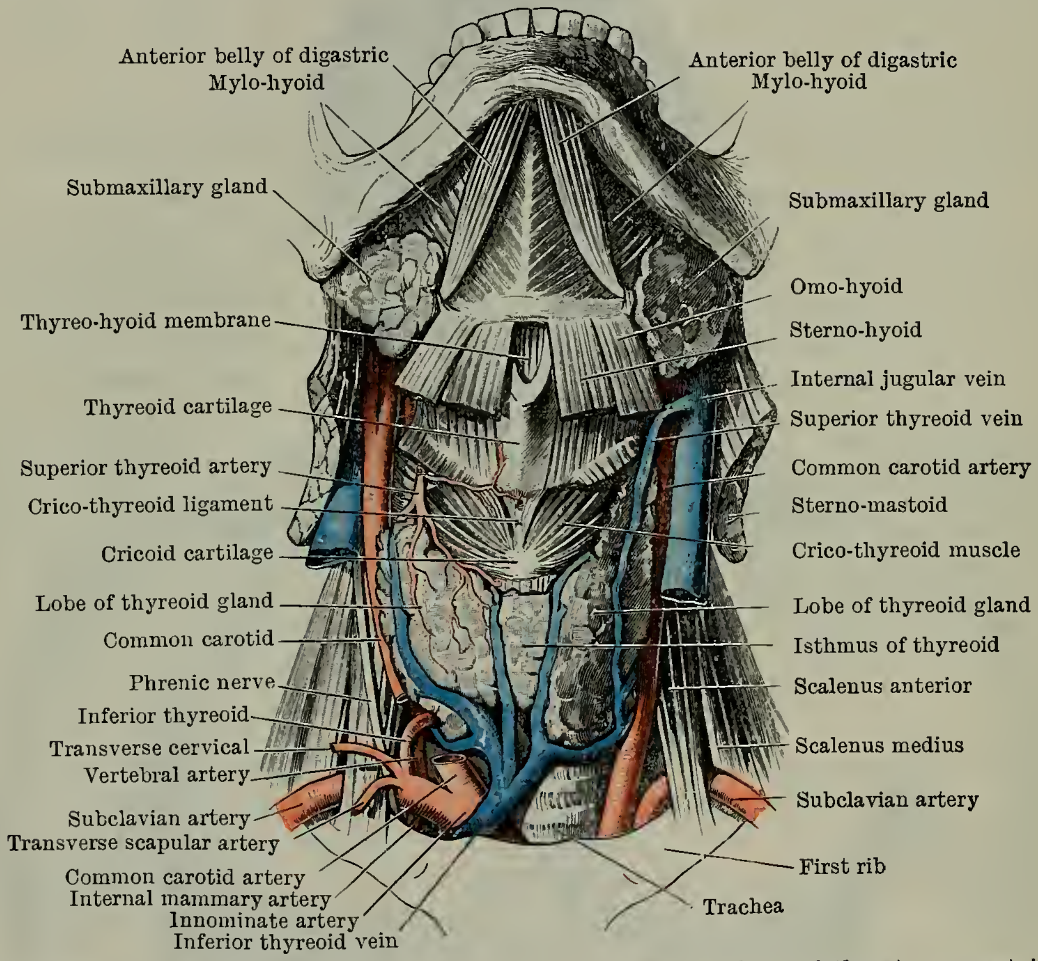

Fig. 1068.—Dissection of the Front of the Neck. The lower portions of the sterno-mastoid muscles have been removed, and the lower part of the right common carotid artery cut away to show the deeper parts. (From Cunningham.)

The wound in suicidal *cut-throat* is generally at this level. The more important structures which are usually divided are: more or less of the left sterno-mastoid muscle, the superior thyreoid vessels, the thyreo-hyoid membrane, the base of the epiglottis, and, less frequently, the carotid vessels, the internal jugular vein, and the superior laryngeal nerve. When the wound is above the hyoid bone, the lingual and external maxillary vessels and the muscles of the tongue are the more important structures injured.

At the level of the middle of the anterior border of the thyreoid cartilage is the **rima glottidis**.

In the operation of thyreotomy care is taken to divide the thyreoid cartilage exactly in the median plane so as to avoid injuring the vocal folds.

A little more than an inch below the prominentia laryngea is the anterior arch of the **cricoid cartilage**, which may be readily felt, and, when the neck is extended, often seen; it lies a little below a point midway between the lower margin of the chin and the superior border of the sternum. Above the cricoid is the **crico-thyreoid ligament**; in the operation of laryngotomy only the middle portion of the ligament is divided, in order to avoid injury to the crico-thyreoid muscles. The small crico-thyreoid branch of the superior thyreoid artery lies close to the inferior border of the thyreoid cartilage. Below the cricoid cartilage is the **trachea**, which recedes as it descends, so that it lies 1½ in. from the surface at the level of the superior border of the sternum. The **isthmus** of the **thyreoid gland** lies in front of the second, third, and fourth rings of the trachea (Fig. 1068); not infrequently, however, it reaches up to the cricoid. Immediately in front of the trachea, below the isthmus of the thyreoid, is the pretracheal fat, containing one or two **lymph glands** and the **inferior thyreoid veins**, each represented by one or more branches which converge as they descend. The pretracheal lymph glands receive afferent vessels from the larynx and thyreoid gland, while their efferent vessels open into the inferior deep cervical glands. In the adult the **innominate artery** crosses the front of the trachea at the level of the superior border of the sternum; in the child, however, it not infrequently crosses half an inch higher, a relation which must be remembered in performing the operation of low tracheotomy.

In the operation of **high tracheotomy** the upper three rings of the trachea are divided. The incision, which should be median, divides the integuments, the tributaries of the anterior jugular veins, the general envelope of deep cervical fascia, and, after passing between the depressor muscles of the hyoid bone, the pretracheal fascia, which descends from the cricoid to enclose the isthmus of the thyreoid gland. By dividing this fascia transversely below the cricoid, the isthmus may be pulled downwards and the upper rings of the trachea exposed. In some cases it is necessary either to divide the isthmus or to extend the incision upwards through the cricoid cartilage. In opening the trachea, the edge of the knife should be directed upwards so as to avoid injuring the vessels at the upper border of the isthmus. The anterior jugular veins are in danger of being wounded if the skin incision is not strictly median. In low tracheotomy the trachea below the isthmus is opened; it is a more troublesome operation, on account of the depth of the trachea and the presence in front of it of the large inferior thyreoid veins and of the transverse anterior jugular vein. In children the difficulty is increased by the higher position of the innominate artery and left innominate vein, by the presence of the thymus gland, and by the shortness of the neck.

Thyreoid Gland.—The thyreoid gland, which is moulded on and adherent to the anterior aspects and the sides of the upper part of the trachea and to the lower and posterior portions of the laminæ of the thyreoid cartilage, is covered by the infrahyoid muscles and overlapped by the sterno-mastoid. The posterior borders of its lobes come in contact with the œsophagus and lower part of the pharynx, while posteriorly they partially overlap the carotid sheath.

The thyreoid gland, like the prostate, possesses, in addition to its own proper capsule, an outer capsule or sheath derived from the cervical fascia. The capsule proper, like that of the liver, is inseparably connected with the gland. The sheath, on the other hand, is formed by the middle (pretracheal) layer of deep cervical fascia, which splits to enclose the thyreoid. Between the true capsule and the sheath is a loose cellular interval which is crossed by branches of the thyreoid arteries and veins on their way to and from the gland. The arteries traverse the space directly, while many of the veins (accessory thyreoid veins of Kocher) ramify for some distance on the surface of the capsule before they pierce the sheath.

The surgeon reaches the gland through the median plane in the interval between the infrahyoid muscles. If, in order to obtain more room, it is found necessary to divide the depressor muscles on one or both sides, this should be done towards their upper attachments, as their nerves of supply, derived from the ansa hypoglossi, enter the muscles nearer their lower attachments.

By freely dividing the middle layer of cervical fascia where it forms the anterior portion of the sheath of the thyreoid, the gland can be delivered out of the wound and so mobilised that the main vessels may be brought into view and ligatured.

The superior thyreoid vessels, on each side, are exposed by freeing and drawing forwards the superior pole of the corresponding lobe. The inferior thyreoid artery is sometimes ligatured as a preliminary step to operating on the thyreoid gland. In this event the ligature is applied to the trunk of the vessel as it lies behind the carotid sheath in the cellular space between it and the prevertebral fascia (De Quervain). In the operation of partial thyreoidectomy the posterior part of the true capsule of the gland and a layer of thyreoid substance are left behind so as to guard against injury to the parathyreoids and the recurrent laryngeal nerve. In this procedure the branches of the inferior thyreoid artery are ligatured after they have pierced the true capsule of the gland. The recurrent nerve, which also lies between the posterior part of the sheath and the postero-medial aspect of the corresponding lobe, ascends, either posterior to the inferior thyreoid artery or between its main divisions.

The parathyreoids can generally be distinguished from the thyreoid tissue itself, and from the lymph glands, by their grayish-yellow colour as well as by their smooth and shining surfaces. The superior parathyreoid is found on each side usually, one at the posterior border of the corresponding lobes, about opposite the cricoid cartilage. It is in close relation to the pharyngo-œsophageal junction, from which it is separated by the posterior part of the sheath of the thyreoid gland. The inferior parathyreoid gland, on each side, is supplied by a small vessel from one of the branches of the inferior thyreoid artery; it occupies the same cellular interval at the posterior aspect of the inferior pole of the gland, a little lateral to the inferior thyreoid artery and the recurrent nerve. When the inferior thyreoid artery has been ligatured the posterior branch of the superior thyreoid artery furnishes a sufficient blood-supply to the inferior parathyreoid gland.

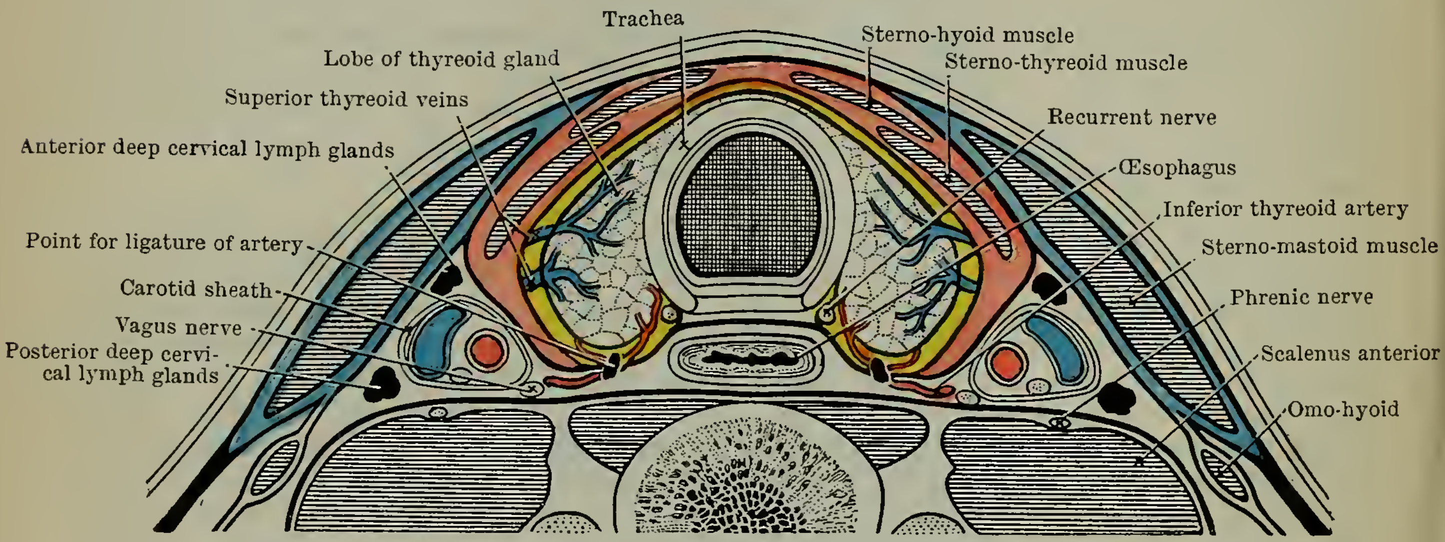

FIG. 1069.—A DIAGRAM OF THE RELATIONS OF THE CERVICAL FASCIA TO THE THYREOID GLAND.

Blue = deep cervical fascia (sterno-mastoid layer). Red = outer capsule of thyreoid gland (pretracheal layer of cervical fascia). Yellow = capsule proper of the thyreoid gland. (Modified from De Quervain.)

Triangles of the Neck.—The lateral aspect of the neck is divided into an **anterior** and a **posterior triangle** by the sterno-mastoid muscle; the former is further subdivided into *digastric*, *carotid*, and *muscular triangles* by the digastric and omo-hyoid muscles. The posterior triangle is subdivided into *occipital* and *subclavian portions* by the posterior belly of the omo-hyoid.

The **sterno-mastoid muscle** forms one of the most important superficial landmarks of the neck. The anterior border of the muscle, the more distinct of the two, may be felt along its whole extent. Between the prominent sternal origin and the broad ribbon-like clavicular origin is a slight triangular depression which overlies the inferior part of the internal jugular vein.

By dividing the cervical fascia along the anterior and posterior borders of the muscle the surgeon is able to displace the muscle backwards and forwards so as to obtain free access to the structures deep to it. If the posterior fibres of the muscle are divided at their clavicular and mastoid attachments the muscle can be still more freely mobilised. In dividing the fascia along its posterior border the cutaneous branches of the cervical plexus are generally divided, but care is taken not to injure the accessory nerve. Should it be found necessary to remove the upper third or more of the muscle, the divided end is stitched to the levator scapulæ or to the scalenus medius, according to the amount resected. In dividing the muscle completely across at the lower part of the neck, as is done, for example, in congenital wry-neck, the close relation of the anterior and external jugular veins to its corresponding borders must be kept in mind. After division of the muscle, the lower part of the anterior belly of the omo-hyoid is seen, lying upon that part of the carotid sheath which overlies the internal jugular vein.

Digastric Triangle.—This triangle is subdivided into an anterior or submaxillary portion and a posterior or parotid portion by a process of the deep cervical fascia, known as the stylo-mandibular ligament. In the anterior portion is the **submaxillary gland**, which is overlapped by the posterior half of the inferior border of the mandible and reaches down to the great cornu of the hyoid bone. The **anterior facial vein** passes downwards and backwards, superficial to the gland, while the **external maxillary artery**, embedded in its deep surface, arches upwards under cover of the angle of the mandible, where it approaches the palatine tonsil, being separated from it, however, by the superior constrictor of the pharynx. The **lingual artery** may be ligatured in the digastric triangle, where it lies behind the hyoglossus a little above the great cornu of the hyoid bone; the superficial guides to the vessel are the inferior border of the submaxillary gland, and the hypoglossal nerve and its vena comitans, which lie upon the hyoglossus, the latter being recognised by the vertical direction of its fibres. The *floor* of the digastric triangle is formed, from before backwards, by the mylo-hyoid, hyoglossus, and superior constrictor of the pharynx. The **lymph glands** of this space receive their lymph from the face, lips, teeth and gums, tongue, and floor of the mouth; hence the frequency with which they become the seat of abscess formation and malignant enlargement. To palpate them the surgeon stands behind the patient and thrusts the fingers well upwards under cover of the mandible, the patient's chin being a little depressed so as to relax the cervical fascia.

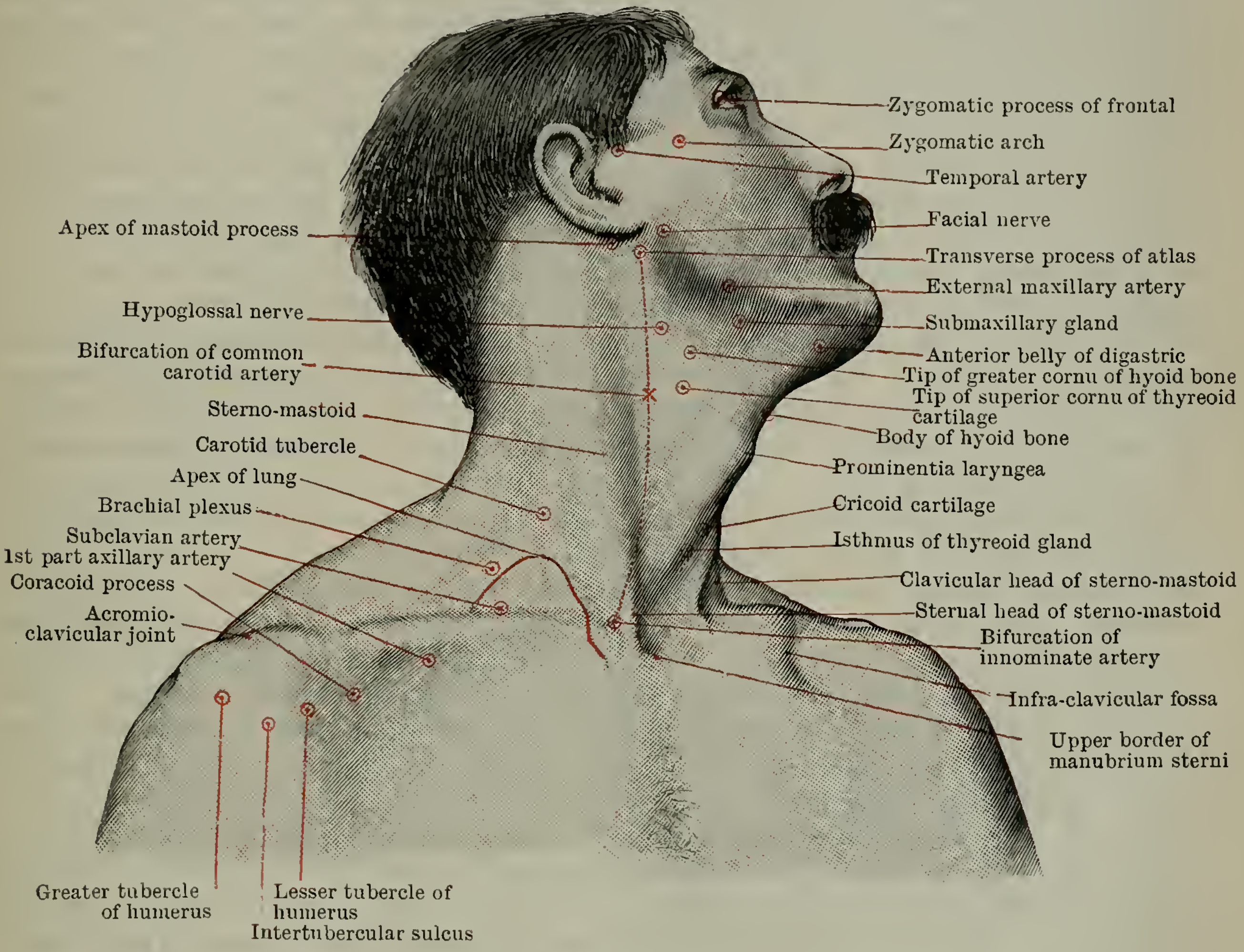
Zygomatic process of frontal
Zygomatic arch
Temporal artery
Facial nerve
Transverse process of atlas
External maxillary artery
Submaxillary gland
Anterior belly of digastric
Tip of greater cornu of hyoid bone
Tip of superior cornu of thyreoid cartilage
Body of hyoid bone
Prominentia laryngea
Cricoid cartilage
Isthmus of thyreoid gland
Clavicular head of sterno-mastoid
Sternal head of sterno-mastoid
Bifurcation of innominate artery
Infra-clavicular fossa
Upper border of manubrium sterni
Apex of mastoid process
Hypoglossal nerve
Bifurcation of common carotid artery
Sterno-mastoid
Carotid tubercle
Apex of lung
Brachial plexus
Subclavian artery
1st part axillary artery
Coracoid process
Acromio-clavicular joint
Greater tubercle of humerus
Lesser tubercle of humerus
Intertubercular sulcus

FIG. 1070.—SIDE OF THE NECK.

Carotid Triangle.—The central landmark of this triangle is the **great cornu of the hyoid bone**, the tip of which, when the fascia is relaxed, may be readily felt, immediately in front of the anterior border of the sterno-mastoid, at a point corresponding to the centre of a line drawn from the tip of the mastoid process to the prominentia laryngea. The deep cervical fascia holds the superior part of the sterno-mastoid forwards towards the angle of the mandible, so that, with the fascia undivided, the anterior border of the sterno-mastoid overlaps the internal jugular vein and the bifurcation of the common carotid artery.

The **course of the carotid vessels** is indicated, upon the surface, by a line extending from the superior end of the sterno-clavicular articulation to a point midway between the angle of the mandible and the tip of the mastoid process; a point upon this line, at the level of the superior border of the thyreoid cartilage, overlies the **bifurcation of the common carotid.** The **anterior belly** of the **omo-hyoid** crosses the common carotid at the level of the cricoid cartilage. The pulsations of the carotid vessels may be felt in the hollow between the larynx and the anterior border of the sterno-mastoid. In the carotid triangle the **external carotid** lies medial and anterior to the internal carotid. The seat of election for *ligation of the external carotid* is between its superior thyreoid and lingual branches, a finger's-breadth below the tip of the great cornu of the hyoid bone; the difficulty in the operation is due to the plexus of veins (formed by the common facial, lingual, and superior thyreoid veins) which overlies the artery. The lingual and external maxillary arteries frequently arise from a common trunk which must not be mistaken for the external carotid. The **superior thyreoid artery** arises opposite the upper cornu of the thyreoid cartilage, which may be distinctly felt 1 in. below the tip of the great cornu of the hyoid bone. The vessel and its companion vein are common sources of hæmorrhage in cut-throat. The guide to the **lingual artery,** in the carotid triangle, is the tip of the great cornu of the hyoid bone, above which it forms an arch, crossed by the hypoglossal nerve. The vessel enters the digastric triangle by passing forward medial to the tendons of the stylo-hyoid and digastric muscles. When ligature of the artery is called for, it is usually necessary to secure the vessel as it lies in the carotid triangle so that the ligature may be applied on the proximal side of its dorsalis linguæ branch.

From a surgical point of view the **internal jugular vein** is the most important structure in the anterior triangle. In the carotid division of the triangle it overlaps the carotid vessels, and its sheath lies close beneath the general envelope of deep cervical fascia from which it is separated by a loose cellular interval. About the level of the hyoid bone it receives the large common facial vein, while at an inferior level it receives the superior and middle thyreoid veins which are often greatly enlarged in goitres.

By the term **deep cervical glands** is included a broad chain of lymph glands which is closely related to the internal jugular vein, and which stretches from the transverse process of the atlas to the root of the neck. The chain is in reality made up of subsidiary glandular groups, each of which receives its lymph vessels from fairly well-defined areas. In the first place, the chain may be divided into an upper and a lower portion, the former situated above the bifurcation of the common carotid artery, the latter below it. Each of these divisions is again subdivided into a medial and a lateral chain.

Of the four groups, the *superior medial* is the most important, as it is there that disease first manifests itself in the vast majority of cases. The reason for this predilection is the fact that this group of glands, in addition to receiving efferent lymph vessels from the glands of the circular chain, receives also lymph vessels directly from the nasal part of the pharynx, including the palatine and pharyngeal tonsils. These latter structures are now known to provide the chief portals of entrance through which the tubercle bacilli reach the efferent lymph vessels. Wood, of Philadelphia, has succeeded in tracing the lymph vessels from the palatine tonsils directly into one of the glands of this group, namely, that situated a little below the angle of the mandible, under cover of the anterior border of the sterno-mastoid immediately below the posterior belly of the digastric. The relations of the deep surface of this gland are important. It lies upon the anterior surface of the internal jugular, in the angle between it and the common facial vein. It plays such an important rôle in tuberculous adenitis that it is now termed by surgeons the *tonsillar lymph gland*. In the great majority of cases it is the first gland in the neck to show signs of tuberculous enlargement. When the superior medial deep cervical glands become enlarged they form a swelling which projects from beneath the sterno-mastoid forwards into the carotid division of the anterior triangle. The mass soon becomes adherent to the general envelope of deep cervical fascia, and, if the disease is allowed to run its course, the latter becomes perforated, with the result that a subcutaneous tuberculous abscess soon develops. The glands are also liable to become adherent to the digastric muscle, and to the stylo-mandibular ligament, which separates them from the submaxillary lymph glands. The most important adhesions, however, from the surgeon's point of view, are to the common facial and internal jugular veins.

The *superior lateral* group of deep cervical glands lies postero-lateral to the internal jugular upon the origins of the splenius and the levator scapulæ muscles. They are smaller in size than the medial group, but when enlarged they may form a swelling which projects across the posterior triangle as far as the trapezius. They are embedded in a quantity of fibro-fatty tissue which supports the accessory nerve and the cervical plexus. Wood has shown that the lymph vessels from the pharyngeal tonsil, after piercing the posterior wall of the pharynx, pass downwards and laterally behind the sheath of the great vessels to enter the glands situated deeply, just below the tip of the mastoid process.

The *inferior medial* group forms a somewhat narrow chain, which is continued down the anterior aspect of the internal jugular as far as its junction with the subclavian. Above the bifurcation of the common carotid artery this chain is continuous with the superior medial jugular group, while, below, it comes into relation with the superior mediastinal glands.

The *inferior lateral* group of deep cervical glands is continuous above with the superior lateral group. Like the superior lateral group, they lie altogether behind the internal jugular vein, upon the levator scapulæ, the scalenus medius, and the brachial plexus. The most inferior glands of the group, viz., the supra-clavicular, are subdivided into a superficial and a deep cluster by the omo-hyoid muscle and the middle layer of deep cervical fascia. They receive their afferent vessels from the subclavicular group of axillary glands.

The **hypoglossal nerve** is deeply placed in the carotid triangle, being overlapped by the internal jugular vein and the inferior border of the posterior belly of the digastric muscle. It crosses forwards, superficial to the occipital and internal and external carotid arteries, immediately below the origin of the superior sterno-mastoid branch of the first-mentioned vessel. The **vagus nerve** descends vertically, within the carotid sheath, behind and between the carotid vessels and the internal jugular vein; care must be taken not to include it when ligaturing the common carotid or internal jugular. Surgically, the **accessory** is the most important nerve in the anterior triangle; it enters the substance of the sterno-mastoid muscle 1½ in. below the tip of the mastoid process. A portion of the nerve is resected in the treatment of spasmodic wry-neck, and it is always exposed in the removal of the medial group of deep cervical glands. The course of the nerve may be mapped out upon the surface by drawing a line from a point midway between the tip of the mastoid process and the angle of the mandible to a little above the middle of the posterior border of the sterno-mastoid muscle, and thence across the posterior triangle to the junction of the middle and lower thirds of the anterior border of the trapezius, beneath which it passes at the level of the seventh cervical spine. The deeper guides to the nerve are the posterior belly of the digastric, and the internal jugular vein which it crosses, very obliquely, from above downwards and backwards below and in front of the **transverse process of the atlas** (felt as a distinct bony landmark midway between the tip of the mastoid and the angle of the mandible).

In paralysis of the trapezius muscle from injury to the accessory nerve the shoulder droops and is pulled forwards and medially by the pectoralis major and minor muscles. If the paralysis occurs during childhood the chest on the same side becomes flattened anteriorly, due to the adaptive shortening of the pectorals and to their diminished pull on the ribs. Unless this mechanism is appreciated the infra-clavicular flattening of the chest is very apt to be erroneously attributed to pulmonary tuberculosis. The upper part of the accessory nerve is surrounded by the superior lateral group of deep cervical glands; it is in this situation, and again when it emerges from beneath the posterior border of the sterno-cleido-mastoid muscle, that it is liable to be injured in operations for the removal of tuberculous glands.

The **cervical sympathetic** lies in the posterior wall of the vascular compartment of the neck, and may be reached by an incision along the posterior border of the sterno-mastoid: the anterior surfaces of the roots of the transverse processes of the vertebræ are the deep guides to the nerve.

The **cervical plexus**, which lies deep to the superior half of the sterno-mastoid upon the levator scapulæ and scalenus medius muscles, may be exposed through an incision along the posterior border of the upper half of the sterno-mastoid muscle. The **phrenic nerve**, the most important branch of the cervical plexus, arises one inch above the carotid tubercle and descends almost vertically towards the inner end of the clavicle; it is overlapped by the lateral margin of the internal jugular vein. Although frequently exposed by the surgeon in removing the lower medial group of deep cervical glands, the phrenic nerve is protected from injury by the prevertebral fascia which binds it down to the scalenus anterior muscle.

The **muscular or lower carotid triangle** is an important triangular intermuscular space bounded by the anterior border of the sterno-mastoid, the anterior belly of the omo-hyoid, and the sterno-hyoid. Behind this space, and forming, as it were, its floor, is a still deeper space bounded by the longus colli and scalenus anterior muscles. It may with advantage be termed the *prevertebral intermuscular triangle*, or, from the fact that it contains the vertebral artery, it may be termed the *vertebral arterial triangle.* At its apex is the prominent anterior tubercle of the transverse process of the sixth cervical vertebra. By making an incision along the anterior border of the left sterno-mastoid muscle, and passing through this triangle, the surgeon reaches, in order from before backwards, the internal jugular vein, the common carotid artery, the vagus, the thoracic duct, the middle cervical ganglion of the sympathetic, the inferior thyreoid artery, the vertebral vessels, the recurrent nerve, and the œsophagus. The most important bony landmark in this triangle is the prominent anterior tubercle of the transverse process of the sixth cervical vertebra. The common carotid artery may be compressed against this tubercle, which is therefore termed the "*carotid tubercle.*" It is the most important guide to the vertebral artery, which enters the foramen in the transverse process of the sixth cervical vertebra.

The **cervical portion** of the **œsophagus**, which begins at the level of the cricoid cartilage, descends behind, and a little to the left of, the trachea. To expose it, the surgeon, after passing through the above-mentioned muscular triangle, divides the pretracheal fascia, and passes between the trachea and the carotid sheath down to the longus colli muscle medial to the inferior thyreoid artery and vertebral vessels. The lower pole of the corresponding lobe of the thyreoid gland is retracted medially along with the trachea. The œsophagus lies in the loose cellular tissue in front of the prevertebral fascia; hence it can be mobilised sufficiently to admit of its being brought to the surface. The œsophagus may also be exposed through an incision in the median plane, the trachea, which is freely movable, being displaced to the right side. In opening the œsophagus care must be taken not to injure the **recurrent nerve**, which ascends in the groove between it and the trachea, and also that the loose submucous cellular interval must not be mistaken for the lumen of the tube. The so-called "pulsion-diverticulum of the œsophagus" does not take origin from the upper part of the gullet, as frequently stated; it begins as a hernia-like protrusion of the posterior wall of the pharynx, between the oblique thyreo-pharyngeal and the transverse crico-pharyngeal fibres of the inferior constrictor muscle (Killian). During the act of swallowing the latter fibres act as a sphincter, while the oblique fibres elevate the larynx. If the sphincter should fail to relax during the detrusor action of the pharynx it is not difficult to understand how a diverticulum might arise, and, when once produced, why it should undergo progressive enlargement.

The Thoracic Duct.

The **thoracic duct**, after entering the root of the neck between the œsophagus and the pleura, ascends to about an inch above the clavicle. At this level it arches laterally behind the lower part of the carotid sheath in front of the vertebral vessels. Great care must therefore be taken not to injure the duct in removing the lymph glands which lie in the loose cellular tissue behind the inferior part of the internal jugular vein, between it and the vertebral vein at the medial border of the scalenus anterior. In addition to those glands a few small lymph glands lie adjacent to the lateral aspects of the cervical portions of the trachea and œsophagus. They receive their afferent vessels from the larynx, trachea, œsophagus, and thyreoid gland.

Posterior Triangle.

The roof of the posterior triangle is formed by the general envelope of deep cervical fascia, while the fascia which covers the muscles forming its floor, as well as that covering the brachial nerve trunks and the subclavian artery, is a lateral continuation of the prevertebral fascia. The lateral deep cervical and supraclavicular lymph glands are embedded in the cellular tissue between these two layers of fascia. In removing these glands, every endeavour should be made to preserve the motor nerves. The accessory nerve, after entering the posterior triangle at the junction of the superior and middle thirds of the posterior border of the sterno-mastoid muscle, crosses the triangle superficially, and parallel to the levator scapulæ. It leaves the triangle by passing under cover of the anterior border of the trapezius, at the junction of its middle and inferior thirds. The lesser occipital nerve curves round the accessory from below upwards, superficially, just at the posterior border of the muscle; it furnishes, therefore, a useful guide to the position of that important motor nerve.

The **dorsalis scapulæ nerve** (O.T. **nerve to the rhomboids**) crosses the triangle, inferior to the accessory, and enters the septum between the levator scapulæ and scalenus medius muscles.

The **supra-scapular nerve** is seen arising from the lateral edge of the upper trunk of the brachial plexus, a little above the posterior belly of the omo-hyoid muscle. The loops of the cervical plexus lie under cover of the upper part of the sterno-mastoid muscle, between it and the origins of the levator scapulæ and the upper part of the scalenus medius muscles.

The posterior belly of the omo-hyoid, which forms the superior boundary of the **subclavian division** of the posterior triangle, passes beneath the posterior border of the sterno-mastoid at a point about one inch above the clavicle. The **external jugular vein**, usually visible through the skin, runs in a line from the angle of the jaw to the middle of the clavicle; it is the vessel which is generally opened to relieve the right side of the heart in asphyxia. The lumen of the vein is kept patent where it pierces the fascia of the subclavian triangle; hence a wound of the vein in that situation is liable to be followed by the suction of air into the circulation during inspiration. The **third part** of the **subclavian artery** can be compressed against the first rib by pressing downwards and backwards, immediately above the clavicle, a little behind the posterior border of the sterno-mastoid muscle. To map out the *course* of the subclavian artery in the neck, draw a line, convex upwards, from the superior border of the sterno-clavicular articulation to the middle of the clavicle, the highest part of the arch to reach from ½ to 1 in. above the bone.

To *ligature the vessel* in the third part of its course, an angular incision is made along the middle of the superior border of the clavicle and the inferior part of the posterior border of the sterno-mastoid muscle. The most important guides to the vessel are the posterior belly of the omo-hyoid, the lateral border of the scalenus anterior, and the scalene tubercle of the first rib. The close relation of the vessel to the lowest trunk of the brachial plexus and to the cervical pleura must be kept in mind. In the rare instances in which a cervical rib is present the subclavian artery lies either in front of it, or arches above it, according to the degree of development of the rib. The **subclavian vein** lies below, and anterior to, the artery, altogether under cover of the clavicle.

Entering the posterior triangle, from behind the lateral border of the scalenus anterior, are the trunks of the **brachial plexus**. They lie upon the scalenus medius, and can be felt, through the skin, immediately above and behind the third part of the subclavian artery. The anterior ramus of the fifth cervical nerve supplies the rhomboids, the abductors and lateral rotators of the arm, and the flexors and supinators of the forearm; that of the sixth the serratus anterior, the adductors and medial rotators of the arm, and the extensors and pronators of the forearm; that of the seventh the flexors and extensors of the wrist; that of the eighth the flexors and extensors of the fingers; that of the first thoracic the small muscles of the hand. Each root of the brachial plexus contributes to the nerve supply of the pectoralis major muscle, and as the fibres of the muscle are supplied from above downwards by the roots in their numerical order, valuable information is obtained by carefully testing the action of the muscle in all suspected cases of injury to the brachial plexus.

When the first thoracic root is ruptured within or close to the spinal canal, the sympathetic fibres which run in it on their way to join the inferior cervical ganglion of the sympathetic are torn across, with the result that, among other symptoms, there will be (1) contraction of the pupil, due to paralysis of the radial fibres of the iris; (2) narrowing of the palpebral fissure, due to paralysis of the involuntary fibres of the upper eyelid; (3) slight recession of the eyeball (enophthalmos), due to paralysis of the non-striated orbital muscle of Müller.

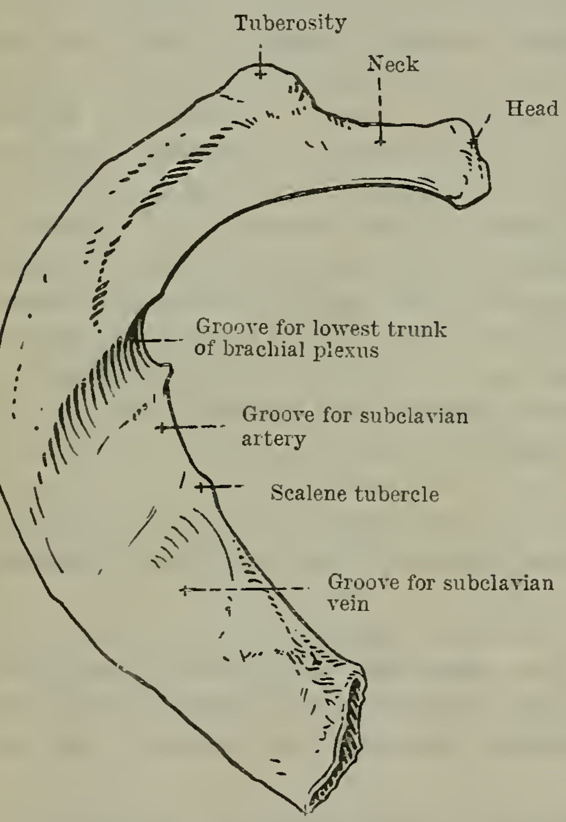
Tuberosity
Neck
Head
Groove for lowest trunk of brachial plexus
Groove for subclavian artery
Scalene tubercle
Groove for subclavian vein

FIG. 1071.—THE FIRST RIB, SEEN FROM ABOVE.

As regards the cutaneous root distribution of the upper limb, the sensory fibres from the lateral (pre-axial) border of the upper arm enter the fifth root, while those from the lateral half of the forearm and hand enter the sixth root. The sensory fibres from the medial (post-axial) part of the hand enter the eighth cervical nerve, those from the medial border of the forearm enter the first thoracic, while those from the medial aspect of the upper arm run in the second thoracic nerve. The carotid tubercle lies between the anterior rami of the sixth and seventh cervical nerves. The fifth and sixth cervical nerves are those which suffer most when the plexus is injured by forcible depression of the shoulder while the head is bent to the opposite side, such as occurs, for instance, in the "Obstetrical Paralyses" of Duchenne. The lowest trunk is most liable to be overstretched when traction is applied either to the upper limb or to the trunk when the former is elevated above the shoulder.

To expose the trunks of the brachial plexus an incision is made from the junction of the middle and inferior thirds of the posterior border of the sterno-mastoid downwards and laterally to the junction of the lateral and intermediate thirds of the clavicle.

The relation of the lowest trunk of the brachial plexus to the first rib is important in relation to those forms of brachial neuritis in which the motor and sensory symptoms indicate pressure on the anterior ramus of the first thoracic nerve. Wood Jones has shown that the sulcus for the subclavian artery on the superior surface of the first rib lodges the lowest trunk of the brachial plexus as well as the artery, and that the more the first and second thoracic nerves contribute to the plexus, that is to say the more "caudal" the plexus (*vide* p. 1387), the deeper is the sulcus.

In 175 dissections of the brachial plexus Abram Kerr found the cephalic type in 62 per cent, the so-called "normal" type in 30 per cent, and the caudal type in 8 per cent. In the cephalic type the fourth cervical nerve sends a branch to the plexus; in the "normal" type the fourth cervical contributes no branch; in the caudal type while only a part of the fifth cervical joins the plexus a large contribution is derived from the first thoracic, and frequently a branch also from the second thoracic.

In several cases the writer has cured the neuralgia and the partial paralysis of the intrinsic muscles of the hand supplied by the first thoracic nerve by removing the portion of the first rib containing the "sulcus nervi brachialis." The symptoms were due to the portion of the first thoracic nerve which goes to join the brachial plexus being stretched and pressed upon by the first rib as it crosses its inner edge to join the eighth cervical nerve. Although similar symptoms may be produced by the first thoracic nerve being stretched across a cervical rib, the surgeon must not expect to find this anomaly in all cases; and when a skiagram has been obtained, care must be taken not to mistake a well-developed posterior tubercle of the transverse process of the seventh cervical vertebra for a foreshortened view of a rudimentary cervical rib.

In cases in which the first rib produces neuritis from pressure on the first thoracic nerve, it is necessary to remove the portion of the bone between its tubercle and the scalene tubercle. In order to expose and detach the scalenus medius muscle from its insertion into this part of the rib the plexus must be freed from the anterior surface of this muscle and then retracted downwards and medially. In doing this, care must be taken not to injure either of the roots of the posterior thoracic nerve which pierce the muscle or the trunk of the nerve; the latter descends behind the lateral edge of the plexus and then crosses the upper digitation of the serratus anterior to enter the axilla. This muscle and the muscles of the first intercostal space are detached from the outer border of the rib, while Sibson's fascia is separated from the inner border of the rib, and in doing this care must be taken not to injure the pleura.

In the median line of the neck posteriorly is the **nuchal furrow**, at the bottom of which are the cervical spines and the ligamentum nuchæ. At the superior part of the furrow, about two inches below the external occipital protuberance, is the large **spine of the epistropheus**, which can be distinctly felt; a line drawn from it laterally and slightly upwards to the transverse process of the atlas corresponds to the position of the inferior oblique muscle and, therefore, to the inferior margin of the **sub-occipital triangle**. The course of the deep part of the **greater occipital nerve** may be mapped out by drawing a line from the centre of the above-mentioned line to a point one inch lateral to the external occipital protuberance. In the floor of the sub-occipital triangle is the posterior arch of the atlas upon which the **vertebral artery** lies.

THE THORAX.

For the convenience of topographical description, clinicians, by the use of vertical and transverse lines, have arbitrarily divided the surface of the chest into certain definite regions or areas. The vertical lines are: the *mid-sternal*, the *lateral sternal*, the *para-sternal*, the *mammary* or *mid-clavicular*, the *anterior*, *mid*, and *posterior axillary*, and the *scapular*. The position of the mid- and lateral sternal lines is sufficiently indicated by their names.

The **mammary**, better termed the **mid-clavicular**, is drawn vertically downwards from the centre of the clavicle, or, what comes to practically the same thing, from a point midway between the centre of the jugular notch and the tip of the acromion. In the male this line usually lies ½ to ¾ in. medial to the centre of the nipple, which is usually placed over the fourth interspace, or fifth rib, four inches from the median plane. In the child the nipple may be as high as the inferior border of the third rib. In the female the position of the nipple is so variable that it is of no topographical value. In a well-proportioned subject, the mid-clavicular line, if prolonged downwards, will be found to be continuous with the vertical or lateral inguinal line, which crosses the costal margin at the tip of the ninth costal cartilage.

The **para-sternal line**, drawn midway between the lateral sternal and mid-clavicular, crosses the costal margin opposite the tip of the eighth costal cartilage.

The **anterior**, the **mid**, and the **posterior axillary lines** are drawn downwards from the anterior fold, the apex, and the posterior fold of the axilla, respectively.

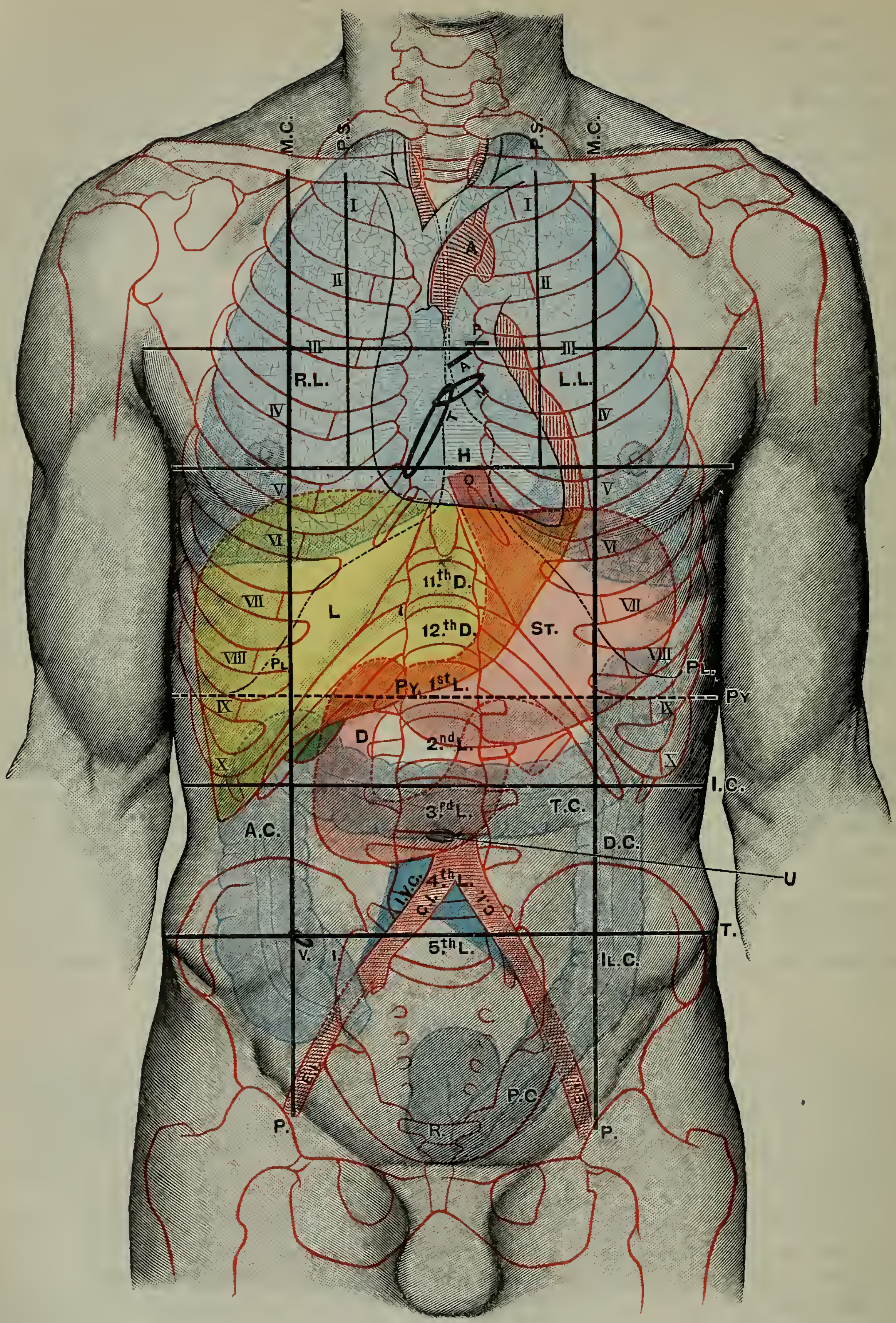

FIG. 1072.—ANTERIOR ASPECT OF TRUNK, SHOWING SURFACE TOPOGRAPHY OF VISCERA.

M.C.	Mid-clavicular line.
P.S.	Para-sternal line.
P.	Inguinal vertical line.
I.C.	Infracostal line.
T.	Intertubercular line.
Py.	Transpyloric line of Addison.
A.	Aorta.
H.	Heart.
P.	Pulmonary orifice.
A.	Aortic orifice.
M.	Mitral orifice.
T.	Tricuspid orifice.
R.L.	Right lung.
L.L.	Left lung.
Pl.	Pleura.
L.	Liver.
O.	Œsophagus.
St.	Stomach.
Py.	Pylorus.
D.	Duodenum.
I.	Ileum.
V.	Valve of the colon.
A.C.	Ascending colon.
T.C.	Transverse colon.
D.C.	Descending colon.
Il.C.	Iliac colon.
P.C.	Pelvic colon.
R.	Rectum.
C.I.	Common iliac artery.
E.I.	External iliac artery.
I.V.C.	Inferior vena cava.
U.	Umbilicus.

The **scapular line** is drawn perpendicularly through the inferior angle of the scapula.

Of the *two transverse lines*, the **superior**, which separates the **infra-clavicular** and **supra-sternal** regions from the **mammary** and **infra-sternal** regions, is drawn at the level of the third chondro-sternal articulation; the **inferior**, which separates the **mammary** and **infra-mammary** regions, is drawn at the level of the sixth chondro-sternal articulation.

The lateral area of the chest is divided into a superior, or **axillary**, and an inferior or **infra-axillary** region, by a horizontal line drawn at the level of the sixth rib.

In muscular subjects there is a well-marked median furrow, the **sternal furrow**, between the sternal origins of the **pectoralis major muscles**. The medial part of the inferior border of each of these muscles forms a curved prominence which, overlying the fifth rib, corresponds to the junction of the mammary and infra-mammary regions. Below this prominence is the infra-mammary region, which forms a somewhat flat surface, corresponding to the upper part of the rectus muscle. In the axillary and infra-axillary regions are the prominences caused by the digitations of origin of the **serratus anterior**, the first to appear below the pectoralis major being that which springs from the fifth rib.

The **superior border** of the **sternum** lies in the same horizontal plane as the inferior border of the body of the second thoracic vertebra, the distance between the two being about two inches. The junction of the manubrium and the body of the sternum forms a slight prominence or angle, known as the *angulus sterni* (*Ludovici*), which, although not usually visible, may always be felt. The angulus lies in the same plane as the body of the fifth thoracic vertebra.

The **xiphi-sternal junction** corresponds to the fibro-cartilage between the ninth and tenth thoracic vertebræ. Immediately inferior to the xiphi-sternal articulation is the **infra-sternal notch**, formed by the junction of the seventh costal cartilages with the sternum. Inferior to the notch is the **epigastric fossa or triangle**, bounded laterally by the seventh costal cartilages. The apex of the triangle forms an angle which varies considerably according to the shape of the chest, the average being about 70°. Not infrequently the eighth costal cartilage articulates with the sternum.

Fracture of the sternum is rare, and generally occurs at or close to the junction of the manubrium and the body; it may occur either from direct violence, or indirectly along with fracture of the vertebral column. Unlike that of the ribs, the periosteum covering the sternum is firmly adherent to the bone.

The **ribs**, which in well-nourished subjects cause no surface prominences, are readily visible in thin persons; in the obese they are very difficult to feel. In counting the ribs from the front, the *second* may always be identified by its relation to the angulus sterni. The *first rib* is to a large extent under cover of the clavicle. The inferior border of the pectoralis major and the first visible digitation of the serratus anterior afford reliable guides to the *fifth rib*. The infra-sternal notch is the guide to the medial end of the *seventh costal cartilage*. The second and third costal cartilages are almost horizontal; below this the cartilages ascend with increasing obliquity, that of the sixth being the first to present a distinct angle. The anterior end of the second intercostal space is the widest, while those of the fifth and sixth are very narrow.

The **costo-chondral junctions** may be indicated, on the surface, by a line drawn from the superior end of the para-sternal line to a point a finger's breadth posterior to the angle of the tenth costal cartilage.

The **internal mammary artery** crosses behind the medial ends of the superior five intercostal spaces, about half an inch from the edge of the sternum; as it descends it approaches a little nearer to the sternum. The vessel is accompanied by two veins which unite to form a single vein opposite the second interspace.

This artery is occasionally injured in punctured wounds of the chest. At the second or third intercostal space it is easily ligatured through a transverse incision, but at a lower level it is generally necessary to resect a portion of one of the costal cartilages.

THE LUNGS AND PLEURÆ.

The **apex** of the lung extends upwards into the root of the neck for a distance of one to two inches superior to the anterior extremity of the first rib, and is mapped out by a curved line drawn from the superior border of the sterno-clavicular articulation across the sterno-mastoid to the junction of the medial and intermediate thirds of the clavicle, the highest part of the curve reaching from ½ to 1½ in. above the clavicle. The apex of the right lung reaches half an inch higher than that of the left lung. Intimately related to the apex of the cervical pleura are the **subclavian artery** and the **inferior cervical ganglion** of the sympathetic.

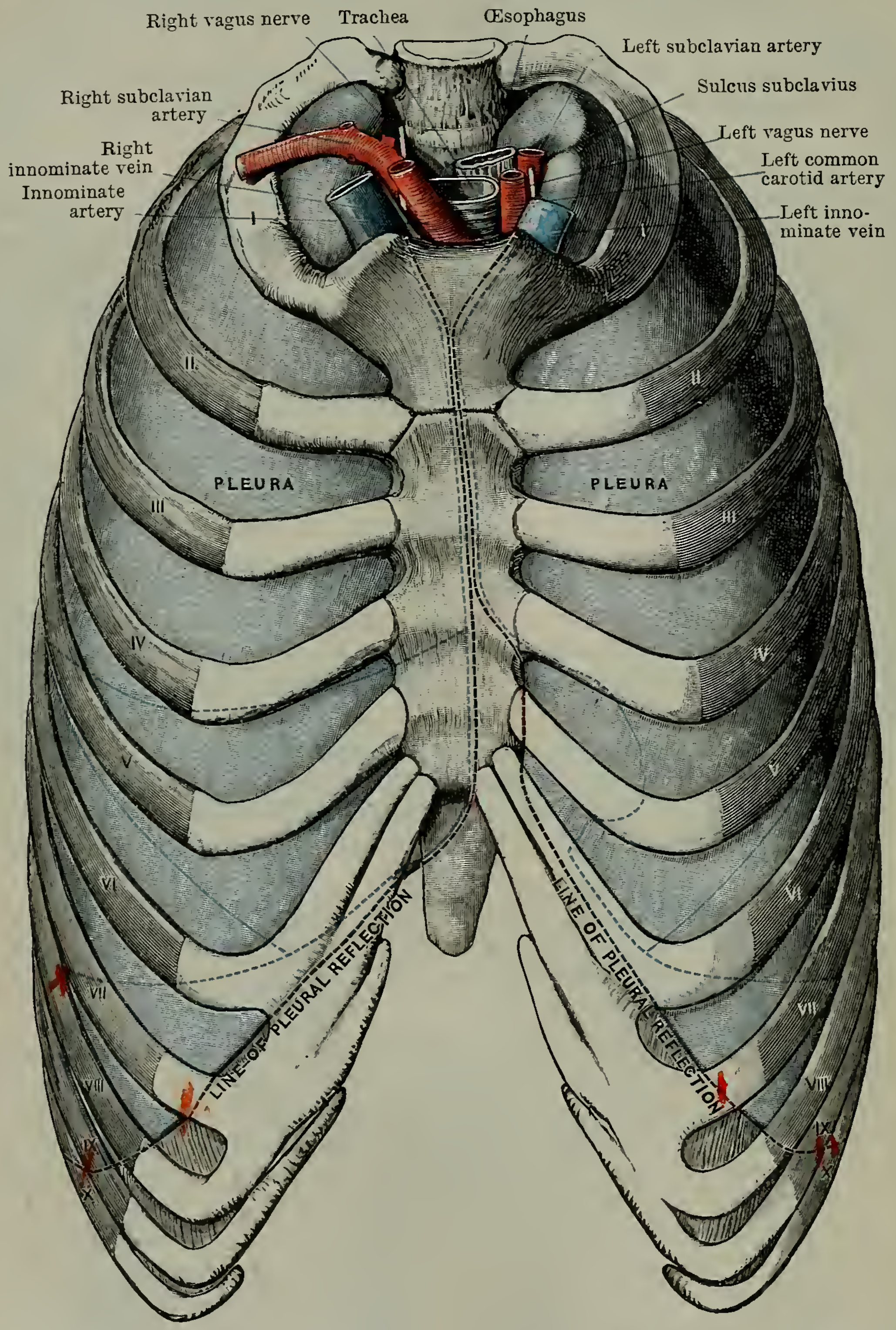

FIG. 1073.—DISSECTION OF A SUBJECT HARDENED BY FORMALIN INJECTION, to show the relations of the two pleural sacs as viewed from the front. The anterior and diaphragmatic lines of pleural reflexion are exhibited by black dotted lines, whilst the outlines of the lungs and their fissures are indicated by the blue lines. (From Cunningham.)

Both the **cervical pleura** and the **subclavian artery** may be injured by one of the fragments in a fracture of the clavicle; the scaleni muscles, however, affording considerable protection to the pleura. In ligaturing the third part of the subclavian artery, care must be taken not to injure the cervical pleura.

To delineate the **anterior border** of the **right lung**, draw a line from the superior border of the sterno-clavicular articulation to the centre of the manubrium sterni, and from there vertically downwards, in or slightly to the left of the median plane to the level of the sixth or seventh costal cartilage, or, it may be, even to the infrasternal notch (Fig. 1073).

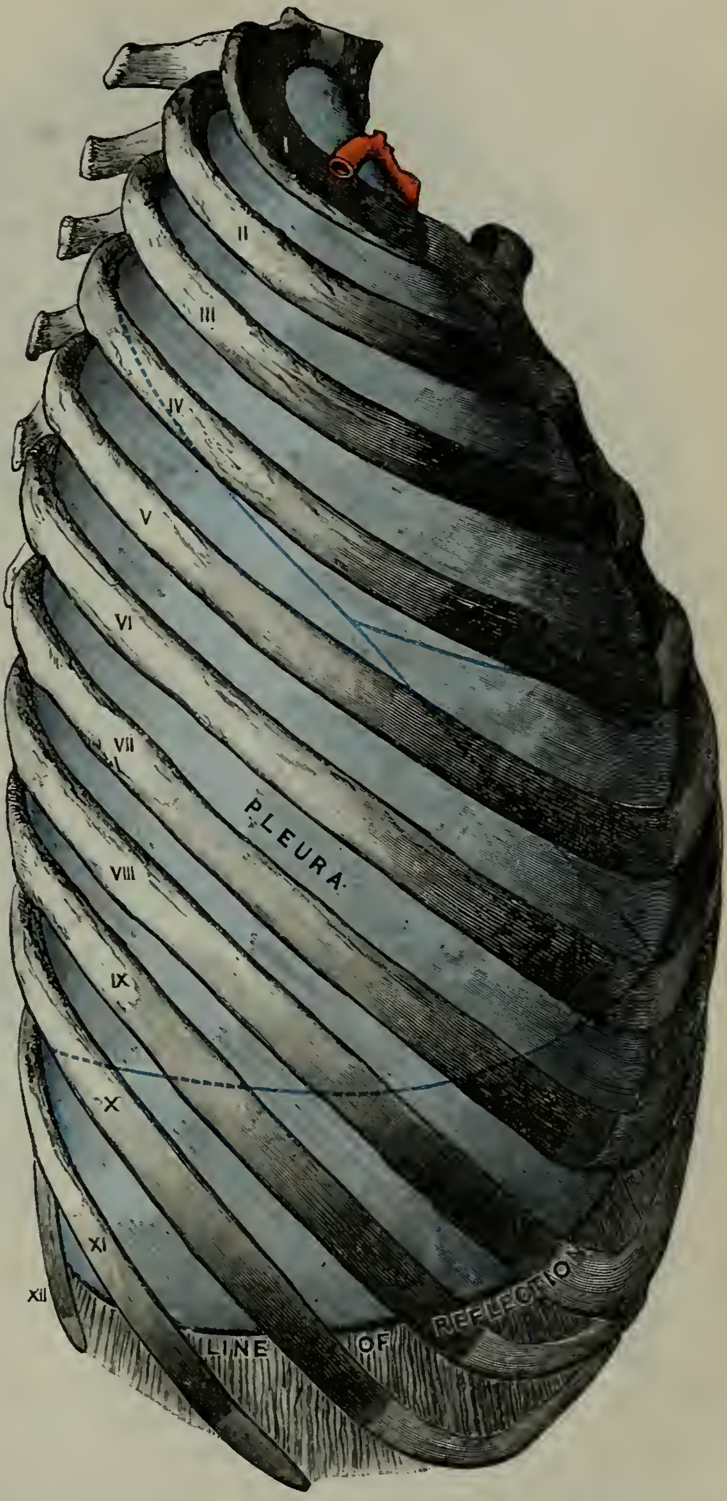

Fig. 1074.—Lateral View of the Right Pleural Sac in a Subject hardened by Formalin Injection. The blue lines indicate the outline of the right lung, and also the position of its fissures. (From Cunningham.)

The **anterior border** of the **left lung** is mapped out by a corresponding line as far as the fourth costal cartilage; thence it is directed laterally along the inferior border of the fourth costal cartilage to the para-sternal line; it then passes downwards and slightly laterally across the fourth interspace, and curves medially behind the fifth costal cartilage and fifth interspace to reach the superior border of the sixth costal cartilage in the para-sternal line. The inferior part, therefore, of the anterior surface of the right ventricle is uncovered by lung and gives a completely dull note on percussion; this area is spoken of as the area of "*superficial or absolute cardiac dulness.*"

The level of the **inferior border** of the lung is practically the same on both sides; it is mapped out by a line extending laterally from the inferior extremity of the anterior border to the sixth costal cartilage in the mid-clavicular line, and thence in a slightly curved direction, with the convexity downwards, across the lateral aspect of the chest to the tenth thoracic spine. This line crosses the eighth rib in the mid-axillary line and the tenth rib in the scapular line (Figs. 1073 and 1074).

To indicate the position of the **oblique fissure** a line is drawn from the second thoracic spine across the interscapular region to the root of the spine of the scapula, and thence downwards and laterally across the infraspinous fossa, to end at the inferior border of the lung opposite the sixth costal cartilage, a little medial to the mammary line. When the arm is raised above the level of the shoulder, and the hand placed on the back of the head, the inferior angle of the scapula is rotated upwards and forwards so that the vertebral margin practically corresponds with the line of the oblique fissure.

The **transverse fissure** of the right lung is mapped out by drawing a line from the anterior border of the lung, at the level of the fourth costal cartilage, laterally and slightly upwards to join the middle of the oblique fissure.

Pleuræ.—The **line of reflexion** of the **right pleura** from the back of the sternum may be said to correspond to the anterior border of the right lung.

On the **left side**, the pleural reflexion corresponds to the anterior border of the left lung as far as the inferior edge of the fourth chondro-sternal junction, from which point it diverges slightly and descends, behind the left border of the sternum, to the sixth costal cartilage (Fig. 1073). It is only occasionally that the anterior extremities of the fifth and sixth interspaces are uncovered by pleura.

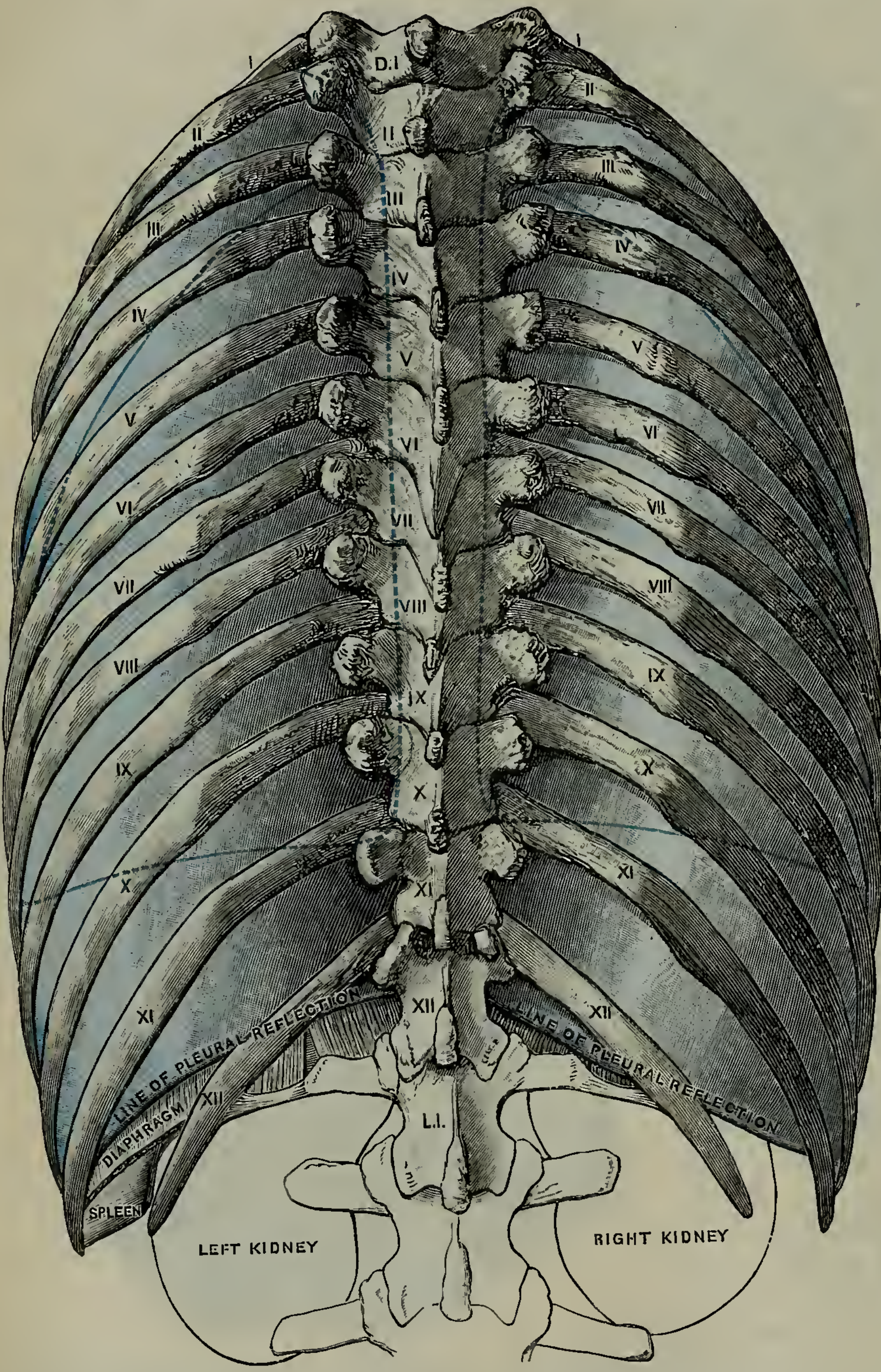

Fig. 1075.—Dissection of the Pleural Sacs from behind.

The blue lines indicate the outlines and the fissures of the lungs. (From Cunningham.)

The **right costo-diaphragmatic reflexion** (see Figs. 1074 and 1075) is indicated on the surface by a line drawn from the sixth or seventh chondro-sternal junction (sometimes the infrasternal notch) downwards and laterally to a point two inches vertically above the angle of the tenth costal cartilage; from that point the line is carried, with a slightly downward curve, across the lateral aspect of the chest to the twelfth rib at the lateral margin of the sacro-spinalis; thence it passes below the twelfth rib and reaches the vertebral column at the level of the superior border of the twelfth thoracic spine. The relation of the costo-diaphragmatic reflexion to the seventh, eighth, and ninth costal arches may be conveniently expressed by stating that it lies a little in front of the costo-chondral junction of the seventh, opposite that of the eighth, and a little behind that of the ninth. The **left costo-diaphragmatic reflexion** is indicated by a line drawn from a point opposite the sixth costal cartilage, a finger's breadth from its junction with the sternum, to a point one and a half inches vertically above the angle of the tenth costal cartilage, and thence to the vertebral column, as on the right side, but at a slightly inferior level.

The costo-diaphragmatic reflexion reaches its *lowest limit* a little behind the mid-axillary line two inches vertically above the tip of the eleventh costal cartilage, a level which may be readily indicated, according to Cunningham, by a point in the mid-axillary line intersected by a horizontal line drawn round the trunk at the level of the lowest part of the extremity of the first lumbar spine (Fig. 1072). The same author localised the level of the diaphragmatic pleural reflexion in the mammary line at the point where this line is intersected by another horizontal line at the level of the spine of the last thoracic vertebra.

The **relations** of the **pleura** to the **twelfth rib** are of importance to the surgeon, especially in connexion with operations on the kidney (Figs. 1075 and 1076). When this rib is not abnormally short, the pleural reflexion crosses it opposite the lateral border of the sacro-spinalis muscle; hence an incision may be carried deeply as far as the apex of the angle formed by the twelfth rib and the lateral border of the sacro-spinalis without entering the pleura. When, however, the twelfth rib does not reach the lateral border of the sacro-spinalis, an incision carried upwards into the apex of the angle between this muscle and the eleventh rib is certain to wound the pleura (Melsom). It is important, therefore, to count the ribs from above downwards, in order not to mistake the eleventh for the twelfth, when the latter is rudimentary.

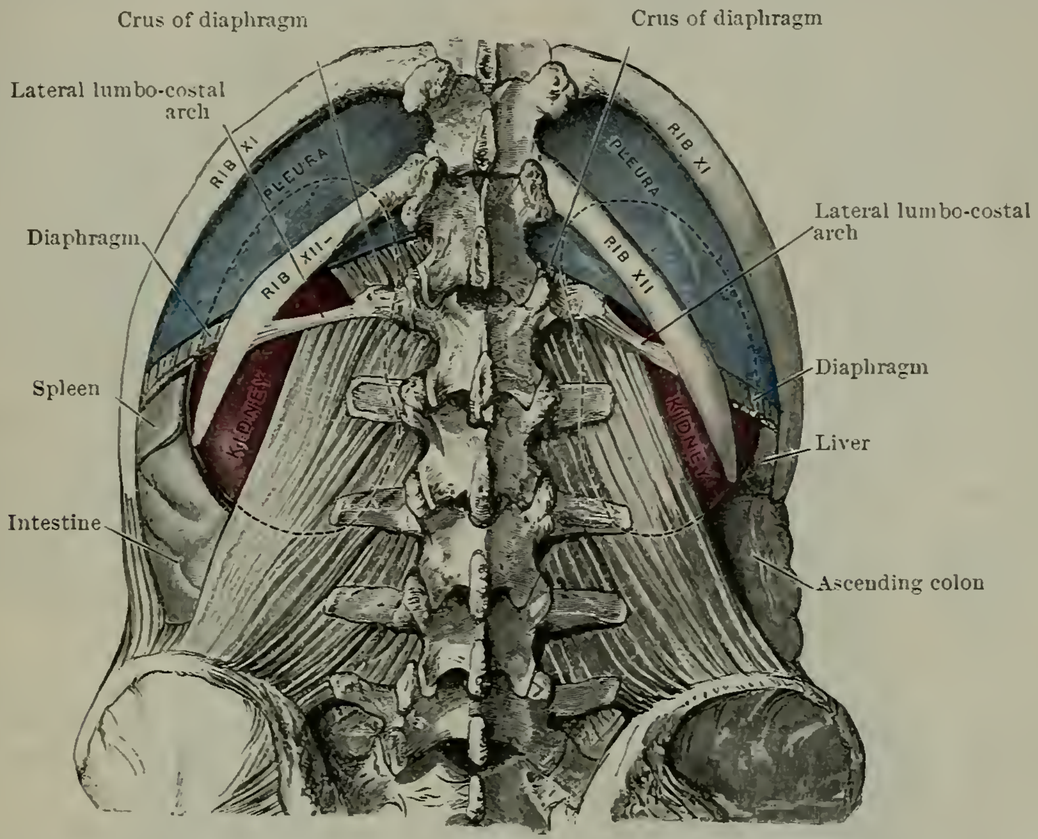

FIG. 1076.—DISSECTION FROM BEHIND TO SHOW THE RELATION OF THE TWO PLEURAL SACS TO THE KIDNEYS. Outlines of superior portions of the two kidneys are indicated by dotted lines. (From Cunningham.)

Medial to the lateral edge of the sacro-spinalis the pleural reflexion lies below the level of the twelfth rib, and not infrequently descends as far as the transverse process of the first lumbar vertebra.

On the *right side* the **posterior mediastinal pleura**, as it passes from the posterior aspect of the pericardium, backwards, to the front of the vertebral column, sweeps over the right side of the œsophagus; hence malignant ulcers of the œsophagus are more likely to invade the right pleura than the left. On the *left side* the posterior mediastinal pleura passes from the lateral aspect of the bodies of the vertebræ on to the left side of the aorta. Hence, to evacuate pus from the posterior mediastinum, there is less risk of opening the pleura if the space is entered from the left side of the vertebral column.

The seat of election for *tapping the pleura* (*paracentesis pleuræ*) is the sixth or seventh costal interspace, a little in front of the posterior axillary fold. To allow of the introduction of a tube to drain away the pus from the pleural cavity in empyema, a portion of one of the ribs (sixth to ninth) is resected. The intercostal vessels and nerves, which lie in the groove at the inferior border of the rib, are avoided by removing the portion of bone subperiosteally. If the chest is opened in the scapular line, care must be taken not to resect either the seventh or the eighth ribs, which are exposed when the arm is elevated, but are overlapped by the inferior angle of the scapula when the arm is lowered.

Anteriorly, the **bifurcation** of the **trachea** lies opposite, or a little below, the *angulus sterni*, while posteriorly it lies a little below the level of the root of the spine of the scapula, opposite the fourth thoracic spine. The bifurcation takes place one vertebra higher in the infant than in the adult (Symington).

The septum between the right and the left bronchus lies a little to the left of the middle of the trachea, and the right bronchus is wider and more nearly in a line with the trachea than the left bronchus; hence the greater tendency of foreign bodies to enter the right bronchus.

The **roots** of the **lungs** are situated opposite the fourth, fifth, and sixth thoracic spines, midway between them and the vertebral margins of the scapulæ.

The lower end of the trachea, the bronchi, the vagi, and the left recurrent nerve, are all more or less surrounded by lymph glands, which, when enlarged, may exert injurious pressure upon them.

THE HEART AND GREAT VESSELS.

Viewed from the front, the **outline** of the **precordial area**, like that of the pericardial sac, is roughly triangular, the base of the triangle being below and the apex above. The boundaries are delineated upon the surface as follows:—

The *right side* of the triangle, formed by the right atrium, is indicated by drawing a lines lightly convex laterally from the superior end of the third to the sixth costal cartilage, a finger's breadth from the edge of the sternum; the curve attains its maximum opposite the fourth intercostal space, where it reaches one and a half inches from the median plane.

The *base* of the triangle, formed by the *margo acutus* of the right ventricle and to a very slight extent by the apical portion of the left ventricle, is almost horizontal, and corresponds to a line drawn from the inferior extremity of the right side of the triangle to the apex of the left ventricle, which lies behind the fifth left intercostal space, three and a half inches from the median plane, and half an inch medial to the mid-clavicular line. The base line crosses the xiphoid process at its junction with the body of the sternum.

The *left side* of the triangle, formed by the *margo obtusus* of the left ventricle, is indicated by a slightly curved line extending from the apex of the heart upwards to the inferior edge of the second interspace, a finger's breadth from the sternum, the convexity of the curve being directed laterally and slightly upwards.

The truncated *apex* of the triangle, which lies behind the sternum at the level of the second intercostal space, corresponds to the highest part of the heart, namely, where the auricles of the atria embrace the aorta and pulmonary artery.

The situation of the anterior part of the **coronary sulcus** is mapped out by a line drawn from the median plane, opposite the inferior border of the third left costal cartilage, downwards and laterally to the sixth right chondro-sternal junction; the line should be slightly convex upwards and to the right. The **right auricle** lies at, or a little to the right of, the median plane, at the level of the second intercostal space and the superior border of the third costal cartilage. The **left auricle** lies behind the second left intercostal space, close to the edge of the sternum.

The *diaphragmatic* or *inferior surface* of the heart rests upon the diaphragmatic or basal part of the pericardium. The *base,* or true *posterior surface,* of the heart is formed mainly by the **left atrium,** which is moulded posteriorly upon the œsophagus, the aorta, the bronchi, and the bronchial glands, the pericardium intervening. The left atrium extends behind the right atrium for a considerable distance to the right of the median plane.

In a radiographic examination in cases of general visceroptosis, the diaphragm, which should rise and fall opposite the xiphisternal junction, will be seen to be an inch or more lower down, while the heart is seen to hang more vertically than normal (cardioptosis).

In determining the position of the *cardiac orifices* and *their valves* it is to be remembered that they are all situated below and to the left of the anterior part of the coronary sulcus, and that they lie in the following order from above down-

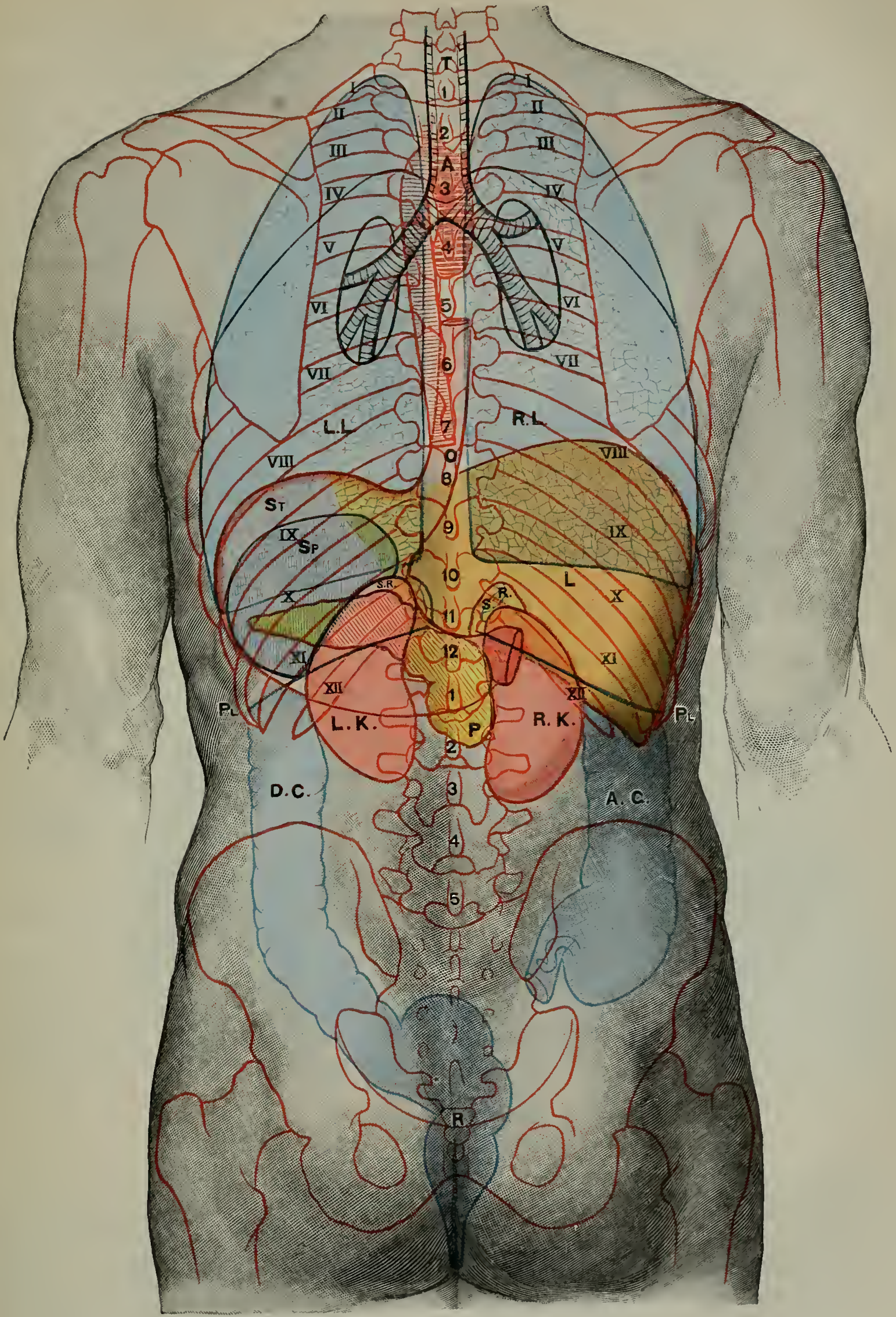

Fig. 1077.—Posterior Aspect of Trunk, showing Surface Topography of Viscera.

T.	Trachea	Sp.	Spleen.	P.	Pancreas.
A.	Aorta.	L.	Liver.	Pl.	Pleura.
L.L.	Left lung.	S.R.	Suprarenal gland.	D.C.	Descending colon.
R.L.	Right lung.	L.K	Left kidney.	A.C	Ascending colon.
St.	Stomach.	R.K	Right kidney.	R.	Rectum.

wards—viz., pulmonary, aortic, mitral, and tricuspid. When delineated on the surface they will be seen to lie within an ellipse whose long axis extends from the superior border of the third left to the sixth right chondro-sternal junction.

The **pulmonary orifice**, directed upwards and slightly backwards and to the left, lies opposite the superior border of the third left chondro-sternal junction ; the **aortic orifice**, directed upwards, backwards, and to the right, lies further from the surface, behind the left half of the sternum, opposite the inferior border of the third costal cartilage; the **mitral orifice** lies at an inferior level, behind the left half of the sternum, opposite the fourth rib; the orifice of the opening is directed downwards, forwards, and to the left. The **tricuspid orifice**, situated nearer the anterior wall of the chest than the mitral, lies very obliquely behind the right half of the sternum at the level of the fourth and fifth cartilages and intervening space.

Although the first and second **sounds of the heart** are heard all over the cardiac area, the sounds produced by the individual valves are heard most distinctly, not directly over their anatomical situation, but over the area where the cavity in which the valve lies approaches nearest to the surface. Hence the mitral sound is best heard over the apex (mitral area), the tricuspid over the inferior part of the body of the sternum (tricuspid area), the aortic over the second right costal cartilage (aortic area), and the pulmonary over the second left intercostal space (pulmonary area).

In **tapping the pericardium** (paracentesis pericardii) the pleura will be avoided by making the puncture through the fifth or sixth left intercostal space as close as possible to the edge of the sternum. When, however, the pericardial sac is distended with fluid, the pleura is pushed laterally, and will therefore escape injury if the puncture is made at a safe distance lateral to the internal mammary vessels, viz., one inch lateral to the left border of the sternum.

To establish free drainage in suppurative pericarditis, the sixth left costal cartilage must be resected and the internal mammary vessels ligatured; the transversus thoracis and the pleural reflexion are then pushed aside and the pericardium exposed and incised.

The **ascending aorta** lies behind the sternum, opposite the second and third ribs, and, unless dilated, does not project beyond its right border. The superior border of the **aortic arch** lies at or a little above the centre of the manubrium sterni; in the child the vessel may reach as high as the superior border of the manubrium.

The **innominate and left common carotid arteries** diverge from either side of the median plane between the upper part of the manubrium sterni and the front of the trachea. A pin pushed directly backwards immediately above the middle of the supra-sternal notch will strike the medial border of the innominate artery a little below its bifurcation.

The **pulmonary artery** lies behind the left border of the sternum opposite the second interspace and the second costal cartilage.

The **left innominate vein** lies behind the superior part of the manubrium sterni, the **right** behind the medial end of the right clavicle. The **superior vena cava** lies immediately to the right of the margin of the sternum, opposite the first and second interspaces and the intervening second rib; its opening into the right atrium, behind the third chondro-sternal articulation, corresponds to the centre of the root of the right lung.

ŒSOPHAGUS.

The average length of the **œsophagus** in the adult is 10 in. (25 cm.); the distance from the incisor teeth to its commencement is 6 in.; to the point or level where it is crossed by the left bronchus, 9 in.; to the œsophageal opening of the diaphragm, 14 to 15 in.; to the cardiac orifice of the stomach, 16 in. These measurements, which are of great importance in diagnosing the seat of œsophageal obstructions, should be marked off from below upwards upon all œsophageal bougies and probangs. Posteriorly, the œsophagus extends from the level of the sixth cervical spine to that of the tenth thoracic, a little to the left of which is the situation at which the stethoscope is placed in order to hear the sound produced by the passage of fluid into the stomach.

Clinically it is important to bear in mind the relation of the œsophagus to the trachea and left bronchus, to the left recurrent nerve, to the bronchial and posterior mediastinal glands, to the descending thoracic aorta, and to the right posterior mediastinal pleura. Ulcers of the œsophagus are liable to open into either the trachea, the left bronchus, or the right pleura.

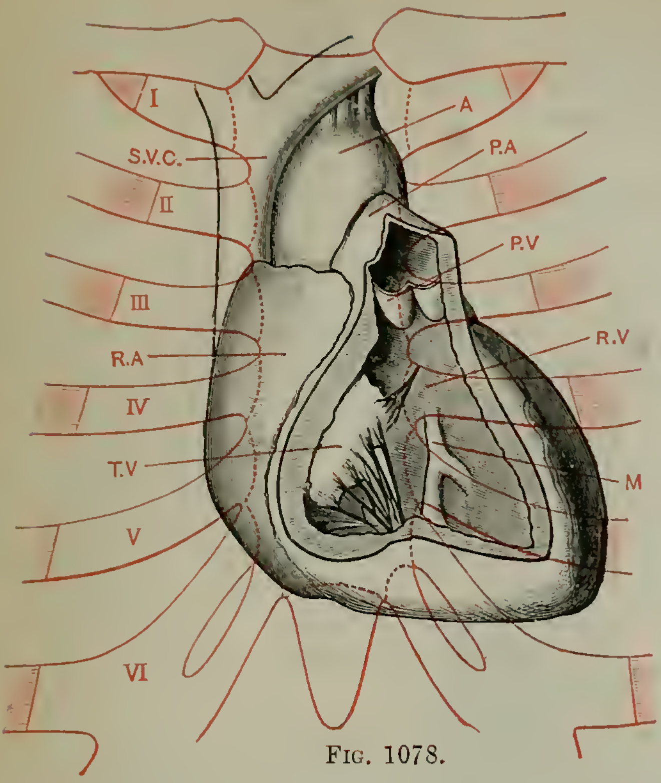

Fig. 1078.

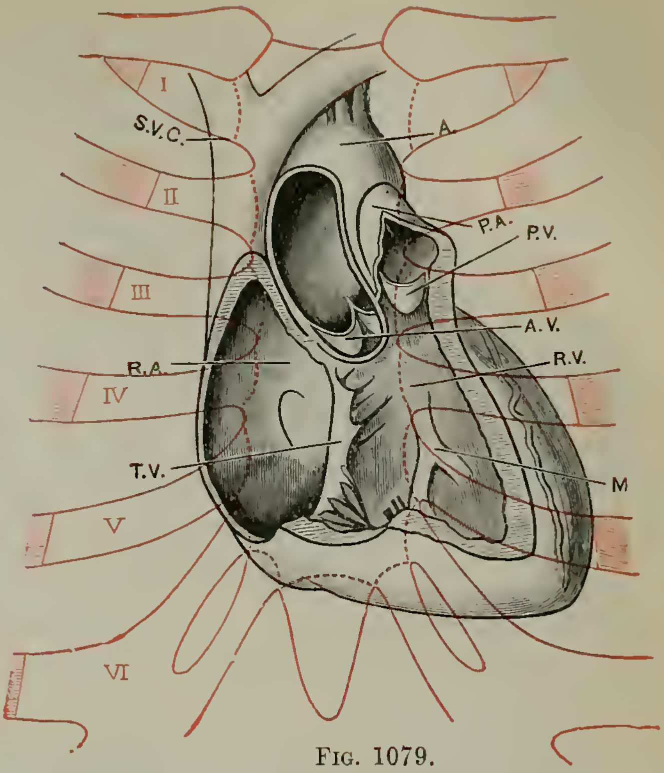

Fig. 1079.

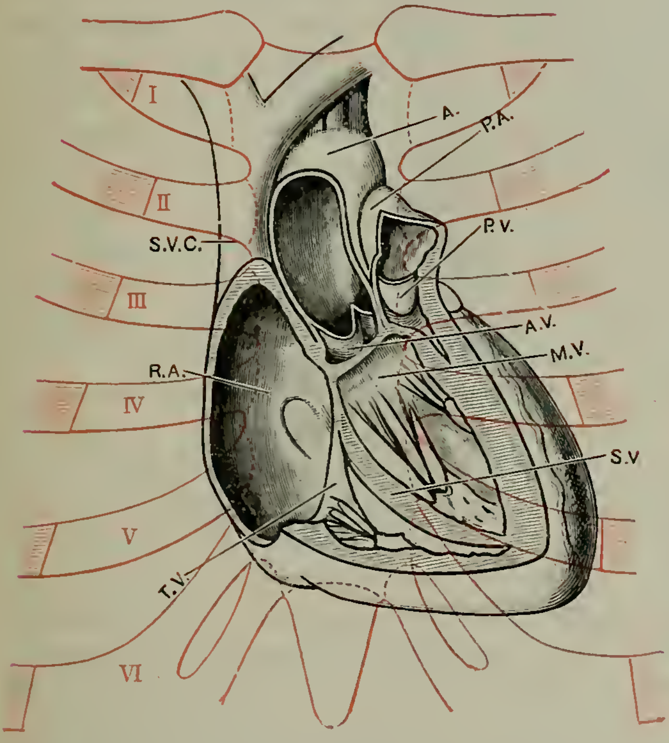

Fig. 1080.

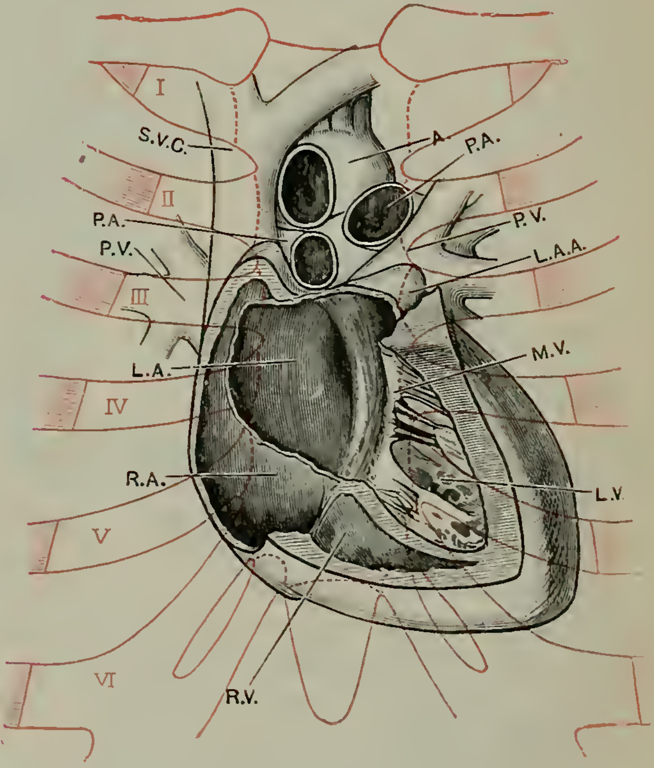

Fig. 1081.

From photographs of a formalin-hardened subject, with the heart dissected *in situ*, to show the relations of its cavities and valves to the anterior wall of the thorax.

In Fig. 1078 the anterior wall of the right ventricle has been removed and the pulmonary artery opened.

In Fig. 1079 the anterior walls of the ascending aorta and of the right atrium have been removed; also the anterior cusp of the tricuspid valve.

In Fig. 1080 the greater part of the interventricular septum has been removed, exposing the anterior cusp of mitral valve.

In Fig. 1081 the ascending aorta, anterior cusp of mitral valve, trunk of pulmonary artery, and interatrial septum have been removed; the cavities of the left atrium and left ventricle are exposed, also the left atrium and posterior cusp of mitral valve.

R.A.	Right atrium.	P.A.	Pulmonary artery.	M.V.	Mitral valve.
R.V.	Right ventricle.	P.V.	Pulmonary valve.	S.V.C.	Superior vena cava.
L.A.	Left atrium.	A.	Aortic arch.	P.V.	Pulmonary vein.
L.A.A.	Left auricle.	A.V.	Aortic valve.	M.	Moderator band.
S.V.	Interventricular septum.	T.V.	Tricuspid valve.		

The *veins* of the inferior end of the œsophagus open partly into the systemic veins and partly into the portal system; like those at the inferior end of the rectum they are liable to become varicose in conditions which give rise to chronic interference with the portal circulation.

The *lymph vessels* of the upper part of the œsophagus open into the inferior deep cervical glands, the remainder into the posterior mediastinal glands.

THE ABDOMEN.

THE ANTERIOR ABDOMINAL WALL.

The configuration of the abdomen varies with the age, sex, obesity, and muscular development of the individual. In the child it is wider above than below, while the reverse is the case in the adult female. It is most prominent in the region of the **umbilicus**, which is situated, normally, below the mid-point between the infra-sternal notch and the symphysis pubis, usually a little below the level of the highest part of the iliac crest, and opposite the middle of the body of the fourth lumbar vertebra. In the obese, and especially when the abdominal muscles have lost their tone, the umbilical region becomes prominent and more or less pendulous, so that the umbilicus may come to lie considerably below the normal level. In the child it is relatively lower than in the adult, in consequence of the undeveloped state of the pelvis.

In spare subjects the inferior end of the body of the sternum, the xiphoid process, and the costal margin, can readily be traced. The slight depression or notch formed by the seventh costal cartilages and the inferior border of the body of the sternum is termed the **infra-sternal notch.** Below the notch, and bounded on each side by the seventh, eighth, and ninth costal cartilages, is the **infra-costal angle**, which varies considerably according to the shape of the chest; it is relatively wider in the child than in the adult. The inferior border of the curve of the **tenth costal cartilage** is easily recognisable, and was selected by Cunningham as the level of the plane of separation (**infra-costal plane**) between the upper and middle abdominal zones.

The anterior abdominal wall is limited below by the fold of the groin and the crest of the pubes. In a spare muscular subject the recti, the furrows corresponding to the **inscriptiones tendineæ** (O.T. **lineæ transversæ**) and the supra-umbilical portion of the **linea alba**, can be readily made out. When the outline of the rectus is not visible the lateral border may be indicated by a line drawn from the tip of the ninth costal cartilage to the mid-point of a line joining the umbilicus and the anterior superior iliac spine, and from thence to the pubic tubercle. In the angle between the lateral border of the rectus and the ninth costal cartilage, on the right side, is a slight triangular depression which overlies the fundus of the **gall-bladder.** Between the inferior part of the lateral border of the rectus and the prominence above the anterior part of the iliac crest, caused by the lower muscular fibres of the external oblique, is another slight triangular depression, which corresponds to the inferior and narrow part of the aponeurosis of the external oblique muscle.

Close above, and almost parallel to, the medial half of the inguinal ligament is the **inguinal canal**, traversed by the **spermatic funiculus** (Fig. 1082); the latter can be felt to emerge at the subcutaneous inguinal ring immediately above the pubic tubercle. The **abdominal** and **subcutaneous inguinal rings** have been fully described elsewhere; the former is triangular in shape, with its apex directed superiorly and laterally, and its base immediately above the pubic crest. By invaginating the skin of the scrotum the little finger may be passed through the ring into the canal. It is to be noted that the neck of an *inguinal hernia* lies above the pubic tubercle, whereas the neck of a *femoral hernia* emerges below the medial end of the inguinal ligament, lateral to the pubic tubercle. The **abdominal inguinal ring**, an opening in the fascia transversalis, lies half an inch above a point a little medial to the middle of the inguinal ligament. The **inferior epigastric artery** may be mapped out by drawing a line from a point midway between the superior anterior iliac spine and the symphysis pubis towards the umbilicus. The vessel, together with the medial third of the inguinal ligament and the inferior part of the lateral border of the rectus, bounds a triangle known as **Hesselbach's triangle.** As the inferior epigastric artery passes superiorly and medially to disappear behind the falx aponeurotica inguinalis and the lateral border of the rectus, it lies behind the spermatic funiculus immediately medial to, and below, the abdominal inguinal ring. The floor of Hesselbach's triangle is formed throughout by the fascia transversalis, superficial to which, over the medial half or so of the triangle, is the **falx aponeurotica inguinalis.** An **oblique inguinal hernia** leaves the abdomen at the abdominal inguinal ring and traverses the whole length of the inguinal canal; its coverings are therefore the same as those of the spermatic funiculus, and the neck of the sac lies lateral to the inferior epigastric artery, hence this variety of hernia is also termed *lateral inguinal hernia.* A **direct inguinal hernia,** on the other hand, instead of traversing the whole length of the inguinal canal, pushes before it that part of its posterior wall which is formed by the floor of Hesselbach's triangle. The neck of the sac, therefore, lies medial to the inferior epigastric artery, and this variety of hernia may be termed a *medial inguinal hernia.* If a direct hernia makes its way through the medial part of Hesselbach's triangle, it derives a covering from the falx inguinalis, as well as from the fascia transversalis; if through the lateral part of the triangle, the lateral edge of the falx inguinalis curves round the medial side of the neck of the sac. To relieve the constriction at the neck of the sac, in the case of an *oblique inguinal hernia,* the edge of the knife is directed superiorly and laterally to avoid the inferior epigastric artery, while in a *direct hernia* the artery is avoided by dividing the constriction in a superior and medial direction. In an *oblique inguinal hernia* the sac lies within the internal spermatic fascia (fascia propria of the hernia), whereas in a *direct hernia* the fascia propria is derived from the fascia transversalis of Hesselbach's triangle. The extra-peritoneal fat which covers the outer surface of the hernial sac is sometimes hypertrophied to such an extent as to amount to a fatty tumour.

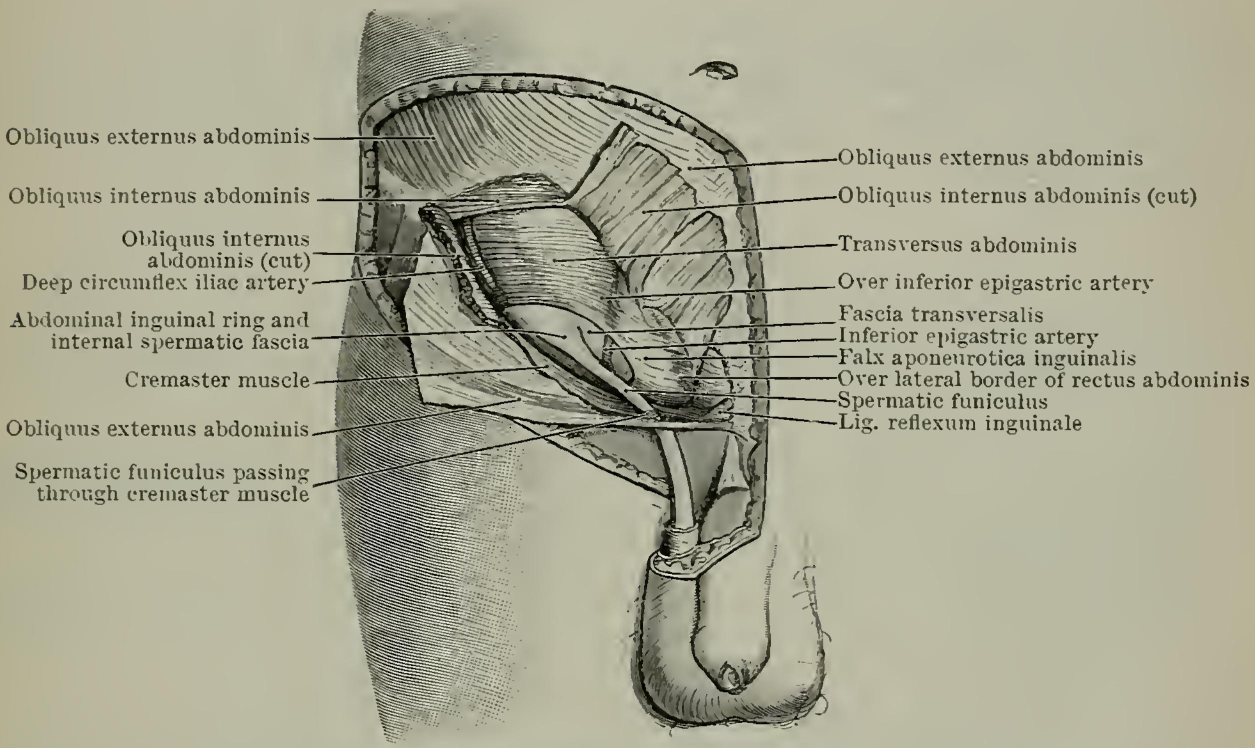
Obliquus externus abdominis
Obliquus internus abdominis
Obliquus internus abdominis (cut)
Deep circumflex iliac artery
Abdominal inguinal ring and internal spermatic fascia
Cremaster muscle
Obliquus externus abdominis
Spermatic funiculus passing through cremaster muscle
Obliquus externus abdominis
Obliquus internus abdominis (cut)
Transversus abdominis
Over inferior epigastric artery
Fascia transversalis
Inferior epigastric artery
Falx aponeurotica inguinalis
Over lateral border of rectus abdominis
Spermatic funiculus
Lig. reflexum inguinale

FIG. 1082.—THE GROIN. The structures seen on reflexion of part of the obliquus internus abdominis. (A. M. Paterson.)

In a large proportion of children, at birth, the **vaginal process** of peritoneum, which connects the tunica vaginalis testis with the abdominal peritoneum, is still patent, especially on the right side. Should the bowel force its way along the patent process a **congenital inguinal hernia** arises. In the majority of the cases of congenital inguinal hernia it will be found that the tunica vaginalis testis has been shut off by closure of the lower part of the vaginal process, only the superior part remaining patent and forming the sac of the hernia.

In the child the persistence of a patent vaginal process can almost invariably be detected by rolling the cord between the finger and thumb; after the ductus deferens and spermatic vessels have slipped away from one's grasp the edge of the sac can be felt to follow them. In regard to the operation for the cure of inguinal hernia, it should be borne in mind that in the acquired form the *hernia produces the sac*, whereas in the congenital variety the *sac is the cause of the hernia*; it follows, therefore, that in the operation for *acquired* hernia the closure of the canal is as important as the removal or obliteration of the sac, while in a *congenital* hernia the most essential part of the operation is the closure of the neck of the sac, and as the muscular and fascial apparatus forming the walls of the canal are often well developed (especially in children), they should be interfered with as little as possible. A patent vaginal process may persist during adult life without any bowel descending into it; on the other hand, years after birth, bowel may suddenly enter it. In practically all oblique inguinal herniæ, which develop suddenly in children as well as in adolescents and young adults, the *sac* is of congenital origin.

In the ordinary form of hydrocele the fluid is confined to the tunica vaginalis testis, but when the vaginal portion of the processus vaginalis remains patent, the hydrocele may extend upwards into the inguinal canal, and may or may not communicate with the general peritoneal cavity. In the condition known as encysted hydrocele of the cord the patent funicular process is shut off both from the tunica vaginalis testis and from the peritoneal cavity.

ABDOMINAL INCISIONS.

Before proceeding to deal with the abdominal cavity reference must be made to some anatomical points connected with the more typical incisions made by surgeons in opening the abdomen.

Incisions in the Median Plane.—Median line incisions through the linea alba have the advantage of being comparatively bloodless and rapid of execution, of dividing no motor nerves, and of enabling the surgeon to expose a wide area of the abdomen. Unless special precautions are taken, however, they are more liable to be followed by a ventral hernia.

Above the umbilicus the linea alba is comparatively broad, so that the edges of the recti are separated by a distinct interval, which may be of considerable width in obese subjects and multiparous women. Deep to the linea alba is the transversalis fascia, which is so thin and adherent that the two structures form practically a single layer. The extraperitoneal fat, which forms a comparatively thick stratum, must not be mistaken for omentum. The peritoneum presents itself as a thin, bluish, semi-transparent membrane. If it is necessary to prolong the incision downwards below the level of the umbilicus, it should skirt its left margin so as to avoid the round ligament of the liver. If, in closing a median supra-umbilical laparotomy wound, the surgeon merely sutures the edges of the stretched linea alba without opening into the rectal sheaths, a hernia may result. To ensure against it the medial borders of the recti are exposed by opening into their sheaths along each edge of the wound. In closing the wound, the deepest suture (continuous) includes on each side the posterior layer of the rectal sheath along with the split linea alba, the transversalis fascia, and the peritoneum. This gives a substantial "first line of defence." The next suture takes up some of the fibres of the medial edges of the recti, along with the anterior layer of their sheaths. The skin is sutured separately. By the above procedure the edges of the recti are brought into actual contact and a double-layered linea alba is fashioned, one layer behind the margins of the recti and the other in front of them.

Below the umbilicus the medial edges of the recti are practically in contact, so that an incision between them opens into the rectal sheath on both sides.

The nearer the opening into the abdomen approaches the symphysis pubis, the more likely is the bladder to be encountered; this applies more especially in children in whom the bladder extends higher up out of the pelvis. Before opening the abdomen, therefore, by a low median incision, the bladder should be emptied; in supra-pubic cystotomy, on the other hand, it is intentionally filled so as to elevate the peritoneum (superior false ligament of the bladder) well above the symphysis. Below this peritoneal layer is the **space of Retzius**, occupied by a pad of extra-peritoneal fat which must be separated by blunt dissection before the bladder wall is actually exposed. In opening the bladder the pre-vesical veins, which ramify on its surface, are avoided as far as possible. Above the pubes the fascia transversalis recedes somewhat from the posterior surface of the recti, leaving behind it a cellular interval which must not be mistaken for the space of Retzius.

If a transverse incision is added to the inferior end of a supra-umbilical median incision, free access may be obtained to the hypochondriac as well as to the epigastric region. Before dividing the fibres of the rectus, however, the anterior layer of the sheath is stitched to them to prevent their retraction. In dividing the posterior layer of its sheath the terminal portions of the ninth and tenth intercostal nerves need not be injured as they run in a transverse direction.

Incisions through the Recti.—In opening the abdomen by **longitudinal incisions through the recti**, the superior epigastric artery will be encountered above the umbilicus, and the inferior epigastric below it. The nearer the opening approaches the lateral border of the rectus, the more will its nerve-supply be injured. **Above the level of the umbilicus**, the posterior layer of the rectal sheath is well developed; and in closing the wound it is included in the same suture as the transversalis fascia and the peritoneum, the three together forming a most efficient "first line of defence." The higher up and further lateral the incision is made through the rectus, the more will the posterior layer of the sheath be found to be made up of transverse muscular fibres prolonged inwards from the transversus abdominis muscle. **Below the level of the umbilicus**, the posterior layer of the rectal sheath is much thinner, and where it ceases, namely, about midway between the umbilicus and the pubes, it constitutes what is known as the linea semicircularis **(semilunar fold of Douglas)**. Below this level, therefore, the "deep closure" of a laparotomy wound through the rectus is less secure than is the case at a higher level. It is all the more important, therefore, to see that the edges of the anterior layer of the sheath are accurately sutured.

Incisions lateral to the Rectus.—Longitudinal incisions lateral and parallel to the lateral border of the rectus are as far as possible to be avoided, firstly, because they divide the motor nerves, and, secondly, because the abdominal wall is almost entirely aponeurotic, and, therefore, a hernia is liable to result.

Incisions lateral to the rectus, **above the level of the umbilicus**, are generally made more or less parallel to the costal margin. Such incisions give access to the gall-bladder and bile-ducts. The fibres of the external oblique muscles are divided transversely, but those of the internal oblique and transversus muscles may be divided more or less parallel to the fibres. The abdominal portions of the eighth, ninth, and tenth thoracic nerves lie between the two deep muscles, running in a medial and slightly downward direction, so that it is practically impossible to avoid dividing one or other of them.

In the iliac regions, to reach the cæcum and vermiform process on the right side, and the pelvic colon on the left side (colostomy), it is customary, by using what is known as the "grid-iron incision," to split the three abdominal muscles in the direction of their fibres. The external oblique is split in the direction of the skin incision, which is made obliquely from above downwards and medially. After retracting the edges of this muscle the fibres of the internal oblique and transversalis muscles are split horizontally. The abdomen is then opened by dividing the transversalis fascia and peritoneum. If a comparatively large opening is required the branch of the deep circumflex iliac artery, which ascends between the internal oblique and transversus muscles, a little medial to the anterior superior iliac spine, is divided and ligatured, while the ilio-hypogastric and ilio-inguinal nerves are to be avoided. If it is necessary to extend the incision in a medial direction, the lateral part of the anterior layer of the sheath of the rectus is opened and the rectus muscle retracted medially; while the inferior epigastric artery, now exposed, is pushed aside or ligatured before the opening in the fascia transversalis and peritoneum is enlarged.

Distribution of Sensory Nerves in Anterior Abdominal Wall.

A knowledge of the segmental distribution of the sensory fibres of the anterior rami of the lower intercostal nerves enables us to appreciate the significance of the so-called girdle pain often associated with lesions of the spinal medulla and its nerve-roots. In tuberculous disease of the vertebral column, for example, the girdle pain may be an early symptom of the disease, and when present it affords a valuable guide to the situation of the disease in the vertebral column. The seventh thoracic nerve supplies the skin at the level of the epigastric triangle, the eighth and ninth, that between it and the umbilicus, the tenth that at the level of the umbilicus, the eleventh and twelfth that between the umbilicus and groin.

THE ABDOMINAL CAVITY.

Subdivisions of the Abdominal Cavity.—To simplify the topography of the abdominal viscera the abdomen is arbitrarily divided into nine regions by two horizontal and two vertical planes. Of the two horizontal planes, the **superior** or **infracostal plane** is at the level of the lowest part of the tenth costal cartilages; the **inferior** or **intertubercular plane** is at the level of the tubercles of the iliac crests. The **two vertical planes** correspond upon the surface to a line drawn vertically upwards on each side from a point midway between the anterior superior iliac spine and the pubic symphysis. Superiorly, these vertical planes generally strike the tip of the ninth costal cartilages. The subdivisions of the **superior zone** are termed the *epigastric* and *right* and *left hypochondriac regions*, of the **middle zone**

the *umbilical* and *right* and *left lumbar regions*, of the **inferior zone** the *hypogastric* and *right* and *left iliac regions*. The epigastric, umbilical, and hypogastric regions may be further divided into right and left halves by the median plane. The **xiphisternal junction** is on a level with the fibro-cartilage between the ninth and tenth thoracic vertebræ. The **infracostal plane** passes through the superior part of the third lumbar vertebra; the **intertubercular plane** through the fifth lumbar vertebra, about one inch above the sacral promontory. The umbilicus is situated usually from one to two inches above the intertubercular line.

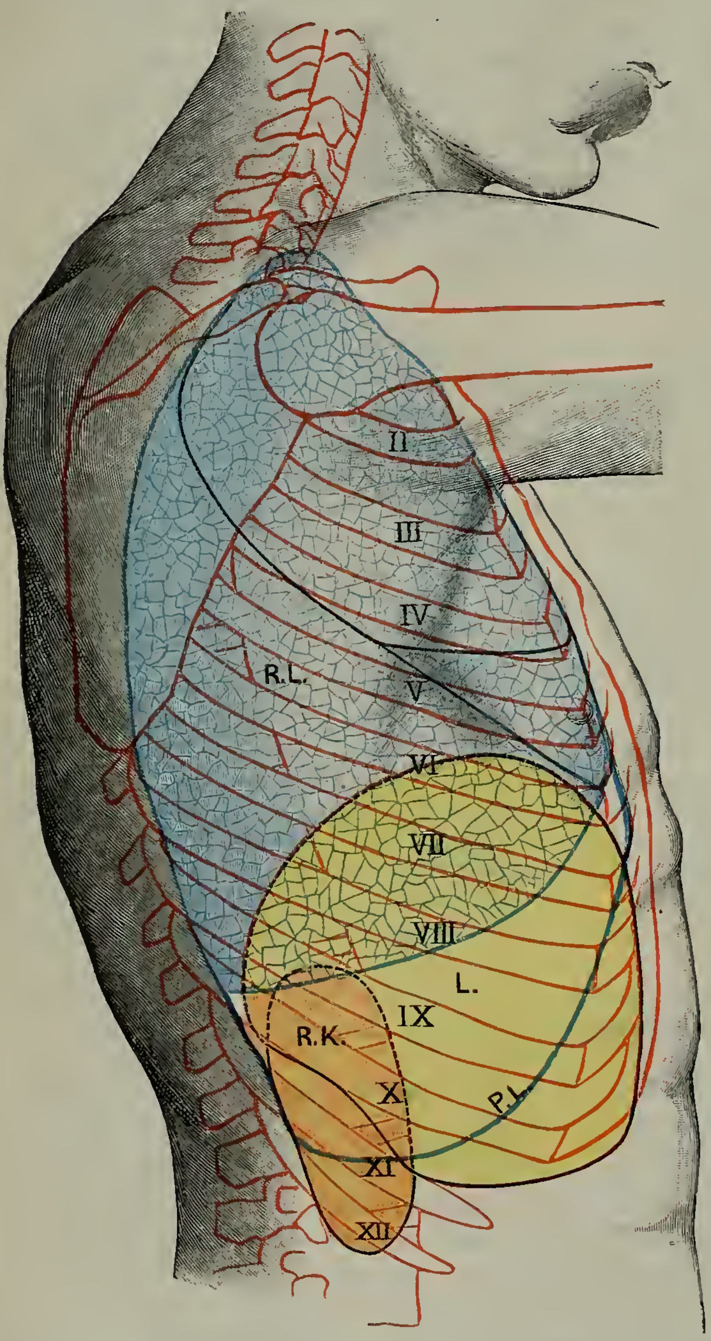

Fig. 1083.—Lateral Aspect of Trunk, showing Surface Topography of Viscera.

R.L. Right lung.
L. Liver.
R.K. Right kidney.
P.L. Pleura.

In the method of surface topography employed by Addison the plane of separation between the superior and middle abdominal zones is placed midway between the superior border of the manubrium sterni and the superior border of the pubic symphysis. It will be found to lie at or near the mid-point between the xiphisternal junction and the umbilicus. Posteriorly, this plane strikes the inferior border of the first lumbar vertebra, and it passes so constantly through the pylorus that it may with advantage be termed the **transpyloric plane**.

The **peritoneal cavity** may be regarded as a large and complicated lymph sac which is intimately related to the abdominal viscera, and more especially to the gastro-intestinal canal. Inflammatory infections of the peritoneum are therefore almost always secondary to lesions of the viscera. The peritoneal lymph sac is brought into direct communication with the subperitoneal lymph vessels of the diaphragm through stomata which open upon the peritoneum covering the abdominal surface of that muscle. With the object, therefore, of diminishing septic absorption after operations for peritonitis, the patient is kept in the half-sitting posture, and pelvic drainage is established. The healthy peritoneum, in virtue of the vital action of its endothelial cells, is endowed with great absorptive properties, and, when irritated, has the power of throwing out an abundant exudation, the cell-elements of which are actively phagocytic.

The reflexion of the peritoneum and its relations to the various organs have been fully described in the section on the Digestive System.

The attachment of the **transverse mesocolon** to the posterior abdominal wall is at the level of the first lumbar vertebra, and lies, therefore, a little above the infracostal plane. The attachment, which ascends slightly as it passes from right to left, crosses the right kidney, the descending part of the duodenum, and the head of the pancreas, after which its attachment follows the anterior border of the pancreas. The *peritoneal subdivision above this attachment* is roofed in by the

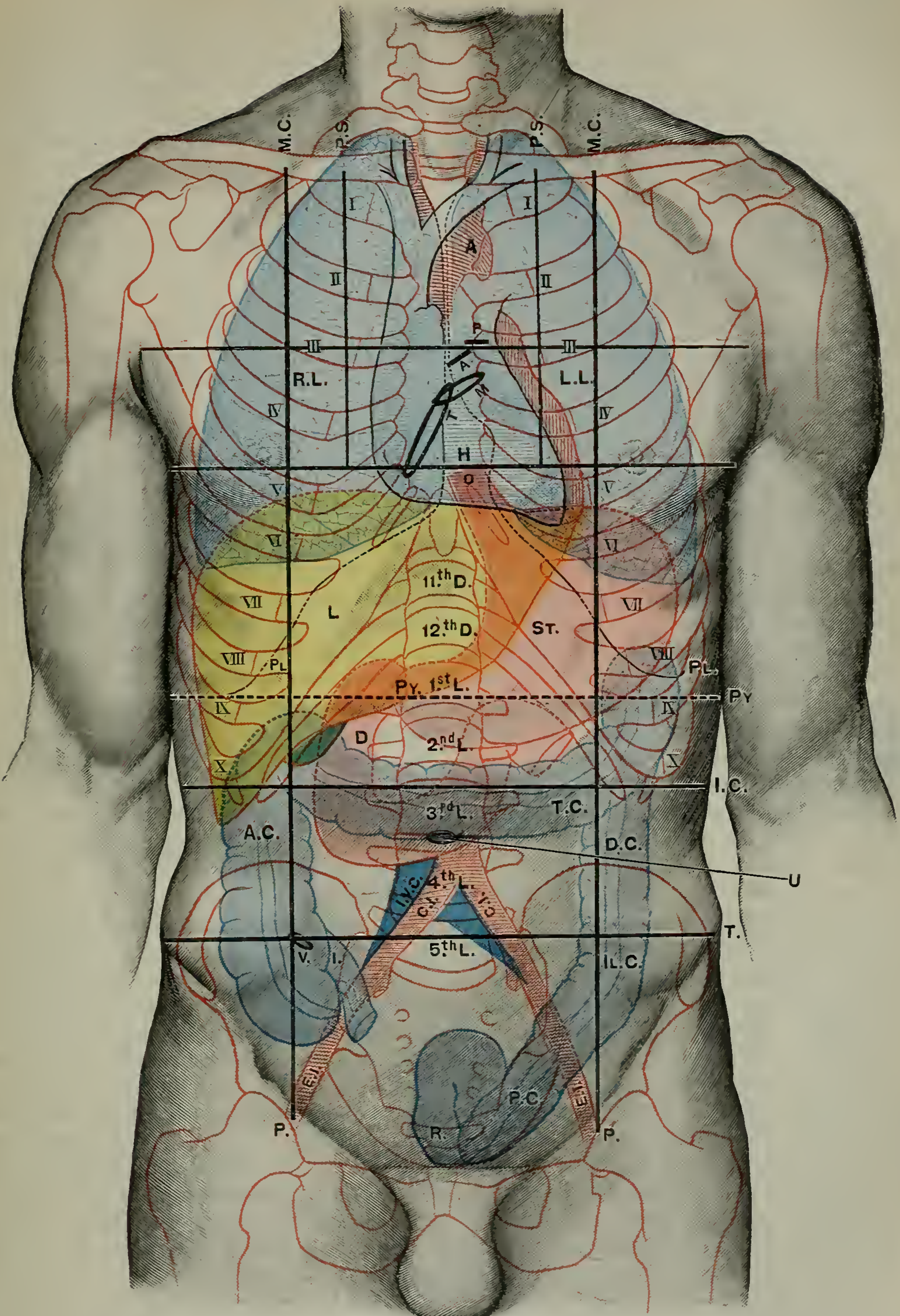

FIG. 1084.—ANTERIOR ASPECT OF TRUNK, SHOWING SURFACE TOPOGRAPHY OF VISCERA.

M.C.	Mid-clavicular line.
P.S.	Para-sternal line.
P.	Inguinal vertical line.
I.C.	Infra-costal line.
T.	Intertubercular line.
Py.	Transpyloric line of Addison.
A.	Aorta.
H.	Heart.
P.	Pulmonary orifice.
A.	Aortic orifice.
M.	Mitral orifice.
T.	Tricuspid orifice.
R.L.	Right lung.
L.L.	Left Lung.
Pl.	Pleura.
L.	Liver.
O.	Œsophagus.
St.	Stomach.
Py.	Pylorus.
D.	Duodenum.
I.	Ileum.
V.	Valve of the colon.
A.C.	Ascending colon.
T.C.	Transverse colon.
D.C.	Descending colon.
Il.C.	Iliac colon.
P.C.	Pelvic colon.
R.	Rectum.
C.I.	Common iliac artery.
E.I.	External iliac artery.
I.V.C.	Inferior vena cava.
U.	Umbilicus.

diaphragm, and includes the superior part of the great sac, and, behind it, the larger portion of the omental bursa. The organs related to this area of the peritoneum are the liver, along with the bile-ducts and gall-bladder, the stomach and part of the duodenum, the spleen, the pancreas, the upper parts of the kidneys, and the suprarenal glands. Suppuration connected with any of these organs is liable to spread upwards under the cupola of the diaphragm, producing what is known as *subphrenic abscess.*

The attachment of the **mesentery** of the **small intestine** extends from the left side of the second lumbar vertebra downwards to the right iliac fossa. The attachment may be mapped out on the surface by drawing a line from a point on the transpyloric line, one inch to the left of the median plane, to the mid-point of a line drawn horizontally between the right anterior superior iliac spine and the median plane.

Subdivisions of the Peritoneal Cavity.—From the surgical point of view the peritoneal cavity may be arbitrarily divided into **four great subdivisions**: namely, a supracolic, a right infracolic, a left infracolic, and a pelvic. All these subdivisions communicate freely with one another behind the anterior abdominal wall, as well as on each side, along the gutter-like channels in the loins. It is along these gutters that pus readily makes its way from the upper part of the abdomen along the lumbar regions into the iliac regions, and thence into the pelvis; and, on the other hand, the pus may ascend from the pelvis along the same channels, especially when the patient is in the recumbent posture.

The highest (subphrenic) region of the **supracolic compartment** is further subdivided into a right and left portion by the falciform ligament.

The **omental bursa** may be looked upon as a diverticulum of the first-mentioned subdivision.

The subphrenic lymph plexus communicates, by means of lymph vessels which pierce the diaphragm, with the subpleural plexus on its superior surface; hence pus confined under tension in either of these spaces is liable to give rise to secondary infection of the corresponding pleural cavity. By adhesions of the transverse colon and greater omentum to the anterior abdominal wall, the supracolic subdivision of the peritoneal cavity may become more or less completely shut off from the rest of the abdomen. Suppuration in the right half of the phrenicocolic subdivision is generally secondary to leakage from an ulcer of the first part of the duodenum or to disease of the gall-bladder and bile-ducts; while the left half of the space is more usually infected from the stomach. The best method of draining the supracolic subdivision of the peritoneal cavity is to pass a tube through the **hepato-renal pouch** (Morrison). The entrance to this pouch lies lateral to the gall-bladder between the inferior margin of the liver above and the right flexure of the colon below. The bottom of the pouch is formed by the reflexion of the peritoneum from the superior part of the kidney on to the fascia transversalis covering the aponeurosis of origin of the transversus abdominis muscle below the tip of the twelfth rib. To drain it, a tube is introduced into it either from the wound in the anterior abdominal wall, or, still better, through a puncture opening made through the loin lateral to the kidney, in the angle between the twelfth rib and the lateral border of the sacro-spinalis muscle. Another drainage route is by a tube passed from the wound in the anterior abdominal wall into the omental bursa, through either the gastro-hepatic ligament or the great omentum.

The **right infra-colic subdivision** lies above and to the right of the mesentery of the small intestine. It is bounded, above, by the right and middle two-thirds of the transverse colon and the corresponding part of its mesentery, while laterally it is limited by the cæcum and ascending colon. At its right inferior angle are the ileo-cæcal junction and the vermiform process; at its right upper angle is the right flexure of the colon, while at its left upper angle is the inferior part of the duodenum, crossed by the superior mesenteric vessels. In rare instances this portion of the duodenum is so compressed between these vessels and the vertebral column that partial, or even complete, obstruction results. The condition has been named gastro-mesenteric ileus, but a more correct term would be duodeno-mesenteric ileus.

The organs related to this subdivision are, in addition to the parts of the large intestine already mentioned, coils of small intestine, the inferior third of the right kidney, the right ureter, the inferior half of the descending and the horizontal part of the inferior portions of the duodenum.

Suppuration in connexion with the organs in this area involves more especially the right lumbar region, and may extend upwards along the colon into the subdiaphragmatic region, or downwards into the pelvis minor. To drain this region a tube is introduced into the right lumbar region either through the anterior abdominal wall or through a stab-wound in the loin lateral to the ascending colon.

The **left infra-colic subdivision**, which lies below and to the left of the mesentery, narrows as it passes upwards and reaches to a higher level than the right infra-colic subdivision. Inferiorly, it is directly continuous at the superior aperture of the pelvis with the peritoneal cavity of the pelvis minor. Above, it is bounded by the left third of the transverse colon and its mesentery, and, still more posteriorly, by the inferior surface of the body of the pancreas; laterally it is bounded by the descending and iliac portions of the colon. At its right upper angle is the duodeno-jejunal flexure, lying immediately to the left of the vertebral column, in the angle between it and the inferior surface of the pancreas. At its left superior angle is the left flexure of the colon, while at its left inferior angle is the junction of iliac with pelvic colon. This subdivision of the peritoneal cavity, in addition to containing the majority of the coils of the small intestine, is related to the inferior third of the left kidney, the left ureter, the lower part of the abdominal aorta and vena cava, and the inferior mesenteric and common iliac vessels. Drainage of this subdivision may be established through the left loin, or by a tube introduced down to the bottom of the pelvis, namely, into the recto-vesical pouch in the male, and into or through the recto-vaginal pouch (pouch of Douglas) in the female.

On account of the oblique manner in which the mesentery proper is attached to the posterior abdominal wall, it follows that in order to examine the organs related to the right infra-colic subdivision of the abdomen, the coils of small intestine should be displaced downwards and to the left, while to investigate the left infra-colic subdivision they should be carried upwards and to the right.

ABDOMINAL VISCERA.

Liver.—The *anterior margin of the liver*, as it crosses the costal angle, can readily be determined by palpation and light percussion; it passes from the eighth left to the tip of the tenth right costal cartilage, and crosses the median plane at the level of the transpyloric line. In the *mid-clavicular line* it reaches down to a point a little below the most inferior part of the tenth right costal cartilage. Above the left costal margin the anterior margin passes upwards and to the left to join the left border of the liver at the fifth interspace in the mammary line. The *highest part of the liver*, which corresponds also to the highest part of the right arch of the diaphragm, reaches, during expiration, to the level of the fourth intercostal space in the mammary line. To the right of the median plane the superior surface of the liver is too far removed from the anterior wall of the chest, and overlapped by too thick a layer of lung substance, to be accurately determined by percussion. *Behind the sternum* the superior surface reaches to the level of the sixth chondrosternal junctions. To the left of the median plane the superior limit of the liver cannot be determined by percussion since it merges into the cardiac dulness. The base or **right lateral surface** extends from the level of the seventh to the level of the eleventh rib in the mid-axillary line and is separated by the diaphragm from the lower part of the right lung and pleura.

The **falciform ligament** of the liver lies, as a rule, a little to the right of the median plane.

By dividing the *round ligament*, which passes backwards and upwards within its free margin, the liver can be rotated backwards around its transverse axis so as to expose more of its inferior surface; this procedure is sometimes taken advantage of by the surgeon in cases in which there is unusual difficulty in reaching the cystic duct or the ductus choledochus. The ligament is sutured before the abdominal wall is closed.

The **anterior surface** of the liver may be reached through a median incision, extending downwards from the xiphoid process, or by an oblique incision, a finger's-breadth below and parallel to the right costal margin. To obtain free access to the **superior surface** the eighth and ninth costal cartilages must be resected; the seventh cartilage should, if possible, be avoided; otherwise the pleural cavity may be opened into. Division of the round and falciform ligaments allows of greater downward displacement of the liver. To reach the upper part of the **lateral surface** of the right lobe, portions of the seventh and eighth ribs should be resected in the mid-axillary line, and both the pleural and peritoneal cavities must be traversed.

Gall-Bladder.—The relation of the fundus of the **gall-bladder** to the surface of the body is subject to considerable variation. Normally it is situated behind the angle between the ninth costal cartilage and the lateral border of the right rectus; exceptionally, it is pendulous and suspended from the liver by a more or less distinct mesentery; or it may be elongated and drawn downwards by adhesion to the duodenum or colon. When displaced downwards it is liable to be mistaken for a movable kidney, but may be distinguished from that by the fact that although it may be pushed backwards into the lumbar region it returns at once to its habitual position, immediately behind the anterior abdominal wall, as soon as it ceases to be manipulated.

The **cystic duct** is enclosed in the right extremity of the superior border of the gastro-hepatic ligament. It is about an inch and a half in length, is sharply bent upon itself close to its origin at the neck of the gall-bladder. It joins the hepatic duct at a very acute angle. The passage of a probe along the *normal* duct is rendered difficult by the marked flexure at its commencement, as well as by the folded condition of its mucous membrane; hence also the frequency with which calculi become impacted at the neck of the gall-bladder.

In excising the gall-bladder, it is an advantage to divide and ligature the cystic artery and duct before proceeding to detach the organ from the inferior surface of the liver, and care must be taken not to injure the common duct or the portal vein.

The **bile-duct**, about three and a half inches in length, lies, in its *superior third*, close to the right free border of the gastro-hepatic ligament. When cutting into this, the most accessible part of the duct, it should be drawn forwards by the finger introduced behind it, through the epiploic foramen; the portal vein, which must be avoided, lies posterior and a little to the left of the duct. The *middle third* of the duct lies a little to the right of the commencement of the gastro-duodenal artery behind the superior part of the duodenum about a finger's-breadth from the pyloro-duodenal junction. The *inferior third* of the duct, which passes downwards and to the right, is intimately related to the pancreas; in about two out of three instances it is so embedded in the posterior aspect of its head that it cannot be freed by blunt dissection. Close to its termination the duct is joined by the main pancreatic duct of Wirsung, the two opening separately, but close together, at the bottom of a diverticulum, which pierces the wall of the duodenum obliquely, and opens at the summit of a small papilla situated at the inferior part of the medial wall of the descending part of the duodenum, about four inches from the pylorus. When a calculus becomes impacted in the ampulla there is retention of the pancreatic as well as of the biliary secretion. Frequently, however, the gland possesses an accessory pancreatic duct (duct of Santorini) which opens into the duodenum at a higher level than the main duct, with which it also communicates.

A calculus in the ampulla may be reached either by opening the duodenum from the front (trans-duodenal route), or by freeing the duodenum and gaining access to the duodenum from behind (retro-duodenal route). In the latter instance an incision is made, lateral to the right border of the descending part of the duodenum, through that portion of the peritoneum which passes upwards and to the right from the superior layer of the transverse mesocolon, over the superior part of the pars descendens of the duodenum on to the anterior surface of the right kidney. By blunt dissection, directed medially, behind the duodenum, that organ, along with the adjacent part of the head of the pancreas, can be separated from the kidney and vena cava, and folded over towards the left like a door on its hinges. In freeing the bile-duct from the posterior aspect of the head of the pancreas a vein of considerable size will be encountered; this vein, which returns the blood from the pancreatico-duodenal system of arteries, lies close to the bile-duct as it ascends behind the head of the pancreas to open into the commencement of the vena portæ. Of the lymph glands related to the bile passages it is to be remembered that one lies at the neck of the gall-bladder, another at the junction of the cystic and hepatic ducts, while a third lies close to the termination of the bile-duct. When these glands are enlarged and indurated, care must be taken not to mistake them for impacted gall-stones. On account of the very free anastomosis between the lymphatics of the gall-bladder, bile-ducts, and pancreas, infective inflammatory processes readily spread from one organ to the other.

Stomach.—The stomach lies almost entirely within the left half of the epigastric region and in the left hypochondriac region. The **cardiac orifice**, which lies 1 in. below and to the left of the œsophageal opening in the diaphragm, is about 4 in. from the surface, and corresponds, on the anterior surface of the body, to a point over the seventh left costal cartilage 1 in. from the median plane. The **pylorus**, which is generally partly overlapped by the anterior margin of the liver, lies in, or a little to the right of the median plane; when the stomach is *empty* it generally lies in the median plane, when *distended* it may reach two, or even three inches to the right of the median plane. Passing from the superior to the inferior border of the pylorus opposite its junction with the duodenum is the **anterior pyloric vein** (Mayo). This vein affords a useful visible guide to the position of the pylorus. Another guide is furnished by the ring-like thickening of the pyloric sphincter which projects into the commencement of the duodenum (like the cervix uteri into the vagina), and can be readily palpated through its thin wall. The pyloric portion of the stomach is practically bisected by a horizontal plane which passes through the abdomen at the level of a point midway between the jugular notch of the sternum and pubic symphysis (Addison); it lies, therefore, three to four inches below the infra-sternal notch, midway between it and the umbilicus, opposite the first lumbar vertebra. The highest part of the **fundus of the stomach** corresponds to the left vault of the diaphragm, and lies at the level of the fifth rib in the mammary line, a little above and behind the apex of the heart. The **greater curvature** crosses behind the left costal margin opposite the tip of the ninth costal cartilage, that is to say, where the transpyloric line intersects the left lateral line. The lowest part of the great curvature, situated generally in the median plane, extends down to, or a little above, the infracostal plane, about two inches above the umbilicus. The **lesser curvature** and the adjacent part of the anterior wall of the stomach are overlapped by the anterior margin of the liver.

Radiography of Stomach.—Radiograms of the stomach, taken after an "opaque meal," show that the form and position of the stomach in the living subject differ considerably from that which it presents in the cadaver.

In the cadaver, owing to loss of muscular tone, it presents itself as a more or less empty pear-shaped bag with collapsed and flaccid walls. The same applies to a large extent to the stomach as seen in the operating room, its normal tonicity being almost entirely held in abeyance by the anæsthetic.

In the living subject, the form and position of the stomach are found to vary not only according to the amount of food it contains, but also according to whether the patient occupies the erect or the recumbent posture. The most reliable, as well as the most useful, information regarding the form, the position, and the motor activity of the stomach is obtained by "screen" examinations and radiograms taken with the patient in the erect posture. When examined in this way, after partly filling the stomach with an "opaque meal," the organ is seen to possess a distinctly J-shaped form. The stem of the J, which is represented by the **body of the stomach**, lies immediately and entirely to the left of the vertebral column. The **fundus**, which is slightly more expanded than the body, reaches up to the left cupola of the diaphragm; it is represented in the skiagram as a light semilunar shadow, the horizontal inferior margin of which corresponds to the superior limit of the meal. This clear semilunar area is due to the rising up of the gaseous contents of the stomach to the highest part of the cavity. The **cardiac orifice** is seen to lie opposite the left side of the fibro-cartilage between the tenth and eleventh thoracic vertebræ. The shadow of the curved **pyloric portion of the stomach**, after crossing the left side of the vertebral column opposite the third and fourth lumbar vertebræ, ascends as the **pyloric canal** to join the duodenum at or a little to the right of the median plane, opposite the second (not infrequently the third) lumbar vertebra. The **pylorus** itself is represented by a light disc due to a hiatus in the continuity of the bismuth, caused by contraction of the pyloric sphincter. The lowest portion of the **greater curvature**, which generally lies at or a little to the left of the median plane, reaches, in the erect posture, down to the level of the middle or inferior border of the fourth lumbar vertebra, or, in other words, to the umbilicus and the highest part of the iliac crest.

As more food enters the stomach its capacity is increased by lateral expansion rather than by any elevation of its fundus or downward expansion of its greater curvature. The normal tonic action of the gastric muscle is able to hold up the meal against the action of gravity to the level of the cardiac orifice.

When, as not infrequently happens, the normal muscular tonicity of the stomach is lost, the bismuth meal is no longer held up against the action of gravity, but at once sinks to the most dependent part of the stomach, where it lies as in a flaccid sac, and gives rise to a crescentic shadow which may reach down almost, or even quite, to the level of the pubes.

In gastroptosis, and in general visceroptosis, the whole stomach may be displaced downwards without any great loss of its tonicity.

During a "screen" examination after an opaque meal, the peristaltic movements of the stomach can be seen to pass in distinct wave-like indentations from left to right along the greater curvature, and to increase in force as they approach the pylorus.

When the stomach is hypertrophied and dilated, as a result of pyloric obstruction, the peristaltic waves are more pronounced, and the bismuth shadow extends well over to the right of the median plane, owing to the dilated pyloric antrum and pyloric canal being carried over to the right, in front of the superior part of the duodenum. The stomach tends, therefore, to lose its somewhat J-shaped tubular form, and the axis of its body becomes more oblique. In the infant and young child the stomach is flask-shaped rather than fish-hook or J-shaped, and its axis is less vertical than in the adult. The elongated form of the adult stomach is acquired as a result of the erect posture. Occasionally the axis of the adult stomach inclines more towards the horizontal and gives rise to a röntgenogram shaped more like the horn of a steer (steer-horn stomach).

It must be remembered that the only really fixed part of the stomach is the region of the cardia, so that the form and position of the organ may be considerably influenced by the condition of the neighbouring organs. For example, it may be displaced downwards and to the left by enlargement of the liver, upwards by distension of the intestines, and to the right by distension of the left colic flexure.

Overlying the stomach is an important surface area known to clinicians as the **semilunar space of Traube.** This space, which yields a deeply tympanitic note on percussion, is bounded, above, by the inferior margin of the left lung; below, by the left costal margin; to the right, by the anterior margin of the left lobe of the liver; behind and to the left, by the anterior border and anterior basal angle of the spleen. The line of the costo-diaphragmatic pleural reflexion crosses the space about midway between its superior and inferior limits. The tympanitic area of the space is diminished superiorly by pleuritic effusion, towards the right by enlargement of the liver, and towards the left by enlargement of the spleen.

Perforation of an ulcer on the *anterior wall* of the stomach leads to extravasation into the greater sac of the peritoneum, while if the perforated ulcer is on the *posterior wall*, extravasation takes place into the omental bursa. The close relation of the splenic artery and its branches to the posterior wall of the stomach explains the severe hæmorrhage which is sometimes caused by a posterior gastric ulcer. The surgeon may reach the posterior wall of the stomach through the gastro-colic ligament, or, after throwing upwards the greater omentum and transverse colon, by traversing the transverse mesocolon; by the former route the posterior wall of the stomach is reached through the anterior wall of the omental bursa, in the latter through its posterior wall.

When a **partial resection of the stomach**, for malignant disease, is performed, the bleeding is controlled by ligaturing the main vessels at an early stage of the operation. These are the right and left gastrics at the lesser curvature, the gastro-duodenal behind the first part of the duodenum, and the right and left gastro-epiploics at the greater curvature. The left gastric should be ligatured as near the cardia as possible, so that the whole chain of lymph glands along the lesser curvature may be removed. Care is taken to remove also all the glands which lie behind the first part of the duodenum in relation to the gastro-duodenal artery and head of the pancreas, as well as those along the right half of the greater curvature in relation to the right gastro-epiploic artery. If the disease has spread to the retro-peritoneal lymph glands, surrounding the cœliac artery, above the pancreas, the chances of a permanent recovery are very remote.

In the classical "no-loop" **gastro-enterostomy operation** a longitudinal opening in the commencement of the jejunum is anastomosed by suturing it to an opening in the posterior wall of the stomach, near the greater curvature. The jejunum is applied to the stomach in such a way that it maintains its normal direction, namely, obliquely upwards and to the left. To bring the surfaces of the two organs in contact, surgeons are in the habit of protruding the posterior wall of the stomach through an opening made in the transverse mesocolon, on the proximal side of the arch formed by the middle and left colic arteries. A better plan, however, is to make an opening also into the omental bursa through the gastro-colic ligament a little below the gastro-epiploic vessels, and then to bring the jejunum into contact with the posterior wall of the stomach by pushing it (the jejunum) upwards through the opening in the transverse mesocolon. By this plan the posterior wall of the stomach along with the jejunum can be protruded through an opening in the gastro-colic ligament; they can then easily be delivered out of the abdominal cavity, and another advantage is that the transverse colon can be replaced into the abdominal cavity while the anastomosis is being made.

When the posterior wall of the stomach and transverse colon are held down by adhesions, a long loop of jejunum is brought up in front of the greater omentum and transverse colon and anastomosed to the anterior wall of the stomach.

The Duodenum.—The duodenum is the widest, thickest, and most fixed part of the small intestine. For descriptive purposes it is divided by anatomists into three parts. From the surgical standpoint it may with advantage be subdivided into a supra-colic and an infra-colic portion, the former, comprising the superior and the upper half of the descending part, being situated above the attachment of the transverse mesocolon; while the latter, comprising the lower half of the descending part along with both subdivisions of the third part, is situated below this attachment. To expose the supra-colic portion the greater omentum and the transverse colon must be pulled downwards, while to expose the infra-colic portion they are thrown upwards along with the transverse mesocolon.

The first portion proper (**pars superior**) lies in the right part of the epigastric region, medial to the gall-bladder, where it is overlapped by the quadrate lobe of the liver. As regards its **blood-supply**, it occupies the frontier zone between the cœliac and superior mesenteric vascular areas, and the vessels which supply it vary considerably in their size and mode of origin.

This peculiarity of its blood-supply may partly account for the relative frequency with which this portion of the intestine is found to be the seat of ulceration. The first inch or so of the duodenum possesses some degree of mobility, being surrounded by the same two layers of peritoneum which invest the stomach. Beyond this it is in direct contact posteriorly and inferiorly with the pancreas, while descending behind it are the common bile-duct and the gastro-duodenal artery. The relations must be borne in mind in performing the operation of pylorectomy. When an ulcer of the superior part perforates, extravasation takes place, in the first instance, into the supra-colic compartment of the peritoneum, thence into its hepato-renal pouch, and subsequently down along the ascending colon into the right iliac fossa,—hence the possibility of mistaking the condition for an acute appendicitis. Perforation of the ulcer into the peritoneal cavity is often prevented by the duodenum becoming adherent especially to the pancreas, to the gall-bladder, or to the omentum.

If the finger is passed upwards, backwards, and to the left, immediately above the first part of the duodenum and behind the right free border of the lesser omentum, it will pass through the foramen epiploicum into the omental bursa of the peritoneum.

The second portion of the duodenum (**pars descendens**) descends in the epigastric and umbilical regions a little medial to the right lateral plane. The attachment of the transverse mesocolon crosses it about its middle, while posteriorly it lies in front of the hilum and medial border of the right kidney, from which it is separated by loose areolar tissue. The procedure necessary to mobilise this portion of the duodenum has been referred to already.

The *horizontal portion* of the **inferior part** of the duodenum occupies the superior part of the umbilical region, and crosses the median plane about one inch above a line joining the highest part of the iliac crests; behind its commencement is the superior part of the right ureter.

The *ascending portion* of the **inferior part** of the duodenum crosses the infracostal plane, and ascends upon the left side of the vertebral column opposite the second and third lumbar vertebra.

The röntgen shadow of the first portion of the duodenum usually takes the form of a more or less vertical truncated cone (" duodenal cap " or " bulb ") with its base directed towards the pyloric ring. Owing to the fact that the opaque meal is held up for a short time in the bulb, the shadow is denser than that caused by the other divisions of the duodenum which are rapidly traversed by the meal. And as the first part of the duodenum contains no valvulæ conniventes the outline of the bulb is smooth and nearly symmetrical. In duodenal ulcer the outline of the bulb is generally distorted, due partly to the ulcer itself and partly to the spasm which it sets up.

The **duodeno-jejunal flexure**, which lies in the transpyloric plane one inch to the left of the median plane, is the landmark which the surgeon makes for when he wishes to identify the commencement of the jejunum (Fig. 925, p. 1195). To find the flexure the greater omentum and transverse colon should be thrown upwards and the finger passed along the inferior layer of the transverse mesocolon to the left side of the vertebral column. The flexure lies in the angle or recess formed by the left side of the second lumbar vertebra and the inferior surface of the body of the pancreas. With the finger in this recess the commencement of the jejunum may be hooked forward a little to the left of the superior mesenteric vessels at the root of the mesentery. In connexion with the duodeno-jejunal junction is the **inferior duodenal fossa**, formed by a fold of peritoneum which stretches from the left side of the fourth or ascending part of the duodenum upwards to become attached to the peritoneum of the posterior abdominal wall close to the medial border of the left kidney. The free edge of the fold and the mouth of the fossa look upwards. This is one of the situations at which an internal hernia sometimes develops, the sac, as it enlarges, extending further and further into the extra-peritoneal tissue on the posterior abdominal wall. Should strangulation occur, the inferior edge of the orifice must be divided in a downward direction, in order to avoid the inferior mesenteric vein which curves round the anterior and superior aspects of the orifice (Treves).

Jejunum and Ileum.—To expose the coils of the jejunum and ileum completely, the greater omentum, along with the transverse colon and the greater curvature of the stomach, must be turned upwards. On account of the oblique attachment of the mesentery, the greater number of the coils lie in the left infra-colic peritoneal compartment, where they extend upwards to the left of the vertebral column as far as the attachment of the transverse mesocolon and the inferior surface of the pancreas; here they lie in front of the inferior pole of the left kidney, in the angle of the left colic flexure.

The only certain means which the surgeon has of distinguishing the superior from the inferior coils of small intestine is by their relation to the duodeno-jejunal flexure and the ileo-cæcal junction. Occasionally the plicæ circulares and the aggregated lymph nodules can be seen from the peritoneal aspect and the jejunum and ileum thereby respectively identified. The *terminal portion of the ileum,* which is attached by the inferior end of the mesentery to the superior part of the right wall of the pelvis major, crosses the superior aperture of the pelvis minor, and ascends along the medial edge of the cæcum before opening into it. The terminal loop of the ileum may be hooked up by passing the finger along the medial side of the cæcum downwards over the medial border of the psoas major and the external iliac vessels into the pelvis minor.

To bring out a loop of the upper jejunum in the operation of jejunostomy the abdomen is opened through the left rectus muscle at, or a little above, the level of the umbilicus. The duodeno-jejunal flexure is then identified and a catheter is introduced into the jejunum, and the bowel itself is then sutured to the edges of the opening in the divided peritoneum.

Meckel's diverticulum, which is due to persistent patency of the proximal portion of the vitelline duct, is situated usually from two to three feet above the valve of the colon; its average length is two inches. Springing from the anti-mesenteric border of the ileum, its termination is usually free, but it may be adherent either to the anterior abdominal wall, to the mesentery, or, more rarely, to one of the adjacent viscera. When its termination is fixed it may give rise to strangulation of the intestine.

Cæcum.—The cæcum occupies the right iliac region and extends from the anterior superior spine of the ilium to the superior aperture of the pelvis minor. **When empty**, it is generally more or less completely overlapped by small intestine, and frequently also by the greater omentum. **When partly distended**, the cæcum comes in contact with the anterior abdominal wall immediately above the lateral half of the inguinal ligament. **In the normal condition** it is completely surrounded by peritoneum, and can, therefore, along with the vermiform process, be readily delivered out of the abdomen. In chronic constipation, associated with intestinal atony, the cæcum is thin-walled, dilated, abnormally movable, and often prolapses into the pelvis.

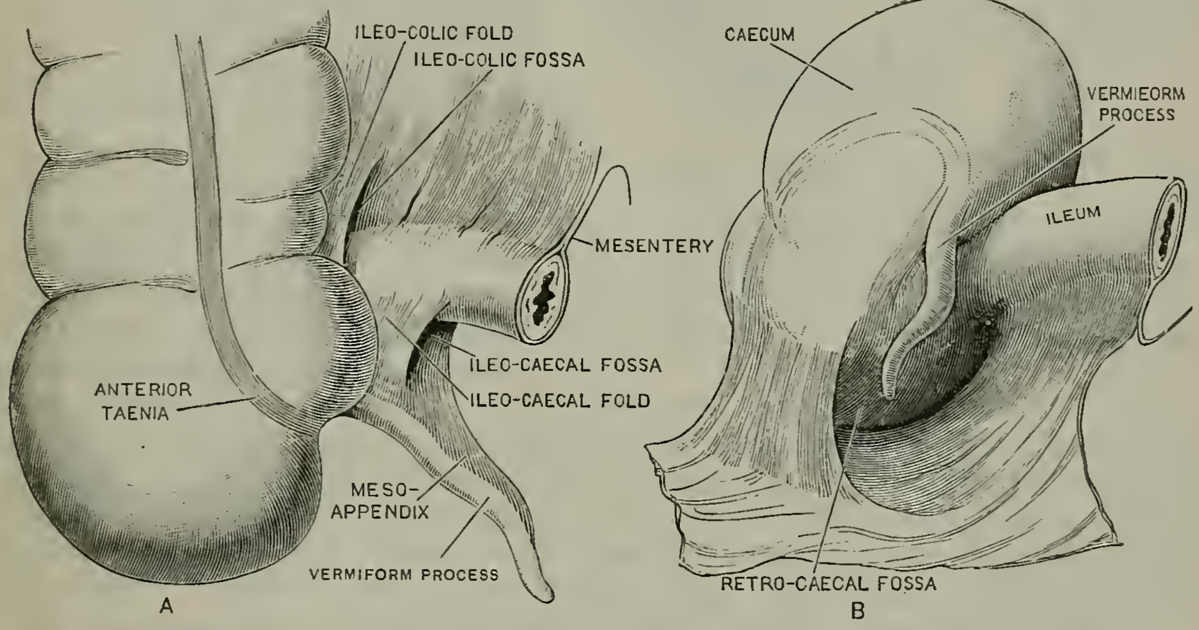

Fig. 1085.—The Cæcal Folds and Fossæ.

In A, the cæcum is viewed from the front; the mesentery of the vermiform process is distinct, and is attached above to the inferior surface of the portion of the mesentery going to the end of the ileum. In B, the cæcum is turned upwards to show a retro-cæcal fossa, which lies behind it, and the beginning of the ascending colon. (From Birmingham.)

The position of the ileo-cæcal valve corresponds, on the surface of the body, to the medial angle between the intertubercular and right lateral lines, while the orifice of the vermiform process is one inch lower. It is to be noted that the lower end of the ileum protrudes somewhat into the cæcum, and that its circular muscular fibres are prolonged into the flaps of the colic valve. Both of these anatomical arrangements favour the occurrence of intussusception. In infants, other predisposing causes are: (1) the relatively rapid enlargement of the lumen of the large intestine as compared with the small; (2) the greater mobility of the cæcum; and (3) the frequent presence of a mesentery to the ascending colon.

Vermiform Process.—The vermiform process (O.T. vermiform appendix), which springs from the postero-medial aspect of the cæcum, one inch below the ileo-cæcal junction, is provided with a well-developed "meso-enteriole" derived from the posterior aspect of the lowest part of the mesentery of the ileum. It is this portion of the posterior layer of the mesentery which sometimes develops a band-like thickening, which, by dragging upon the inferior end of the ileum, produces the kink to which attention has been directed by Arbuthnot Lane. The artery of the vermiform process is the only vessel which supplies the process; it occupies the free border of the meso-enteriole and gives off several branches which pass between its two layers to reach the organ. In amputating the vermiform process the artery is ligatured on the proximal side of its first branch in order to control the blood-supply to the stump of the process. The fact that the vermiform process is supplied by a single artery predisposes it to gangrene should the vessel become thrombosed, or should the circulation in it be interfered with by kinking as a result of adhesions.

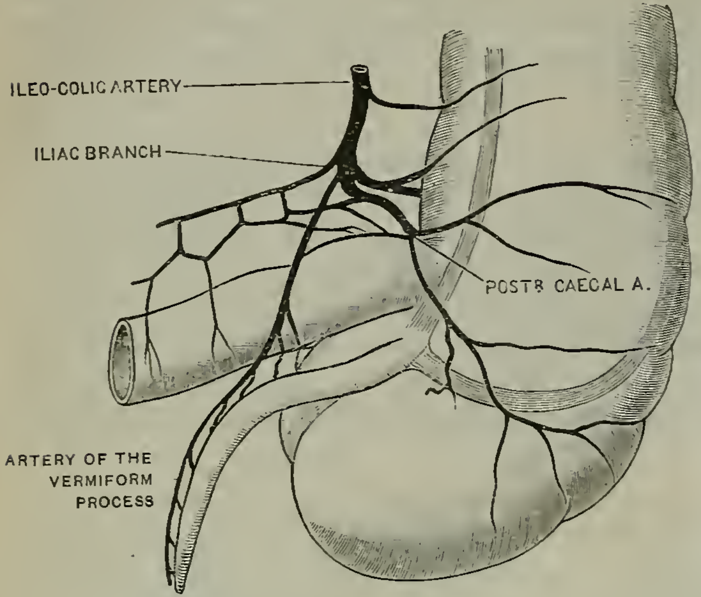

Fig. 1086.—The Blood-supply of the Cæcum and Vermiform Process.

The illustration gives a view of the cæcum from behind. The artery of the vermiform process, and the three tæniæ coli springing from the base of the process, should be specially noted. (Modified by Birmingham from Jonnesco.)

The vermiform process will generally be found to pass either upwards and medially, behind the lower end of the ileum, or downwards and medially, so as to overhang the external iliac vessels at the superior aperture of the pelvis minor; less frequently it ascends in the pouch behind the cæcum and commencement of the ascending colon. When, as not infrequently happens, the retro-cæcal fossa is prolonged upwards to form a pouch behind the colon, the vermiform process almost invariably ascends into it, and should it be diseased, it may give rise to a retro-cæcal abscess. The abscess may perforate the posterior wall of the cæcum, or it may ulcerate through the posterior peritoneum; in the latter case the suppuration may spread upwards, in the loose fatty sub-peritoneal tissue behind the colon, into the lumbar and perinephric regions; and it may reach even the under surface of the diaphragm and form a subphrenic abscess. When, in the course of its development, the cæcum has failed to complete its descent, the vermiform process may lie in the lumbar region in relation to the inferior pole of the kidney. When it dips downwards into the pelvis minor it may become adherent to the pelvic colon, the rectum, or the bladder, and in the female to the uterine tube or the ovary.

To find the vermiform process, the best plan is simply to pull the cæcum out of the wound, and if the parts are normal the process will be delivered along with it; if, on the other hand, the cæcum and vermiform process are tacked down by adhesions, the vermiform process is best discovered by following the anterior tænia coli to the root of the process.

Ascending Colon.—The ascending colon, after crossing the iliac crest, lies deeply in the right lumbar region upon the fascia covering the quadratus lumborum and the adjacent aponeurotic origin of the transversus abdominis. Between the bowel and the fascia is a quantity of loose cellular tissue and fat, which may be the seat of a large abscess, secondary, (1) more especially, to disease of the colon itself, (2) to disease of a retro-colic vermiform process, or (3) to disease of the right kidney. This cellular tissue is directly continuous above with a thin layer lining the inferior surface of the diaphragm; hence the suppurative process may extend upwards, giving rise to one form of subphrenic abscess. In some cases the ascending colon is completely surrounded by peritoneum, and it may even be provided with a distinct mesentery. The latter condition is almost invariably present in infants suffering from extensive ileo-cæcal intussusception. After the invagination has been reduced the mesentery proper is seen to be continuous, through the ascending mesocolon, with the mesentery of the transverse colon.

In order to resect the cæcum and ascending colon the surgeon mobilises it by dividing the peritoneum along its line of reflexion from the lateral aspect of the colon on to the abdominal wall. The colon, along with the posterior peritoneum medial to it, is then stripped, from the lateral side towards the median plane, off the quadratus lumborum, the psoas, and the inferior pole of the right kidney. While this is being done, the branches of the ileo-colic and right colic vessels which pass laterally to supply the gut are secured, and the lymph vessels and associated lymph glands are removed along with the bowel. As the peritoneum is stripped off, care must be taken not to injure the important structures which lie behind it, namely, the duodenum, the ureter, and the testicular or ovarian vessels.

The **right colic flexure** reaches upwards beneath the tenth costal cartilage into the most inferior part of the right hypochondrium, where it lies immediately to the right of the gall-bladder, between the liver and the inferior half of the anterior surface of the kidney. Posteriorly, it is separated from the anterior surface of the right kidney by a quantity of loose cellular tissue; hence by dividing the peritoneum to the right side of the flexure it can readily be mobilised and separated from the kidney.

Transverse Colon.—The transverse colon crosses the lower part of the umbilical region immediately below the greater curvature of the stomach. In cases of chronic constipation it may form a U-shaped or V-shaped loop, extending down to the level of the pubes. When this is the case the natural kinking at the right and left colic flexures becomes more acute, and tends, therefore, to aggravate the constipation. In such cases the right and left portions of the transverse colon often lie parallel and close to the ascending and descending colon, respectively, like the barrels of a gun.

The transverse colon receives its blood-supply from the arch formed by the middle and left colic arteries. The arch lies in the posterior wall of the bursa omentalis between the two layers of the transverse mesocolon.

In resecting portions of the stomach for malignant disease, the surgeon removes also the glands which lie between the two layers of the gastro-colic ligament in relation to the right gastro-epiploic vessels. At this step of the operation care must be taken not to endanger the blood-supply of the transverse colon by injuring the middle colic artery.

The **left colic flexure** is more acute and more fixed than the right flexure; and it is situated at a higher level as well as more deeply. A tumour originating in this portion of intestine lies generally under cover of the left costal margin, and is therefore difficult to palpate.

To expose the left colic flexure, the omentum along with the transverse colon and the body of the stomach is turned upwards. To mobilise it for the purpose of resection the surgeon must divide (1) the phrenico-colic ligament, which attaches it to the diaphragm opposite the eleventh rib; (2) the left border of the greater omentum, which attaches it to the stomach; and (3) the left portion of the transverse mesocolon, which attaches it to the left extremity of the pancreas.

Descending Colon.—The descending colon, like the ascending, is deeply placed in the lumbar region and is related to the inferior half of the lateral border of the left kidney. It is less frequently provided with a mesentery than is the ascending colon.

Iliac Colon.—The iliac colon commences at the junction of the posterior and middle thirds of the iliac crest, and ends at the superior aperture of the pelvis minor by joining the pelvic colon. It possesses no mesentery and is connected to the fascia covering the iliacus and psoas major muscles by loose areolar tissue. Towards its termination it turns medially immediately above and parallel to the inguinal ligament, and at its junction with the pelvic colon it lies in front of the external iliac artery. Although, as a rule, it is entirely overlapped by coils of small intestine, it can frequently be felt by firm palpation at the lateral part of the left iliac fossa, because its muscular wall is comparatively thick and generally contracted.

Pelvic Colon.—The pelvic colon, in consequence of possessing a well-developed mesentery, forms a freely movable loop which, though usually confined to the pelvis minor, may, when distended, rise well up into the abdomen. It is this section of the large intestine which is opened for the purpose of making an artificial anus in malignant disease of the rectum.

The pelvic colon varies considerably in length, the average being sixteen or seventeen inches. It is relatively longer and of greater calibre in the child than in the adult. It is the part of the large intestine especially involved in the condition known as **megalocolon** or Hirschsprung's disease—a congenital abnormality in which the large intestine is greatly dilated and hypertrophied.

When the pelvic colon is thrown upwards and to the right so as to spread out its mesentery, the latter is seen to be attached in an inverted V-shaped manner to the posterior wall of the pelvis. At the apex of the V is a small peritoneal pouch, the **inter-sigmoid fossa**, situated just in front of the ureter as it crosses the termination of the common iliac artery to enter the pelvis minor. This fossa is one of the situations at which an internal retro-peritoneal hernia may originate. The mouth of the fossa looks downwards and to the left, while above and to its right is the sigmoid artery. The fossa affords a guide to the commencement of the pelvic portion of the left ureter. On account of the V-shaped attachment of this mesentery it is convenient to speak of the pelvic colon as possessing an ascending or proximal and a descending or distal limb. At the junction of the proximal limb with the termination of the iliac colon is a more or less well-marked flexure (the "last kink" of Arbuthnot Lane). It is to the proximal limb of the pelvic colon that the divided inferior end of the ileum is anastomosed in the short-circuiting operation of **ileo-sigmoidostomy**.

In the author's operation of transplanting the ureters into the large intestine for incontinence of urine, the result of epispadias in the female, and of ectopia vesicæ in either sex, the left ureter is implanted into the ascending limb of the pelvic colon and the right ureter into its descending limb.

By dividing the attachment of the mesentery of the pelvic colon in the operation of excision of the rectum, the pelvic colon may be mobilised sufficiently to allow of its being brought down and sutured to the skin in the sacral region or even to the anal region. Further, the mobility of the pelvic colon is such that after resection of the descending and iliac colon and mobilisation of the left colic flexure, the divided ends of the bowel can be sutured together without undue traction.

After operations on the female genital organs by the abdominal route—for example, after abdominal hysterectomy—the surgeon makes use of the pelvic colon and its mesentery by spreading them out over the pelvis, so as to roof it in, and so prevent any of the coils of small intestine from becoming adherent in the pelvis.

Kidneys.—The kidneys lie behind the peritoneum, and extend higher up than is often supposed, and laterally they do not extend so far away from the vertebral column as is almost invariably depicted; hence it is that, unless enlarged, the kidneys can seldom be felt through the abdominal wall. The right kidney as a rule lies a little lower than the left, as well as a little further away from the median plane. The hilum of the right kidney lies 2 in. from the median plane; that of the left 1½ in. from the median plane. For practical purposes the **hilum** of the kidney may be regarded as opposite a point on the anterior abdominal wall a finger's-breadth medial to the tip of the ninth costal cartilage; and a line joining the two hila crosses the vertebral column opposite the fibro-cartilage between the first and second lumbar vertebræ, that is to say, a little below the transpyloric line. The *highest point* of the kidney is situated two inches from the median plane, on a level with a line crossing the abdomen midway between the xiphisternal and transpyloric planes. The *lowest point* of the kidney reaches down to, or a little below, the infra-costal plane.

The student should make himself familiar with the feel of the parts in relation to the kidneys, as far as they can be made out by introducing the hand through a median abdominal incision.

The superior half of the anterior surface of the **right kidney** is felt, at the bottom of the hepato-renal peritoneal pouch, by passing the hand deeply into the right hypochondrium, between the anterior margin of the liver and the right flexure of the colon. The inferior half is palpated by passing the hand deeply into the highest part of the right infra-colic peritoneal compartment; its free peritoneal surface lies in the angle of the right flexure of the colon. The second portion of the duodenum overlaps both the supra- and infra-colic portions of the medial border of the right kidney. When the right kidney is excised by the abdominal route, the peritoneum is divided lateral to the ascending colon and right colic flexure, and these structures, along with the descending part of the duodenum, are stripped off the organ in a medial direction, until the hilum and the renal vessels are reached.

The **left kidney** is crossed transversely, about its middle, by the body of the

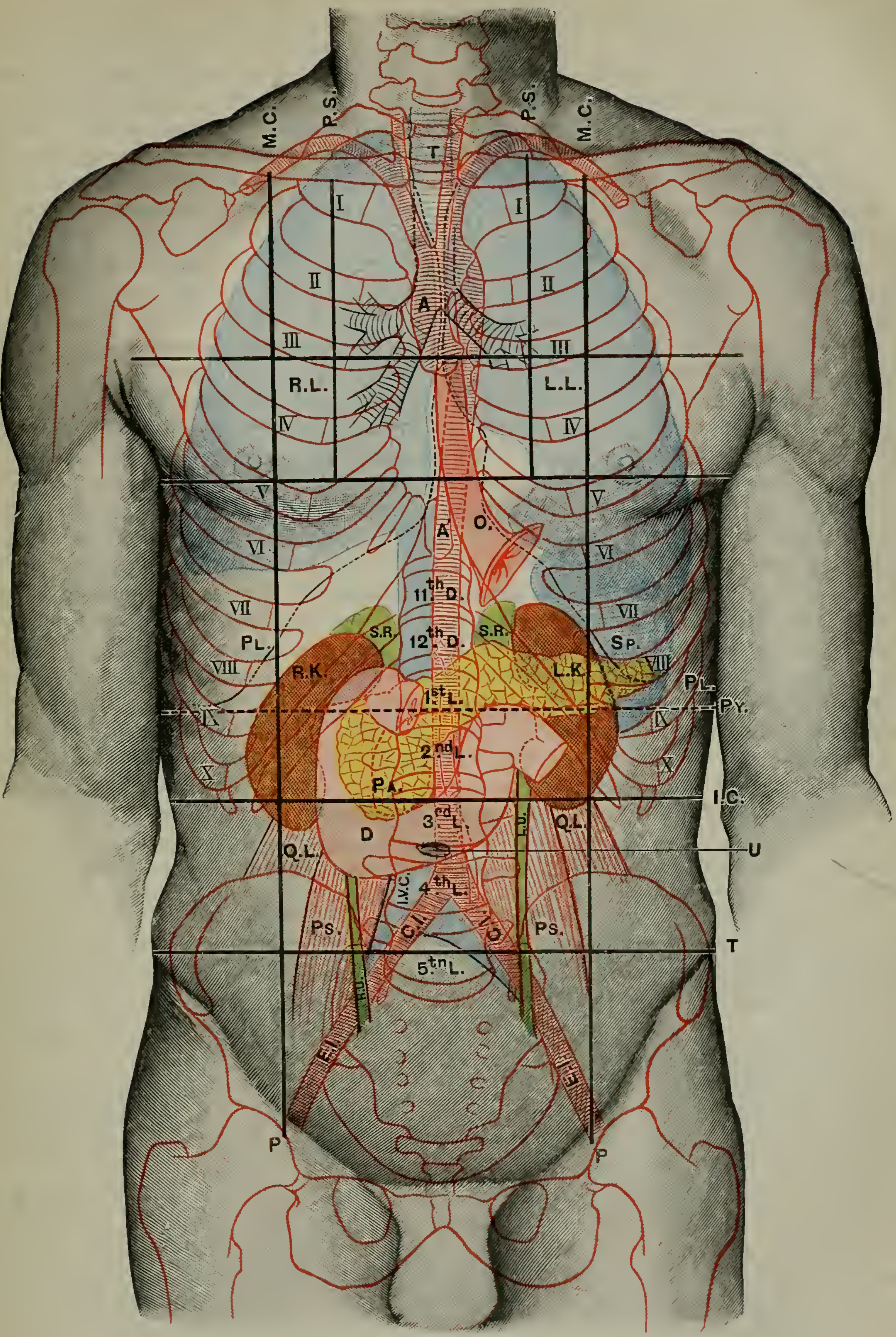

FIG. 1087.—ANTERIOR ASPECT OF TRUNK, SHOWING SURFACE TOPOGRAPHY OF VISCERA.

M.C.	Mid-clavicular line.	L.L.	Left lung.	Q.L.	Quadratus lumborum.
P.S.	Para-sternal line.	Pl.	Pleura.	Ps.	Psoas major.
P.	Inguinal vertical line.	O.	Œsophagus.	R.U.	Right ureter.
I.C.	Infra-costal line.	R.K.	Right kidney.	L.U.	Left ureter.
T.	Inter-tubercular line.	L.K.	Left kidney.	C.I.	Common iliac artery.
Py.	Transpyloric line.	Sp.	Spleen.	E.I.	External iliac artery.
T.	Trachea.	S.R.	Suprarenal gland.	I.V.C.	Inferior vena cava.
A.	Aorta.	Pa.	Pancreas.	U.	Umbilicus.
R.L.	Right lung.	D.	Duodenum.		

pancreas and the splenic vessels. To palpate the supra-pancreatic portion, the hand is passed through the left portion of the gastro-colic ligament, upwards behind the stomach, into the superior part of the omental bursa. The spleen will be felt to overlap the lateral border of the kidney. To palpate the infra-pancreatic portion of the organ, which is covered by the peritoneum continued downwards from the attachment of the inferior layer of the transverse mesocolon, the hand is passed deeply into the upper part of the left infra-colic peritoneal compartment as far as the angle of the left flexure of the colon. This area of the kidney is overlapped by coils of small intestine, while passing transversely laterally in front of it are the left colic artery and its branches. When the left kidney is excised by the transperitoneal route, the left colic flexure and the descending colon are mobilised by dividing the peritoneum lateral to them so as not to injure the left colic artery.

In addition to their true fibrous capsules, the kidneys are surrounded by and enveloped in a well-marked fatty capsule. Outside this perinephric fat is a more or less well-defined fibrous envelope, known as the **renal fascia** or fascia of Gerota, which forms, as it were, a sheath to the organ. Hence, just as in the case of the prostate and thyreoid glands, the kidney possesses, in addition to its true capsule, a sheath derived from the neighbouring fasciæ. The anterior and posterior layers of the sheath remain distinct at the medial border of the kidney and are prolonged, the one in front of, and the other behind the renal vessels. The two layers remain separate also for some distance below the inferior pole of the kidney, and it is into this downward extension of the fascial compartment that the kidney descends in the condition known as **movable kidney**. Above and laterally the sheath joins the fascial lining of the diaphragm and transversus muscles respectively. Outside the perinephric fascia is a second layer of fat sometimes spoken of as the **paranephric fat**.

When the inferior pole of the kidney receives a special blood-supply, either directly from the aorta, or from the renal artery, the abnormal vessel may, by passing either in front or behind the superior part of the ureter, cause the latter to be so kinked over the vessel as to cause a secondary hydronephrosis.

Brodel has shown that the branches of the renal artery are distributed to the cortex of the kidney in an anterior and a posterior group; hence, in splitting the kidney substance to reach the renal pelvis, the incision should be made along the frontier line between the two vascular areas, viz., about half an inch behind and parallel to the lateral border of the kidney.

The **ureters**, 10 in. (25 cm.) in length, lie behind the peritoneum covering the psoas major muscles; they descend almost vertically in the umbilical region 1½ in. from the median plane. At the level of the intertubercular plane they lie in front of the termination of the common iliac arteries, and then pass down into the pelvis minor, in front of the hypogastric arteries.

The diameter of the ureter is not uniform. Its intra-vesical portion has the smallest lumen, and it is here that calculi are most likely to be impacted. A second narrowing occurs at or a little below the pelvi-ureteral junction, and a third where it crosses the brim of the pelvic minor.

The ureter possesses a well-developed muscular wall so that it is well adapted for suturing, while its rich blood-supply favours rapid healing. Its abdominal portion is supplied by the renal and internal spermatic arteries; its pelvic portion by the superior vesical, the inferior vesical, and the middle hæmorrhoidal arteries. By their anastomoses they form a continuous and somewhat tortuous chain which is generally visible beneath the peritoneum along the whole course of the tube.

The outline of the pelvis of the kidney and the relations of it and the ureter to the skeleton have assumed an additional importance now that they can be demonstrated graphically by the X-rays after injecting them with *a colloidal solution of silver*. The shape of the normal pelvis and the arrangement of its primary and secondary calyces vary considerably. The shadow is situated opposite the tips of the transverse processes of the first and second lumbar vertebræ, the upper calyces generally overlapping a portion of the twelfth rib. Normally the pelvis can contain about 7 c.c. of fluid without discomfort to the patient. The wall of the pelvis, like that of the ureter, is very elastic, so that it is capable of great distension in cases of gradually increasing urinary obstruction; and for the same reason incisions into either of these structures heal rapidly because the edges of the wound fall into apposition. To avoid branches of the renal vessels incisions into the pelvis should be made horizontally through its posterior wall.

The radiographic shadow produced by an opaque catheter in the ureter crosses the tips of the transverse processes of the four lower lumbar vertebræ and then descends opposite the sacro-iliac joint to its inferior extremity; from here the shadow curves laterally almost parallel to that of the pelvic basin and terminates at the vesical orifice, which is usually opposite a point a little above and internal to the pubic tubercle. Laterally the shadow reaches almost to that caused by the ischial spine. The ureter is occasionally double throughout, or it may be bifid above or below. When the kidney is prolapsed, the abdominal portion of the ureter is more or less tortuous.

In reading skiagrams with a view of ascertaining the presence or absence of calculi in the abdominal portion of the urinary tract, Hurry Fenwick makes use of a line projected vertically upwards from the highest part, *i.e.* the centre, of the iliac crest to the twelfth rib. As this line corresponds to the lateral limit of the kidney, it follows that a "calculus shadow" close to the medial side of this line will generally occupy one of the calyces and be situated, therefore, towards the cortex, while if the shadow be situated close to the tips of the transverse processes of the vertebræ, the calculus will usually be found either in the pelvis of the kidney or in the abdominal portion of the ureter.

Pancreas.—The *head of the pancreas* occupies the curve of the duodenum, and lies in the lowest part of the right half of the epigastric region, on a level with the second lumbar vertebra. The *neck*, which crosses the median plane opposite the fibro-cartilage between the first and second lumbar vertebræ, lies in the transpyloric plane, while the body lies immediately above that plane. The *tail* lies in the left hypochondriac region. The relations of the pancreas to the transverse mesocolon and to the neighbouring viscera have already been sufficiently referred to.

After opening the abdomen in the median line, the pancreas is best exposed by passing through the gastro-colic ligament; access to the organ through either the hepato-gastric ligament or the transverse mesocolon is more limited and therefore less satisfactory.

A pancreatic cyst gives rise to a tumefaction of the abdomen either in the epigastric or in the umbilical region, depending on whether it pushes the hepato-gastric ligament before it and develops between the liver and stomach, or whether it extends forwards below the stomach. In severe contusions of the abdomen the pancreas may be ruptured against the vertebral column.

Vessels of the Abdomen.—The commencement of the **abdominal aorta** and the **cœliac artery** are situated two fingers'-breadth above the transpyloric plane. The **superior mesenteric** artery arises a finger's-breadth above the transpyloric plane, the **renal arteries** a finger's breadth below it. The **inferior mesenteric artery** arises midway between the transpyloric and the intertubercular plane—that is to say, about 1 in. above the level of the umbilicus. The **abdominal aorta** bifurcates in, or a little to the left of, the median plane, on a level with the highest part of the iliac crest, and about $\frac{3}{4}$ in. below the level of the umbilicus.

The **inferior vena cava** lies immediately to the right of the aorta; its most important surgical relation is the right ureter, which lies close to its right side.

The **common** and **external iliac arteries** may be mapped out by drawing a line, curved slightly laterally, from a point opposite the bifurcation of the aorta to a point midway between the superior anterior iliac spine and the pubic symphysis: the superior third of this line corresponds to the common iliac, the inferior two-thirds to the external iliac.

In ligaturing the common iliac artery, or the superior part of the external iliac, the close relation of the ureter and the ovarian vessels must be borne in mind, while in ligaturing the inferior part of the external iliac it is the internal testicular vessels and the ductus deferens which have to be avoided.

The **common iliac veins** lie mainly to the right of the corresponding arteries, the left vein, however, crossing behind the right artery to join its fellow to form the inferior vena cava.

The fact that the left common iliac vein passes *behind* the right common iliac artery to reach the vena cava would seem to afford a sufficient explanation for the much greater frequency with which thrombosis of the femoral vein is met with on the left side as compared with the right side.

The great vessels upon the posterior abdominal wall, along with the adjacent lymph vessels and glands, lie in the tela subserosa, and therefore within the general fascial envelope of the abdomen. Abscesses originating from the retroperitoneal lymph glands are, therefore, like perinephric abscesses, extra-peritoneal but intra-fascial; abscesses of vertebral origin, whether lumbar, iliac, or psoas, are, on the other hand, extra-fascial. Abscesses connected with the vermiform process are primarily intra-peritoneal; occasionally they ulcerate through the parietal peritoneum and burrow in the extra-peritoneal fat.

THE MALE PERINEUM.

The male perineum is a heart-shaped space, the osseous boundaries of which are the same as those which form the inferior aperture of the pelvis. A line drawn transversely across the perineum between the anterior part of the tuberosities of the ischium crosses the median plane, immediately in front of the anus, and divides the space into an anterior or urogenital triangle and a posterior or rectal triangle.

The **urogenital triangle** is subdivided into a superficial and a deep compartment by the inferior fascia of the urogenital diaphragm; in the **superficial compartment** is the root of the penis, which gives rise to a longitudinal fulness upon the surface. Anteriorly, the surface of the urogenital triangle is continued on to the scrotum, whilst laterally a distinct groove separates it from the medial surface of the thighs. The **central point of the perineum** (common tendon of the perineal muscles) is continuous with the centre of the base of the fasciæ of the urogenital diaphragm, and lies a finger's-breadth in front of the anus. Immediately in front of it, and about 1 in. from the centre of the anus, is the posterior edge of the **bulb** of the **corpus cavernosum urethræ.** The *superficial compartment* of the urogenital triangle is bounded below by the **perineal fascia of Colles**, which is attached posteriorly to the base of the fascia of the urogenital diaphragm, and laterally, on each side, to the margins of the pubic arch. Anteriorly, the fascia of Colles passes on to the scrotum, the penis, and spermatic funiculi, to become continuous with the **fascia of Scarpa** upon the anterior surface of the abdomen.

When the urethra is ruptured below the inferior fascia of the urogenital diaphragm, the course of infiltration of the extravasated urine is determined by these attachments; at first, therefore, the urine is confined within the superficial compartment, but gradually travels forwards, under the fascia of Colles, on to the inferior part of the anterior abdominal wall; it is prevented from passing into the front of the thigh by the attachment of Scarpa's fascia to the fascia lata, a little distal to the inguinal ligament.

The **deep compartment** of the urogenital division of the perineum corresponds to the interval between the inferior and superior fasciæ of the urogenital diaphragm. The most important structures which this compartment contains are the membranous part of the urethra, the bulbo-urethral glands, the internal pudendal vessels, and the artery to the bulb.

The **membranous part of the urethra** lies one inch behind the inferior border of the pubic symphysis. When this division of the urethra is ruptured, the extravasated urine, after filling the deep compartment, may reach the superficial compartment by bursting through the inferior fascia of the urogenital diaphragm where the vessels pierce it; or it may penetrate the superior fascia, infiltrate the perivesical connective tissue and the space of Retzius, and ultimately ascend on the anterior abdominal wall between the fascia transversalis and the parietal peritoneum.

The **bulbo-urethral glands,** which lie immediately behind the membranous part of the urethra, are overlapped by the bulb of the urethra, from which they are separated by the inferior fascia of the urogenital diaphragm. The **internal pudendal**

artery lies just within the margin of the pubic arch. The **artery to the bulb** runs transversely medially $\frac{1}{4}$ in. above the base of the urogenital diaphragm, *i.e.* above the level of a line drawn from the front of the tuberosities to the central point of the perineum.

The **male urethra** measures about eight inches from the external to the internal orifice; the narrowest portion is at the external orifice; a second narrowing occurs at the urogenital diaphragm. It is behind these constrictions that a calculus is liable to become impacted. The *most dependent part* of the urethra is the bulbous portion, and it is in this situation that an organic stricture is most frequently met with. The membranous part of the urethra, situated between the two fasciæ of the urogenital diaphragm, is surrounded by the sphincter urethræ membranaceæ muscle, which, when thrown into spasm, may firmly grip an instrument as it is passed into the bladder. *Rupture of the urethra* from a fall on the perineum generally involves the bulbous portion. A *false passage* made during the passage of an instrument generally traverses the floor of the urethra at the urogenital diaphragm; to prevent this the point of the instrument should always be directed upwards, and the handle at the same time depressed as soon as the instrument is felt to encounter the resistance of the inferior fascia of the urogenital diaphragm. When the *prostate is hypertrophied* the prostatic part of the urethra is elongated, and the internal orifice may look directly forwards, while if the lateral lobes are unequally enlarged it may deviate laterally. Patients with prostatic hypertrophy are seldom able to empty the bladder completely, on account of the dependent well which exists behind the prostate.

From the clinical point of view surgeons speak of an "anterior urethra," situated distal to the membranous portion, and a "posterior urethra," situated proximal to it. While the anterior urethra is the least sensitive portion of the canal, the posterior urethra is highly sensitive and more vascular; and when its mucous membrane is injured toxic agents may be rapidly absorbed by the abundant blood-vessels and lymphatics of its submucous tissue. The anterior urethra is shut off from the posterior urethra by the tonic contraction of the sphincter muscle of the membranous urethra.

Viewed with an endoscope the mucous membrane of the anterior urethra is seen to be smooth and glistening, and to have a pale yellowish-pink colour. The longitudinal row of small pit-like openings on the dorsal wall and the orifices of the lacunæ and mucous glands can be investigated. The mucous membrane of the posterior urethra is of a redder colour. The opening of the utriculus prostaticus is seen as a small slit-like orifice on the most prominent part of the elevation caused by the crista urethralis, while immediately to either side of it is the minute orifice of the ejaculatory duct. At the floor of the sulcus on each side of the crista are the minute openings of the majority of the prostatic ducts.

Cystoscopic Examination of the Bladder.—On making a cystoscopic examination of the bladder special attention is paid to the **trigone**, as most of the pathological lesions are associated with this region. At its anterior angle is the **internal urethral orifice**, while at its postero-lateral angles are the small oblique slit-like **orifices of the ureters**, surrounded by a very slight lip-like elevation of the mucous membrane. At the base of the trigone the mucous membrane is raised into a smooth *transverse ridge* which stretches between the ureteric openings, with a slight forward convexity. The elevation is caused by a bundle of transverse muscular fibres, continuous with the longitudinal fibres of the ureters. The distance of the ureteric orifices from one another is rather more than an inch, while their distance from the internal urethral orifice is slightly less than an inch.

The urine is ejected into the bladder intermittently at intervals of a minute or so. During each ejection the ureteric orifice is seen to pucker up, and as it relaxes the gush of urine takes place in the form of a characteristic whirl "resembling an injection of glycerine into water." The **mucous membrane** of the trigone is closely connected with the subjacent muscular wall, so that it presents a smooth appearance; whereas over the rest of the bladder it is thrown into folds owing to the looseness of the submucous tissue. Further, the mucous membrane of the trigone presents a pink injection, while over the rest of the bladder it is of a pale straw colour. This contrast is due to the difference in the arrangement of the blood-vessels; over the trigone they are larger, more numerous, and form a close network; hence, when this surface is inflamed, the congested vessels form a continuous vascular layer. Over the rest of the bladder one sees, here and there in the mucous membrane, small segments of fine vessels giving off a cluster of short branches, the finer anastomoses of which are not visible when the mucous membrane is healthy.

The form and shape of the trigone in women may be distorted by prolapse of the bladder, by alterations in the size and position of the cervix, and by the presence of fibroids. In the male, distortion is usually due either to the enlargement of the prostate or to disease of the vesiculæ seminales.

When the normal bladder is comfortably filled, the bladder walls appear almost smooth, but when the bladder contracts the delicate muscular trabeculæ become visible through the mucous membrane. When the bladder is hypertrophied as the result of urinary obstruction the muscular trabeculæ become greatly hypertrophied, and stand out prominently, even when the bladder is full. The spaces between the trabeculæ may become so deeply pitted as to lead to the formation of little pockets, known as **false diverticula.**

THE PROSTATE.

The operation of *prostatectomy* has proved so successful in removing urinary complications associated with enlargement of the **prostate** that a fresh impetus has been given to the study of the anatomy of the gland from the surgical point of view. With the body erect the **base** of the prostate lies in a horizontal plane at the level of the middle of the symphysis pubis, while its **apex** lies ½ in. behind and below the sub-pubic angle. It follows, therefore, that the vesical orifice and the base of the prostate are within easy reach of the finger introduced through a supra-pubic cystotomy incision. The **anterior surface** of the prostate lies about ¾ in. behind the pubes, to which it is connected by the pubo-prostatic ligaments. Above those ligaments is the *space of Retzius*, occupied by fatty tissue which passes upwards in front of the anterior wall of the bladder, between the umbilical arteries, as far as the umbilicus, while laterally it extends on each side, between the peritoneum and pelvic fascia, as far back as the hypogastric arteries. The **posterior surface** of the prostate is related to that part of the rectal ampulla immediately above the anal canal, and is therefore accessible to palpation *per rectum.* Between the rectum and the posterior part of the sheath of the prostate (formed by the recto-vesical layer of pelvic fascia) is a loose cellular interval, which is taken advantage of in the operation of excision of the rectum, and in exposing the posterior surface of the prostate in the operation of perineal prostatectomy. The **lateral surfaces** of the prostate cannot be felt through the rectum; they are related to the anterior or pubo-rectal fibres of the levatores ani, from which they are separated by the lateral portion of the fascial envelope of the gland.

The *prostate substance* is made up of branching tubular glands supported by a fibro-muscular stroma. The gland tissue is most abundant in the posterior and lateral aspects of the organ; anteriorly the stroma is more abundant and extends backwards from the capsule to the urethra to form a sort of anterior commissure. By the term "*capsule*" of the prostate is understood the immediate or proper envelope of the gland; this envelope consists of parallel layers of fibro-muscular tissue, continuous with, and forming part of, the stroma of the organ. In some instances it is so thin that the gland tissue reaches almost to its surface, while in other instances it is so thick as to deserve to be regarded as forming the cortical portion of the gland. By the term "*sheath*" of the prostate is meant the fibrous envelope derived from the pelvic fascia; the veins of the *pudendal plexus* lie between its lamellæ.

In what is known as "**senile**" **hypertrophy** of the prostate the organ may be uniformly enlarged, or the enlargement may affect chiefly one or other of the lateral lobes, one or both of which may enlarge more particularly in an upward direction so as to project into the bladder. This intra-vesical overgrowth may take the form either of a more or less pedunculated projection, situated immediately behind, or somewhat lateral to, the internal urethral orifice, or it may surround the orifice to form a prominent ring-like elevation. As the intra-vesical growth enlarges, it makes its way towards the bladder within the ring of the sphincter vesicæ, and, having pushed before, or separated, the internal longitudinal fibres of the bladder, it comes ultimately to be separated from the cavity of the bladder by mucous membrane only. In the operation of *supra-pubic prostatectomy* the true capsule of the prostate is at once reached by simply tearing through the mucous membrane immediately behind the vesical orifice. By keeping close to the capsule, the entire organ, including the capsule, may be enucleated from its sheath. As the latter is markedly thicker and denser in the hypertrophied than in the normal prostate, this enucleation can be accomplished without injuring the veins of the pudendal plexus. As a rule, the only part where any difficulty in the enucleation is encountered is anteriorly, where the capsule is more intimately connected with the sheath by the interposition of a layer of striated longitudinal muscular fibres which pass from the urethra to be continuous with the outer longitudinal fibres of the bladder. In "total" prostatectomy, practically the whole of the prostatic urethra is removed along with the gland. In some instances, instead of removing the entire prostate and its capsule along with the prostatic urethra, the surgeon, by working within the capsule, is able to enucleate each lateral glandular mass either separately or united to its fellow in the form of a horse-shoe shaped mass, the urethra and the anterior commissure being left more or less intact. The cavity, which is left behind after the removal of the prostate, at once contracts owing to the approximation of the bladder and rectum antero-posteriorly, and of the levatores ani at the sides.

In perineal prostatectomy the posterior surface of the prostate is exposed by making a horse-shoe shaped incision with the convexity reaching forwards to a point immediately behind the bulb; at the sides, the incision sinks into the ischio-rectal fossæ, its extremities ending at the anterior part of the ischial tuberosities. After reflecting the skin and subcutaneous tissue, the incision is carried through the central point of the perineum. The bulb, the superficial transverse perineal muscles, and the inferior fascia of the urogenital diaphragm are now drawn forwards, and the fibres of the recto-urethral muscle (which connect the anterior wall of the rectal ampulla with the sphincter urethræ) are divided; this allows the anal canal and the inferior end of the rectum to be retracted backwards. The dissection is now carried in a forward direction, between the anterior borders of the levatores ani, towards the prostate, so as to strike the loose non-vascular space which intervenes between the posterior part of the prostatic sheath and the thin fascia outside the muscular wall of the rectum. The posterior surface of the prostate, covered by its true capsule, is reached by incising the fascial sheath. The prostate, along with its true capsule and the urethra, may either be enucleated entire from the sheath, or the true capsule may be incised as well as the sheath, and the adenomatous masses removed separately. The operation is greatly facilitated by pulling the prostate down into the wound by a special retractor (Young) inserted into the bladder through a median incision into the floor of the membranous part of the urethra.

The **epididymis**, which can be felt, as an elongated curved body applied vertically to the posterior margin of the testis, is especially involved in gonorrhœal and tubercular infections of the testis. Occupying the posterior part of the spermatic funiculus is the **ductus deferens**, which, when grasped between the finger and thumb, feels like a piece of whip-cord. The spermatic veins form a plexus in the substance of the funiculus, known as the **pampiniform plexus**; a varicose condition of these veins gives rise to the condition known as *varicocele.* In operating for varicocele the veins are reached by dividing, in succession, all the coverings of the funiculus; the deepest covering, viz., the internal spermatic fascia, derived from the fascia transversalis, forms a well-marked fibrous envelope which immediately surrounds the veins and other constituents of the funiculus. Besides the internal testicular artery, the testis receives its blood-supply from the artery accompanying the ductus deferens and from the external testicular branch of the inferior epigastric.

The marked swelling which attends *œdema and hæmatoma of the scrotum* is due to the loose and delicate character of the cellular tissue which occupies the space between the dartos muscle and the subjacent membrane derived from the inter-columnar fascia.

The **anus** is situated in the rectal division of the perineum about 1½ in. in front of and below the tip of the coccyx. The skin around the orifice is pigmented and thrown into radiating folds. The painful linear crack or ulcer, known as *fissure of* *the anus,* generally occupies one of the furrows at the posterior margin of the anus. The skin of the anus is provided with large sebaceous and sweat glands which are occasionally the site of small and very painful anal abscesses.

On making a *rectal examination* it will be observed that the finger, before it reaches the cavity of the rectum, traverses the narrow or sphincteric portion of the rectum, appropriately named by Symington the **anal canal.** This canal, which is directed from below upwards and forwards, extends from the anal orifice to the ampulla of the rectum; it is from one to one and a half inches in length; its upper end is on a level with the medial borders of the pubo-rectal portions of the levatores ani.

External hæmorrhoids are developed from the anal folds situated outside the white line corresponding to the muco-cutaneous junction; *internal piles* are developed from the veins of the mucosa at the upper part of the anal canal.

In the superior half of the anal canal are the rectal **columns of Morgagni.** According to Ball, fissure of the anus is generally caused by the tearing downwards of one of the posterior **rectal sinuses** (Fig. 1088) during the passage of a scybalous mass.

According to Birmingham, the pubo-coccygeal fibres of the levator ani close the superior part of the anal canal, whilst the external sphincter closes the remaining part. The internal sphincter, according to the same author, acts probably as a detrusor, its use being to empty the anal canal completely after the passage of the fæcal mass.

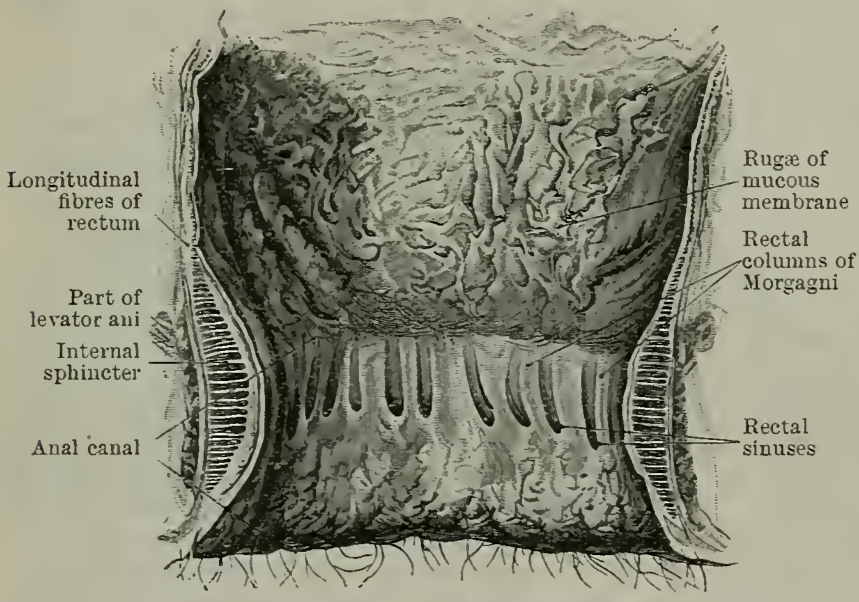

Fig. 1088.—The Interior of the Anal Canal and Inferior Part of the Rectum.

Showing the rectal columns of Morgagni and the rectal sinuses between their inferior ends. The columns were more numerous in this specimen than usual. (From Birmingham.)

Ischio-rectal Fossa.—The apex of the **ischio-rectal fossa** (Fig. 1089), formed by the attachment of the inferior fascia of the pelvic diaphragm (anal fascia) to the obturator portion of the parietal pelvic fascia, is directed upwards towards the pelvis, and lies 2½ in. from the surface. The medial wall of the fossa is bounded by the levator ani and coccygeal muscles covered by the inferior fascia of the pelvic diaphragm (Fig. 1089); the lateral wall by the obturator internus muscle covered by the obturator fascia. An *abscess in the ischio-rectal fossa* should be opened early, otherwise it is liable to burst through the medial wall into the rectum; should it open also upon the skin surface a complete "*fistula in ano*" is formed. When a "fistula in ano" results from the bursting of a submucous abscess of the anal canal the track of the fistula runs either medial to or through the fibres of the internal and external sphincter muscles, and the external or skin opening is, as a rule, close to the anus, while the internal opening is generally within the upper end of the anal canal. Occasionally the ischio-rectal abscess perforates the levator ani towards the apex of the fossa; it then burrows into the peri-rectal cellular tissue of the pelvis, and opens into the ampulla of the rectum. In other cases, again, the abscess starts in the peri-rectal tissue internal to the levator ani, and either bursts into the rectal ampulla or through the levator ani into the ischio-rectal fossa, and so reaches the surface. Or the pus may burrow between the rectum and coccyx, whence it may pass outwards through the greater sciatic foramen, behind the parietal pelvic fascia, into the buttock; or, by piercing the visceral layer of the pelvic fascia, may reach the tela subserosa of fatty tissue of the pelvis and ascend in it to form an iliac abscess.

The *lymph* vessels from the skin of the anus pass along the perineo-femoral folds to the most medial glands of the groin, both superficial and deep subinguinal. According to Poirier and Cunéo, those from the region of the white line end in the hypogastric glands which lie in front of the hypogastric artery, while those which issue from the mucous membrane of the upper part of the anal canal and the rectum proper traverse a few minute glands (ano-rectal glands of Gerota) placed between the muscular and fibrous coats of the rectum, along the superior hæmorrhoidal vein and its two branches, and pass thence to the sacral glands which lie internal to the anterior sacral foramina.

Digital Examination of Rectum.—In making a *rectal examination* the finger should be carried forwards from the tip of the coccyx so as to enter the anus from behind. The finger is then gently pressed upwards and slightly forwards through the sphincteric region, in the axis of the anal canal, until it reaches the cavity of the rectum, the inferior part of which is dilated to form the ampulla. The transverse folds of the rectum or valves of Houston, three in number, project into the cavity of the bowel in the form of prominent crescentic shelves, which are produced by the three permanent or true flexures into which the rectum is thrown (Birmingham); the inferior valve, which may be sufficiently prominent to impede the passage of the finger, must not be mistaken for a pathological condition. An exaggerated development of one of these folds in the fœtus is the main factor in the causation of the condition known as *megalocolon* or *Hirschsprung's disease.* The condition is aggravated by the formation of a lateral pouching of the bowel opposite the valve. When the pouch becomes distended with fæcal matter the valve is

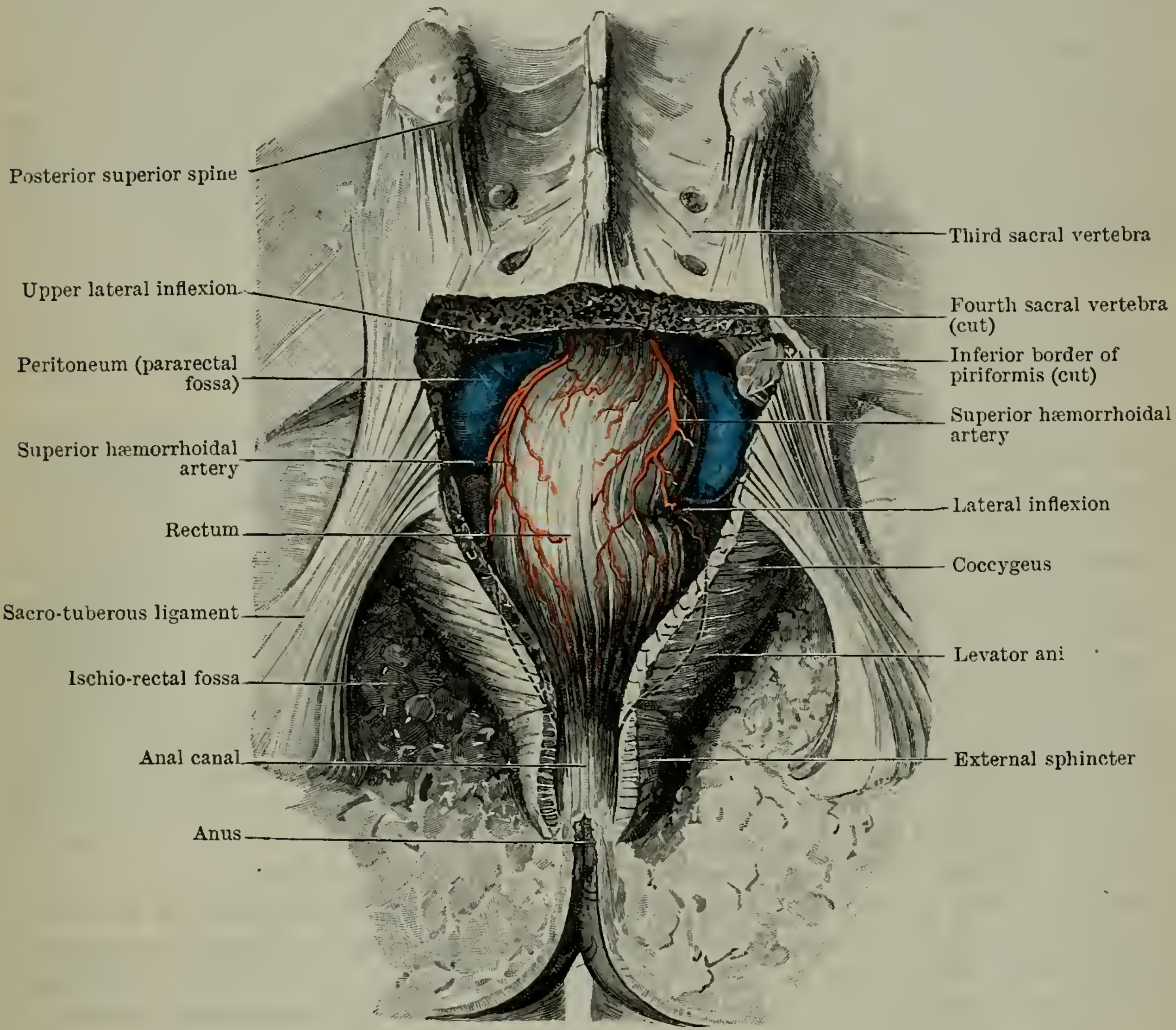

FIG. 1089.—THE RECTUM FROM BEHIND.

The sacrum has been sawn across through the 4th sacral vertebra, and its inferior part removed with the coccyx. The posterior portions of the coccygei, levatores ani, and of the external sphincter have been cut away. The "pinching in" of the inferior end of the rectum by the medial edges of the levatores ani, resulting in the formation of the flattened anal canal, is suggested in the illustration, which has been made from a formalin-hardened male body, aged thirty. The lateral inflexions of the rectum, corresponding to Houston's rectal valves, are also shown. (From Birmingham.)

pressed against the opposite wall of the bowel and the passage is closed. The mechanism is very similar to that which occurs in congenital hydronephrosis due to an abnormally high and therefore lateral attachment of the ureter to the pelvis of the kidney. Through the anterior wall the finger can palpate from below upwards the bulb of the urethra, the membranous part of the urethra, the bulbo-urethral glands (when inflamed and enlarged), the apex and lateral lobes of the prostate, the vesiculæ seminales, and the external trigone of the bladder. With the left forefinger in the rectum, an instrument passed into the bladder can be distinctly felt as it traverses the membranous urethra; as it lies in the prostatic urethra it is separated from the finger by the prostate. Hence, when a *false passage* is made through the bulbous or membranous portion of the urethra, the instrument, if pushed onwards towards the bladder, will be felt immediately outside the rectum between it and the prostate. In the child, owing to the rudimentary condition of the prostate, the instrument is distinctly felt close to the rectum, as it lies in the prostatic as well as in the membranous portion of the urethra. When the prostate is not enlarged the tip of the finger can just reach the external trigone, which is most distinctly felt when the bladder is full. The vesiculæ seminales, indistinctly felt when healthy, may be readily palpated when enlarged and indurated from disease. Through the side wall of the rectum may be palpated the ischio-rectal fossa, the bony wall of the pelvis minor, and, when enlarged, the hypogastric lymph glands; through the posterior wall the hollow of the sacrum and coccyx, and the lymph glands lying in the retro-rectal cellular tissue.

In the child rectal examination enables one to palpate, in addition to the structures in the cavity of the pelvis minor, those which occupy the lower segment of the abdomen. When the bladder is empty even a small calculus can be readily felt by recto-abdominal palpation.

The distance of the apex of the **recto-vesical pouch** of peritoneum from the anus varies considerably, according to the degree of distension of the bladder and rectum; when both are empty it reaches to about 2 in. from the anus; when both are distended it is at least one inch higher (Fig. 1089).

Examination by Sigmoidoscope.—In introducing the sigmoidoscope into the pelvic colon the direction of the anal canal and the curve of the rectum must be borne in mind; as the instrument traverses the anal canal it must be directed forwards as well as upwards, after which it is pushed onwards, in a backward and upward direction, towards the hollow of the sacrum; while, finally, in order to reach the pelvic colon, it is again directed forwards and a little to the left so as to clear the promontory of the sacrum. The instrument is more difficult to pass in women, on account of the greater abruptness of the curvature of the sacrum in the female as compared with the male.

When examined with the sigmoidoscope the mucous membrane of the rectum is seen to possess a deep red colour, and an excellent view is obtained of the rectal valves of Houston. The most conspicuous fold, known as the **plica transversalis**, projects from the right wall about the level of the recto-vesical peritoneal reflexion, *i.e.* about three inches from the anus. The highest valve, situated at the colo-rectal junction, gives rise to a distinct narrowing which must not be mistaken for a stricture. The pulsations of the left common iliac artery can generally be seen to be communicated to the postero-lateral wall of the pelvic colon about four inches from the anus.

Removal of the Rectum.—In removing the rectum and anal canal for malignant disease, an incision is carried round the anus and then upwards and backwards over the coccyx and inferior part of the sacrum. The *ano-coccygeal raphe* is divided longitudinally and the *coccyx* (either alone or along with more or less of the lower part of the sacrum) is excised by dividing the structures attached to its margins, viz., the inferior fibres of the glutæus maximus, the coccygeus, and the sacro-tuberous and sacro-spinous ligaments (O.T. greater and lesser sacro-sciatic). The parietal pelvic fascia, here very thin and adherent, is removed along with the bone. The **middle sacral artery** is ligatured. This is now seen, stretching across the floor of the wound, a well-defined sheet of fascia, viz., the rectal layer of the **visceral pelvic fascia**, which is divided longitudinally and stripped to either side off the posterior surface of the rectum; in doing this the branches of the **middle hæmorrhoidal arteries** are ligatured. Anteriorly, the anal canal is detached from the **central point of the perineum**, after which the anterior surface of the rectum is freed from below upwards from the urogenital diaphragm containing the **membranous urethra**, the posterior surface of the **prostate**, the trigone of the bladder and the **vesiculæ seminales** and the **ductus deferentes**. This procedure is facilitated by the existence of a cellular interval between the anterior wall of the rectum and the strong recto-vesical layer of visceral pelvic fascia, which forms the posterior part of the sheath of the prostate, and, higher up, encloses the vesiculæ seminales and ductus deferentes. In order to strike this cellular interspace, the surgeon, after dividing the central point of the perineum transversely, deepens the incision down to the apex of the prostate. In doing this he divides a band of muscular fibres (**recto-urethral muscle**) which passes from the anterior wall of the lowest part of the rectal ampulla to blend with the sphincter urethræ muscle surrounding the urethra at the apex of the prostate. It is these recto-urethral fibres, which, by pulling forwards the ampulla, bring it into close relation with the urethra; hence it is especially at this stage of the operation that great care must be taken not to open into the rectum or to wound the urethra. After exposing the apex of the prostate the next step is to retract the anal canal well backwards and to define the anterior or pubo-prostatic borders of the **levator ani** muscle. These muscles are then divided, on each side, well above their insertion into the rectum. The posterior surface of the prostate, covered with recto-vesical fascia, is now exposed.

By continuing the separation of the rectum upwards in the cellular plane above mentioned, the bottom of the **recto-vesical pouch** of peritoneum is reached; it can usually be stripped for some distance off the rectum, without opening into the peritoneal cavity. In freeing the rectum laterally, bands of connective tissue containing branches of the **middle** and **superior hæmorrhoidal vessels** are divided. If the tumour is situated at the superior part of the rectum, the recto-vesical pouch of peritoneum is freely opened in a transverse direction. The **colo-rectal junction** is then mobilised by dividing the sacral attachment of the **pelvic mesocolon** and securing the superior hæmorrhoidal artery. After dividing the rectum well above the tumour, the opening into the peritoneal cavity is closed by suturing together the anterior and posterior walls of the recto-vesical pouch. If a permanent colostomy has been established, the divided bowel is closed; if not, a sacral anus is made.

FEMALE PELVIS.

On opening the abdomen by a median incision extending from the umbilicus to the pubes, and looking into the pelvis minor from above, after displacing some coils of the small intestine upwards, the **fundus of the uterus**, directed forwards and a little upwards, is seen resting upon the superior surface of the bladder. Behind the uterus is the rectum, and between the two the recto-uterine **pouch of Douglas**, containing the pelvic colon and the inferior part of the ileum. The **ovary** lies a little below the level of the superior aperture of the pelvis minor upon a triangular shelf, bounded in front by the broad ligament, behind and medially by the utero-sacral ligament, and behind and laterally by the pelvic wall. When the vermiform process overhangs the superior aperture of the pelvis minor its tip may come into close relation with the right ovary, a condition which often leads to a difficulty in distinguishing an inflammation of that ovary from appendicitis. The **round ligaments** are seen passing forwards and laterally from the upper parts of the right and left borders of the uterus to the abdominal inguinal rings, which lie immediately in front and to the medial side of the terminations of the external iliac arteries. Inferiorly and at the medial side of the round ligament, as it leaves the pelvis, is the **inferior epigastric artery.** By pulling the uterus upwards the attachments of the **broad ligament** to the floor and side walls of the pelvis are brought into evidence, as also are the utero-vesical and recto-vaginal peritoneal pouches; the former is shallow, while the deepest part of the latter covers the upper fourth of the posterior wall of the vagina, and comes into relation, therefore, with the posterior fornix.

The utero-vesical peritoneal reflexion takes place at the level of the junction of the body of the uterus with the cervix. The anterior wall of the cervix comes into relation, therefore, with the superior part of the base of the bladder, from which, however, it is separated by a layer of loose connective tissue. It is the existence of this cellular plane which enables the surgeon to separate the bladder readily from the uterus in the operation of hysterectomy.

While the anterior wall of the vagina is firmly united to the urethra, its posterior wall, on the other hand, can be readily separated from the rectum, in consequence of the interposition between the two organs of the recto-vaginal fascia.

The **ureter** crosses the brim of the pelvis in front of the bifurcation of the common iliac artery 1½ in. lateral to and a little below the centre of the sacral promontory. The corresponding point on the anterior abdominal wall is at the junction of the lateral and middle thirds of a line joining the anterior superior spines of the ilium.

After crossing the termination of the common iliac artery from lateral to medial side, the ureter dips vertically into the pelvis minor behind the peritoneum covering the hypogastric artery. It then courses medially in the parametric cellular tissue below the base of the broad ligament. In this position it lies a little above the lateral fornix of the vagina, about three-quarters of an inch lateral to the superior part of the cervix uteri; finally, just before it pierces the lateral angle of the bladder, it lies in front of the antero-lateral aspect of the upper part of the vaginal wall.

The relation of the pelvic portions of the ureters are of special importance in the female as their close relation to the cervix uteri and upper part of the vagina renders them liable to injury, more especially in the operation of hysterectomy performed for malignant disease of the uterus.

The **uterine artery**, in the first part of its course, passes downwards and forwards a little anterior and lateral to the ureter. At the level of the orificium internum uteri it takes a medial direction and passes along the inferior border of the broad ligament, and crosses, above and in front of the inferior part of the ureter, from lateral to medial side; it then passes above the lateral fornix of the vagina and finally ascends close to the side of the body of the uterus, and ends by anastomosing with the ovarian artery below the isthmus of the uterine tube.

The **ovarian artery** enters the pelvis minor between the layers of that portion of the broad ligament known as the **ligamentum suspensorium ovarii**; it is here that the vessel may be most readily ligatured in abdominal hysterectomy, and in ovariotomy.

The **lymph vessels** from the inferior part of the vagina pass to the superficial vaginal and sacral glands, while those from the rest of the vagina, from the cervix uteri and from the body of the uterus, pass to the hypogastric, the external iliac, and the sacral glands. The hypogastric glands are situated on the side wall of the pelvis in close relation to the origins of the branches of the hypogastric artery. The sacral glands form a chain along the medial side of the anterior sacral foramina. The lymph vessels from the fundus of the uterus, and from the ovary, terminate in the glands around the aorta.

The external genitals are fully described elsewhere (p. 1306). The **external orifice of the urethra**, surrounded by a slight annular prominence of the mucous membrane, is situated about 1 in. behind the clitoris, immediately above the centre of the base of the vestibule—a smooth triangular area at the anterior part of the vulva, with its sides formed by the labia minora and its base by the anterior margin of the ostium vaginæ. In passing a *catheter* the instrument is directed along the forefinger (introduced just within the ostium vaginæ with the palmar surface towards the symphysis pubis) to the base of the smooth vestibule, where it is tilted slightly upwards so as to bring its point opposite the urethral orifice.

The larger **vestibular glands**, about the size of a bean, are placed on each side of the posterior third of the orifice of the vagina, below the urogenital diaphragm. Their ducts, nearly one inch in length, open posteriorly between the hymen and the posterior commissure (*fossa navicularis*). Abscesses and cysts not infrequently develop in connexion with these glands. The **bulbs of the vestibule** are two piriform collections of erectile tissue situated on each side of the vestibule, between the bulbo-cavernosus muscle and the inferior fascia of the urogenital diaphragm. Rupture of these bodies gives rise to the condition known as *pudendal hæmatocele.*

The **cervix uteri** projects downwards and backwards into the roof of the vagina so as to leave a distinct **fornix** between the two. The relations of the fornix are of so much practical importance that for descriptive purposes it is customary to subdivide it into an anterior, a posterior, and two lateral portions. The **anterior fornix**, which is shallow, is related to the base of the bladder and to the utero-vesical pouch of peritoneum. The **posterior fornix**, which is deeper, extends upwards for some little distance in front of the anterior wall of the lowest part of the pouch of Douglas. The septum between the two is formed merely by the wall of the vagina; hence the readiness with which the pelvis may be drained by puncturing it and pulling a tube through the opening from the pelvis into the vagina.

The **lateral fornix** lies below the medial part of the base of the broad ligament. An incision carried through it would therefore open into the parametric cellular tissue and would expose the uterine artery as it passes transversely to the uterus, after crossing above and in front of the lower part of the ureters.

Vaginal Examination.—In making a *vaginal examination* the patient should be placed in the dorsal position, with the thighs well flexed; the index-finger of the right hand is now carried along the fold of the buttock towards the median plane, where it will impinge against the posterior aspect of the **introitus vaginæ**, whence it is inserted upwards and backwards into the canal; to render the examination more thorough the middle finger also may be introduced. When the uterus is in its normal position the **vaginal part of the cervix uteri** is felt as a knob-like body projecting downwards and backwards into the upper part of the canal. In nulliparæ the orificium uteri externum is a small transverse slit, whereas in women who have borne children it is larger and more or less fissured. Above and behind the cervix is the **posterior fornix**, which is in close proximity to the **recto-uterine pouch** of Douglas; this pouch, though normally empty, is the frequent site of displaced abdominal and pelvic organs, and collections of intra-peritoneal effusions and exudations. A loaded rectum can be detected through the vagina by the characteristic way in which the contents can be pitted by the finger. In front of the cervix is the shallow **anterior fornix**, through which may be felt the body of the uterus and the base of the bladder, while through the inferior half of the anterior vaginal wall the **urethra** may be detected as a cylindrical, cord-like thickening which may be rolled against the inferior border of the symphysis. The **ureter**, especially if enlarged, can be recognised through the antero-lateral fornix, by compressing it against the pubic bone.

By the *bimanual examination* the pelvic organs are steadied and pushed downwards towards the inferior aperture of the pelvic by the pressure of the left hand applied in the hypogastric region, so that they can be more readily reached and palpated by the finger placed in the vagina with its palmar aspect directed upwards. The **ovary** may be felt as a firm body about the size of the end of the thumb by pushing the fingers well up into the lateral fornix towards the side wall of the pelvis. In health the ovaries are freely movable. The healthy **uterine tubes** cannot, as a rule, be felt per vaginam.

Examination of Interior of Bladder.—The whole of the **interior of the bladder** in the female can be readily seen by reflecting light into it through a speculum introduced into the empty bladder after dilating the urethra. The patient is placed in the genupectoral position, so that the bladder may become inflated with air, the coils of intestine being displaced upwards. In the distended condition of the bladder the mucosa has a dull white or straw-coloured appearance, except in the region of the trigone, which shows a pale pink injection. The **ureteral orifices** placed a little more than one inch apart and connected by a slight transverse ridge (inter-ureteric fold), present the appearance of fine oblique slits situated upon small and somewhat injected elevations of the mucosa.

Rectal Examination.—By rectal examination the finger can palpate, from below upwards, the recto-vaginal septum, the cervix uteri, the posterior fornix of the vagina, the apex of the recto-uterine pouch of Douglas, and the body of the uterus. By washing out the rectum and introducing a speculum into the bowel, with the patient in the genupectoral position, the rectum becomes inflated with air; the finger can now feel very distinctly the posterior surface of the uterus and the uterine tubes, and by running the finger laterally, along the prominent fold formed by the utero-ovarian ligament, the ovary is also very distinctly felt.

THE BACK.

Median Line of the Back.—In the median line of the back is the **vertebral furrow**, which is deepest in the inferior thoracic and superior lumbar regions, where the sacro-spinales muscles are most prominent. Over the superior sacral region, where the sacro-spinales muscles are tendinous, is a flattened area forming an equilateral triangle, the angles of which correspond respectively to the posterior superior spines of the two iliac bones and the third sacral spine. The **vertebral spines** can be palpated at the bottom of the vertebral furrow; they become more distinct when the vertebral column is flexed, and, as pointed out by Holden, they become mapped out by reddened areas when friction is applied along the furrow. The identification and counting of the spines will be facilitated if it is remembered that the first thoracic is more prominent than the vertebra prominens (seventh cervical), that the third thoracic is on a level with the root of the spine of the scapula, the seventh thoracic its inferior angle, the fourth lumbar with the highest part of the iliac crest, and the second sacral with the posterior superior iliac spine.

Lateral Region of the Back.—Above the spine of the scapula is the **supra-scapular region**, which is padded by a thick mass of muscle consisting of the supraspinatus and levator scapulæ, covered by the superior part of the trapezius; the two latter muscles may be thrown into relief by shrugging the shoulders.

In the **interscapular region** are the rhomboid muscles which are thrown into prominence by bracing back the shoulders.

Below the inferior angle of the scapula the last five ribs can readily be felt lateral to the sacro-spinalis muscle; when the twelfth rib does not reach beyond this muscle, the eleventh rib will be mistaken for it, unless the ribs are counted from above downwards.

The **inferior border of the trapezius** is indicated by a line extending upwards and laterally from the twelfth thoracic spine to the root of the spine of the scapula; the **superior border of the latissimus dorsi** by a line extending from the sixth thoracic spine transversely laterally across the angle of the scapula. Between these two muscles and the inferior part of the vertebral margin of the scapula is a triangular area, the floor of which is formed by the rhomboideus major muscle and the sixth costal interspace.

The lateral border of the **sacrospinalis** is indicated on the surface by drawing a line from a point on the iliac crest 3½ in. (four fingers'-breadth) from the median line, upwards and slightly laterally to the angles of the ribs. The lateral border of the **quadratus lumborum**, which passes upwards and slightly medially, lies a little lateral to that of the sacrospinalis at the crest, and a little medial to it at the twelfth rib.

The anatomy of the muscles and fasciæ which complete the abdominal wall between the last rib and the iliac crest is of great importance in connexion with operations in the **region of the loin**. The space between the last rib and the iliac crest varies greatly according to the length of the rib, and according to the general shape of the chest and slope of the ribs as a whole. As a rule, the **tip of the twelfth rib** lies about two inches vertically above the centre of the iliac crest. From a surgical point of view the costo-iliac space may be said to be limited medially by the lateral edge of the sacrospinalis, and, more deeply, by the tips of the transverse processes of the lumbar vertebræ, while laterally it is bounded by the posterior free border of the external oblique, and, more deeply, by the line of reflexion of the peritoneum from the colon on to the side wall of the abdomen. The space is roofed over by the latissimus dorsi, except below, where a narrow triangular interval is left between its lateral border and the posterior border of the external oblique, the base of the triangle being formed by the crest of the ilium, a little behind its centre. This triangle, known as the **lumbar triangle of Petit**, represents a weak area through which a lumbar abscess may come to the surface, and through which a lumbar hernia occasionally develops. On removing the latissimus dorsi and the lower part of the thin serratus posterior inferior, another triangle will be exposed, which constitutes a second weak area in the loin; it is bounded above by the last rib, medially by the lateral border of the sacrospinalis, and laterally by the posterior muscular fibres of the internal oblique; the floor of the triangle is formed by the aponeurosis of origin of the transversus abdominis muscle. At the lateral border of the quadratus lumborum this aponeurosis splits into three layers to form two compartments, the anterior enclosing the quadratus lumborum and the posterior the sacrospinalis.

Kidneys.—The superior limit of the kidney is indicated by a line drawn transversely across the loin opposite the eleventh thoracic spine, the inferior limit by a line on a level with the third lumbar spine. The superior extremity reaches to the eleventh rib; the lower, which lies immediately lateral to the tip of the transverse process of the third lumbar vertebra, reaches to within 1½ to 2 in. of the crest of the ilium. About a third of the kidney lies above the inferior margin of the twelfth rib. The left kidney usually lies about ½ in. higher than the right. The most lateral point of the lateral border lies 4 in. from the median plane, while the hilum lies 1½ in. lateral to the median plane in front of the interval between the tips of the transverse processes of the first and second lumbar vertebræ.

The psoas major muscle intervenes between the postero-medial surface of the kidney and the transverse processes, and protects the organ from injury by a blow directed from the front. Between the superior end of the kidney and the eleventh and twelfth ribs is the diaphragm and the posterior costo-diaphragmatic reflexion of the pleura (Fig. 1074). The relations of the pleura to the last rib have already been considered (p. 1393).

Posteriorly the course of the superior part of the **ureter** may be indicated by a line drawn vertically upwards from the superior posterior iliac spine to the level of the second lumbar spine; the deep guides are the tips of the transverse processes of the second, third, and fourth lumbar vertebræ, covered by the psoas major muscle.

Exposure of Kidney from behind.—In exposing the kidney from the loin, by a **vertical incision** between the lateral border of the sacrospinalis and the free posterior border of the external oblique muscle, the following structures are divided from without inwards: (1) the integuments; (2) the lower fibres of the latissimus dorsi and serratus posterior inferior muscles; (3) the middle layer of the lumbar aponeurosis, just lateral to the sacrospinalis compartment, and parallel to the lateral fibres of the quadratus lumborum muscles; (4) the anterior layer of the lumbar aponeurosis (which forms the aponeurotic origin of the transversus muscles), and the transversalis fascia; (5) the paranephric fat; (6) the perinephric fascia; (7) the perinephric fat surrounding the true capsule of the kidney. The kidney may be readily mobilised and brought to the surface by shelling it out of its fatty capsule with the finger. In cases of difficulty better access to the renal vessels can be obtained if the incision is made a little nearer the median plane, so as to open into the sacrospinalis compartment. This allows of the muscle itself being retracted medially more efficiently.

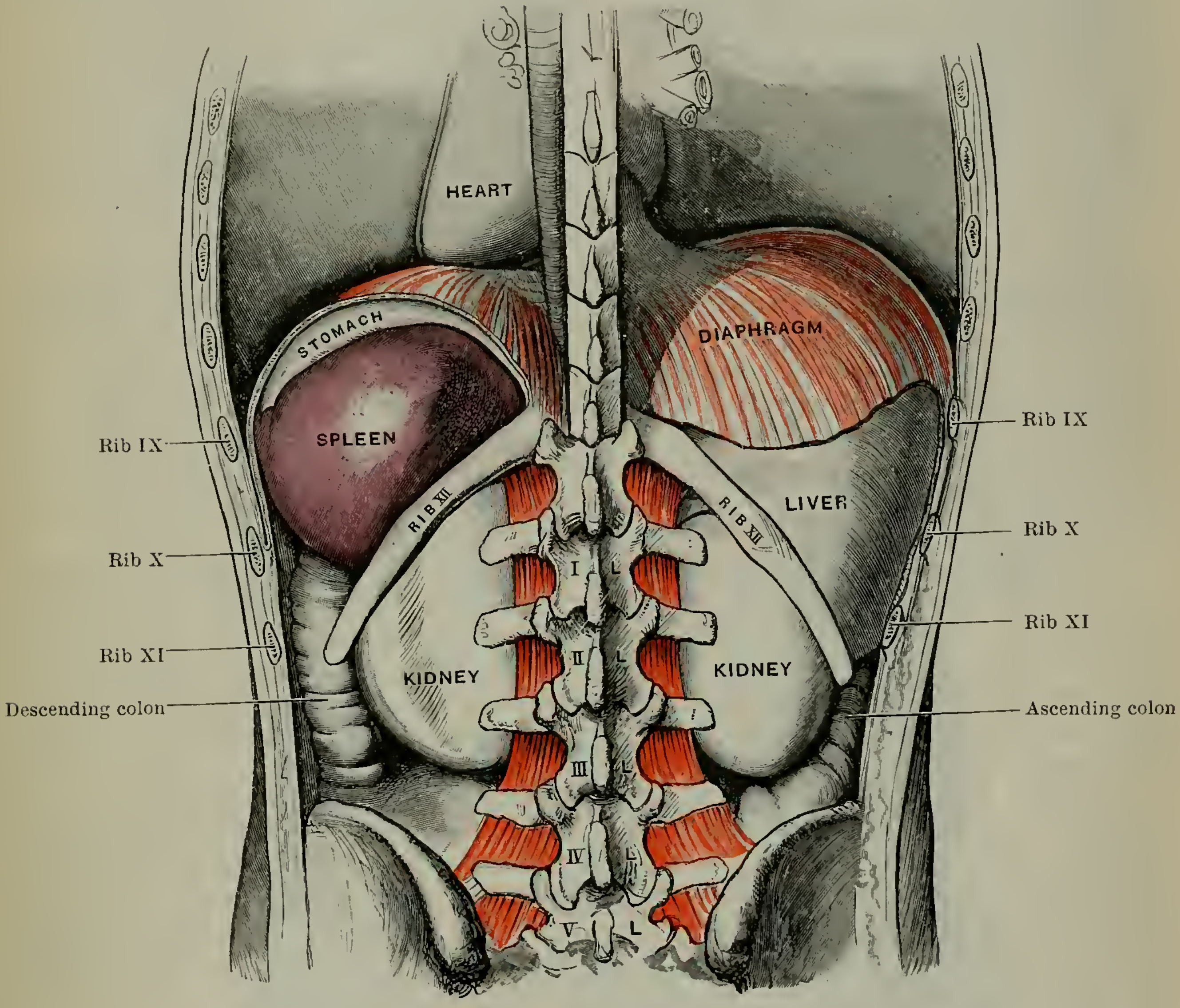

FIG. 1090.—DISSECTION OF THE SPLEEN, LIVER, AND KIDNEYS FROM BEHIND, IN A SUBJECT HARDENED BY FORMALIN INJECTION. (From Cunningham.)

In exposing the kidney by an **oblique incision** in the loin, the latissimus dorsi and serratus posterior inferior muscles are divided at the medial part of the wound, while at its lateral part the posterior fibres of the external and internal oblique muscles are divided; next, the aponeurotic origin of the transversus muscle and the transversalis fascia are split so as to expose the extra-peritoneal fat and the peritoneum, as it is reflected from the ascending colon on to the lateral aspect of the abdominal wall. The latter structures are then stripped forwards and medially off the anterior surface of the kidney, until the hilum and renal vessels are reached.

The sacrospinalis and quadratus lumborum muscles are retracted well medially, and it may be necessary to divide the lateral fibres of the quadratus muscle.

The upper part of the ureter is exposed by extending the division of the abdominal muscles still further downwards and forwards into the iliac region. After stripping the peritoneum off the quadratus and psoas muscles, the ureter will be found to cling to the deep surface of the membrane. Care is taken not to injure the internal testicular or ovarian vessels, which cross the ureter superficially, and from the medial to the lateral side. The ureter is surrounded by a quantity of loose cellular tissue, and, owing to an abundance of elastic fibres in its adventitious coat, is very elastic, so that it can be readily pulled up to the surface.

To deliver an enlarged kidney out of the loin, it is generally necessary to prolong the incision upwards so as to divide the lateral lumbo-costal arch; and it may be necessary to divide, fracture, or resect the twelfth rib also. In doing this it is not always possible to avoid opening into the lowest part of the pleural sinus, which descends in front of the medial half of the rib.

In operating on the kidney, the last thoracic, and the ilio-hypogastric and ilio-inguinal nerves, which lie posterior and then lateral to it, must not be injured; the last thoracic nerve should be retracted upwards and laterally, the other two downwards and medially.

A needle passed through the medial extremity of the eleventh intercostal space will transfix the **suprarenal gland.**

The pus of a **perinephric abscess** occupies the fatty layer of the tela subserosa (perinephric fat), and lies, therefore, within the fascial envelope of the abdomen; the pus in a **psoas abscess**, on the other hand, lies external to the fascia. In opening a psoas abscess from behind, a vertical incision is made in the angle formed by the lateral border of the sacrospinalis and the crest of the ilium; in the deeper part of the dissection the surgeon should keep close to the front of the transverse process of the fourth lumbar vertebra.

Diaphragm, Liver, Stomach, and Large Intestine.—Posteriorly the **right arch of the diaphragm** and the right lobe of the liver extend upwards to the level of the angle of the scapula (eighth rib), while the **left arch** and the fundus of the stomach lie one inch lower (eighth interspace); the central tendon reaches up to the eighth thoracic spine. The **right lobe of the liver** is covered posteriorly by the eighth to the twelfth ribs, and is overlapped by the base of the right lung as far as a line drawn horizontally laterally from the tenth thoracic spine; hence, posteriorly, the superior limit of the liver cannot be defined by percussion, and its inferior limit merges into the dulness of the loin muscles and kidney.

The **cardiac orifice of the stomach** lies one inch to the left of the ninth thoracic spine. The cardiac portion, overlapped by the ninth to the twelfth ribs, extends upwards to the level of the eighth thoracic spine, one inch below the inferior angle of the scapula. The **pyloric portion** crosses the median plane opposite the first and second lumbar spines, the **pylorus** itself being situated one inch to the right of the first lumbar spine. The **lesser curvature** lies to the left of and below the tenth, eleventh, and twelfth thoracic spines.

Viewed from behind, the **large intestine**, on both sides, overlaps the lateral border of the kidneys and lies parallel to the lateral border of the sacrospinalis muscles. The peritoneum is reflected from the colon on to the posterior abdominal wall along a line drawn vertically upwards from the centre of the iliac crest. The **left flexure** of the colon, which reaches up to the level of the twelfth thoracic spine and the tenth rib, lies about five inches above the iliac crest. The **right flexure** lies on a level with the first lumbar spine.

Spleen.—The *spleen*, situated in the left hypochondrium, behind the cardiac end of the stomach, is overlapped by the ninth, tenth, and eleventh ribs, the long axis of the organ corresponding approximately to that of the tenth rib. Between the superior third of the spleen and the chest wall (pleura and diaphragm intervening) is the base of the left lung, the inferior margin of which crosses the organ horizontally at the level of the tenth thoracic spine. The costo-diaphragmatic reflexion of the pleura reaches down as far as the inferior angle of the spleen. The superior limit of the organ cannot therefore be defined by percussion; and unless enlarged, or displaced downwards, the spleen cannot be punctured from behind without traversing the pleural as well as the peritoneal cavity.

Of the *three angles* of the spleen, the *posterior or vertebral* lies at the same level as the inferior margin of the lung, $1\frac{1}{2}$ in. lateral to the tenth thoracic spine. The *inferior angle* lies opposite the eleventh intercostal space on a level with the first lumbar spine, in a line drawn vertically upwards from a point one inch behind the centre of the iliac crest. This angle is situated behind the superior part of the descending colon, immediately lateral to the middle of the lateral border of the

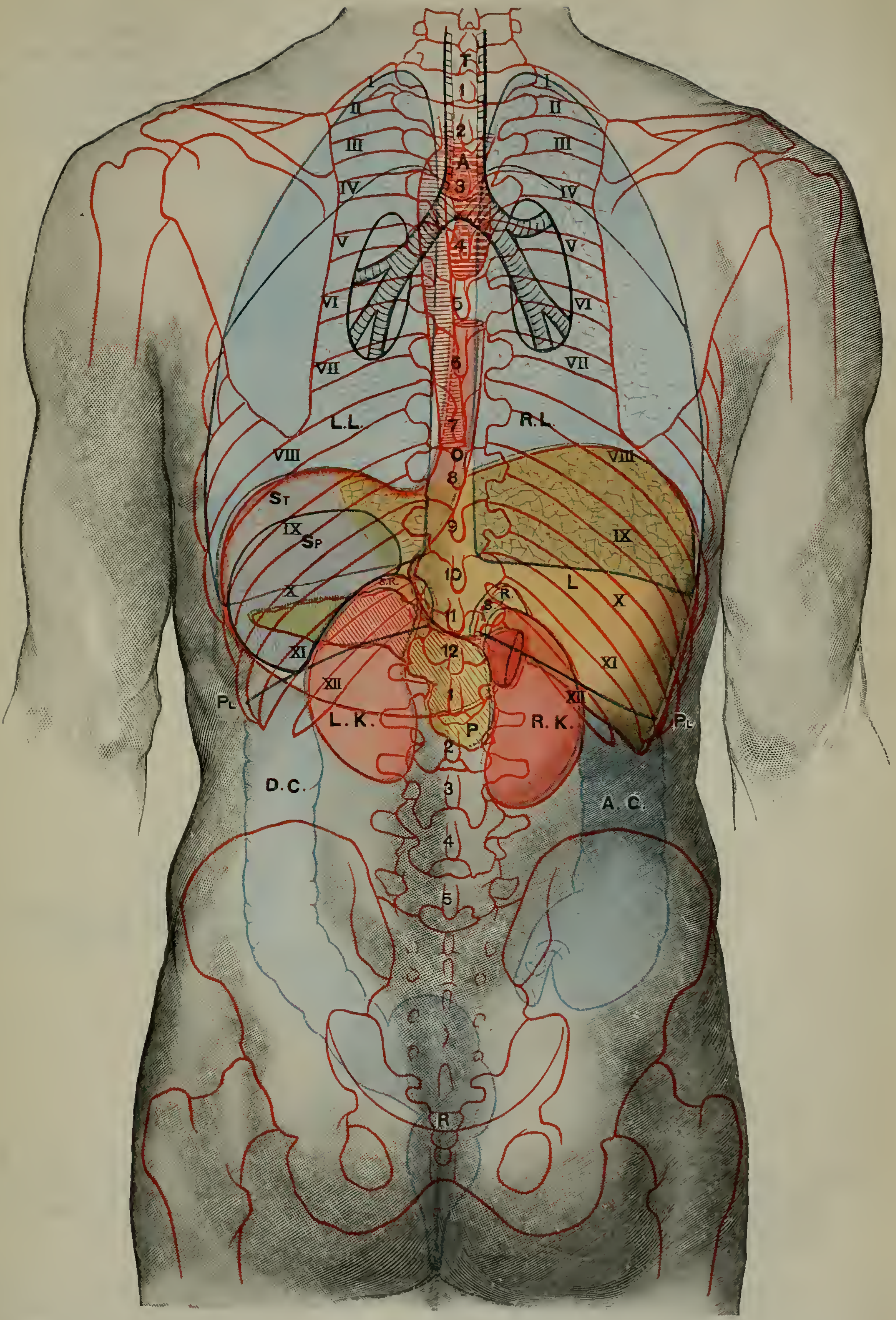

Fig. 1091.—Posterior Aspect of Trunk, showing Surface Topography of Viscera.

T.	Trachea.	Sp.	Spleen.	P.	Pancreas.
A.	Aorta.	L.	Liver.	Pl.	Pleura.
L.L.	Left lung	S.R.	Suprarenal gland.	D.C.	Descending colon.
R.L.	Right lung.	L.K.	Left kidney.	A.C.	Ascending colon.
St.	Stomach.	R.K.	Right kidney.	R.	Rectum.

kidney. The *anterior angle* is at the level of the ninth interspace in the mid-axillary line. Having placed a mark on the skin opposite these three angles the organ is mapped out on the surface as follows:—The *posterior margin* is obtained by joining the posterior and inferior angles; this margin, which gives the key to the position of the spleen, will be found to follow the tenth intercostal space. The short *inferior margin* corresponds to a line joining the anterior and the inferior angles; it is related to the left flexure of the colon. Commencing at the vertebral angle, the *anterior margin* is at first arched, the summit of the arch reaching to the level of the upper border of the ninth rib in the scapular line; thence it is continued downwards and forwards across the posterior axillary line as the "anterior crenated border" to the anterior angle. The upper arched portion lies parallel to and about one inch below the highest part of the fundus of the stomach. The only parts of the splenic outline which can be defined by percussion are the lower crenated part of the anterior margin, the anterior angle, and the short postero-inferior or colic border; and it is these parts which may be felt below the costal margin when the organ is considerably enlarged.

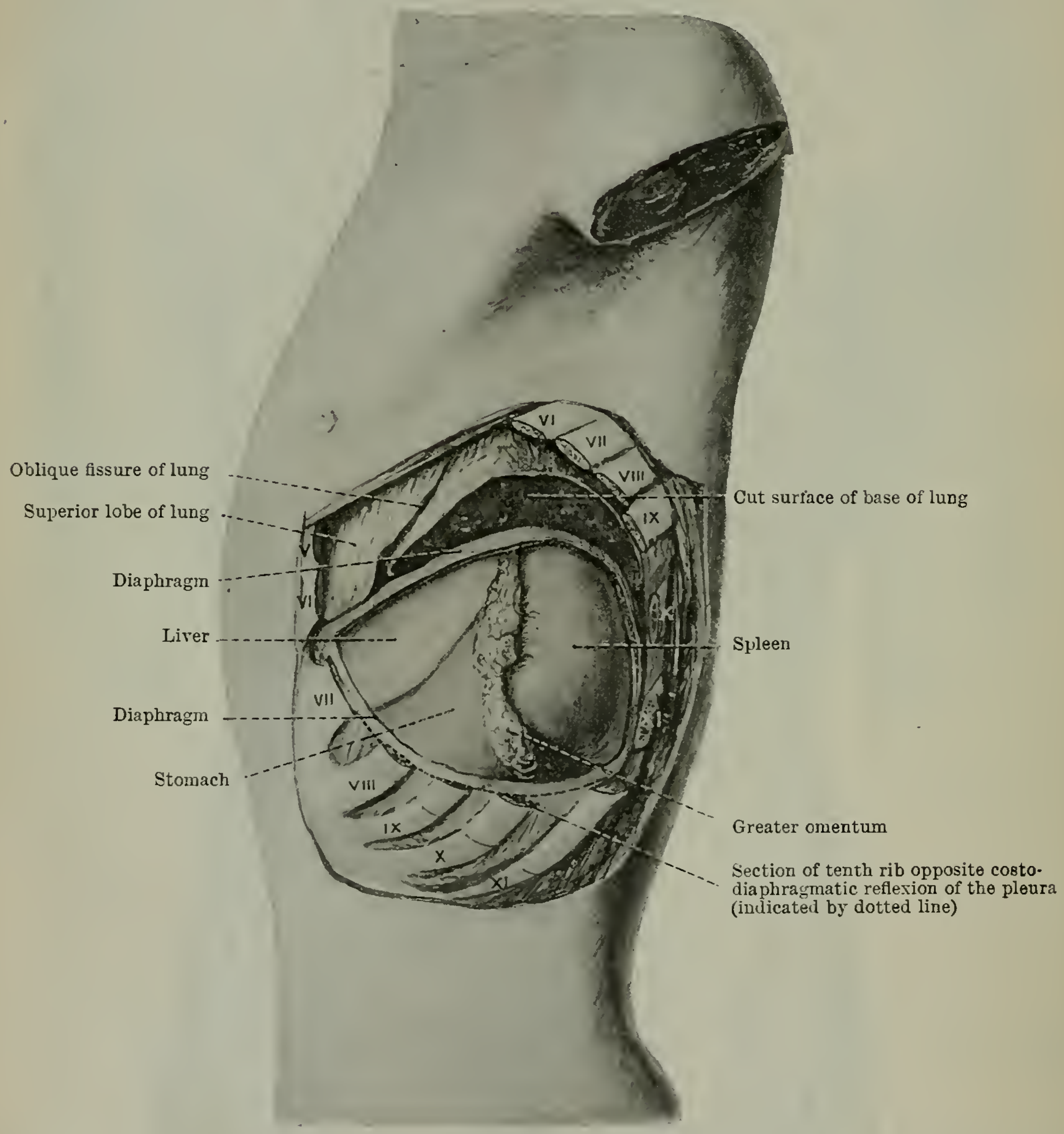
Oblique fissure of lung
Superior lobe of lung
Diaphragm
Liver
Diaphragm
Stomach
VI
VII
VIII
IX
Cut surface of base of lung
V
VI
Spleen
VII
VIII
IX
X
XI
Greater omentum
Section of tenth rib opposite costo-diaphragmatic reflexion of the pleura (indicated by dotted line)

FIG. 1092.—DISSECTION OF THE LEFT HYPOCHONDRIUM TO SHOW THE RELATIONS OF THE SPLEEN TO THE SIDE WALL OF THE CHEST, THE DIAPHRAGM, AND THE ADJACENT VISCERA. In addition to the portions of ribs, there has been removed a part of the base of the left lung, and a window has been made in the diaphragm almost down to the level of the costo-diaphragmatic reflexion of the pleura.

TABLE INDICATING THE LEVEL OF THE MORE IMPORTANT STRUCTURES IN RELATION TO THE SPINES OF THE VERTEBRÆ.

Spines of Vertebræ.	Origins of Spinal Nerves.	Level of other Structures.
1 Cervical	2 Cervical	Soft palate.
2 ,,	3 ,,	Isthmus of fauces.
3 ,,	4 ,,	Upper part of epiglottis.
4 ,,	6 ,,	Vocal folds (O.T. cords).
5 ,,	7 ,,	Conus elasticus.
6 ,,	8 ,,	Arch of thoracic duct. Commencement of trachea and œsophagus.
	1 and 2 Thoracic	Inferior end of cervical enlargement of spinal medulla. Inferior cervical ganglion of sympathetic. Apices of lung.
1 Thoracic	3 ,,	Summit of arch of subclavian artery.
2 ,,	4 ,,	Medial angle of scapula. Just above level of highest part of arch of aorta. Jugular notch.
3 ,,	5 and 6 ,,	Root of spine of scapula. Arch of vena azygos. Highest part of inferior lobes of lungs. Termination of arch of aorta. Bifurcation of trachea. Lower limit of superior mediastinum. Angulus sterni.
4 ,,	6 ,,	Commencement of descending thoracic aorta. Bronchi. Superior limit of heart.
5 ,,	8 ,,	Centre of root of lung. Mitral orifice.
6 ,,	9 ,,	Tricuspid orifice.
7 ,,	10 ,,	Inferior angle of scapula. Orifice of inferior vena cava. Right arch of diaphragm.
8 ,,	11 ,,	Lowest limit of heart. Left arch of diaphragm. Fundus of stomach. Xiphi-sternal articulation.
9 ,,	12 Thoracic and 1 Lumbar	Superior limit of spleen.
10 ,,	2 Lumbar	Cardiac orifice of stomach. Upper end of lumbar enlargement. Lower border of lung, posteriorly. Vertebral angle of spleen (apex of spleen). Superior end of left kidney. Lesser curvature of stomach.
11 ,,	3 and 4 ,,	Lower limit of pleura at vertebral column. Superior end of right kidney. Suprarenal gland. Body of pancreas. Lesser curvature of stomach.
12 ,,	1, 2, 3 Sacral	Level at which pleura crosses twelfth rib. Inferior end of spleen. Left flexure of colon. Superior part of head of pancreas. Pylorus and pyloric portion of stomach.
1 Lumbar	4 and 5 Sacral	Conus medullaris. Lower limit of pleura (mid-axillary line). Hila of kidneys. Head of pancreas. Right flexure of colon. Portal vein. Descending part of duodenum. Greater curvature of stomach. Bile-duct.

TABLE INDICATING THE LEVEL OF THE MORE IMPORTANT STRUCTURES IN RELATION TO THE SPINES OF THE VERTEBRÆ—*Continued.*

Spines of Vertebræ.	Origins of Spinal Nerves.	Level of other Structures.
2 Lumbar . .	...	Commencement of ureters. Lowest part of head of pancreas.
3 ,, . .	...	Inferior limit of spinal medulla in child. Inferior ends of kidneys. Horizontal part of duodenum.
4 ,, . .	...	Highest part of crest of ilium. Bifurcation of aorta. Umbilicus.
5 ,, . .	...	Common iliac arteries. Valve of the colon.
1 Sacral . .	...	Sacral promontory.
2 ,, . .	...	Lower end of sub-dural space.
3 ,, . .	...	Superior end of gluteal cleft. Inferior limit of sub-arachnoid and sub-dural spaces.

To excise the spleen the abdomen is opened by a vertical incision through the upper half of the left rectus muscle a little lateral to the middle line. The spleen is drawn forwards into the wound after displacing the stomach and transverse colon downwards and to the right. The vasa brevia are secured as they course between the two layers of the gastro-splenic omentum. The large splenic vessels, which form the main pedicle, lie between the two layers of the lieno-renal ligament. Care must be taken not to injure the tail of the pancreas, which not infrequently extends to the left across the lower part of the gastric surface of the spleen as far as its hilum. In a floating spleen its two peritoneal ligaments are elongated to form a distinct pedicle.

Pancreas.—The head of the pancreas lies opposite the last thoracic and first lumbar spines; the tail lies at the same level as the left flexure of the colon, a little above the inferior basal angle of the spleen.

Spinal Medulla.—While the spinal medulla usually ends opposite the inferior border of the first lumbar spine, it may terminate one vertebræ higher or lower; in the infant it reaches to the interval between the second and third lumbar spines. The *cervical enlargement,* which corresponds to the lower four cervical and the first two thoracic segments, ends opposite the seventh cervical spine. The five lumbar segments are opposite the last three thoracic spines. According to Elsberg the fourth cervical segment lies opposite the third cervical spine, the eighth cervical segment opposite the interspace between the fifth and sixth cervical spines, the fourth thoracic opposite the second thoracic spine, the eighth thoracic opposite the fifth thoracic spine, the twelfth thoracic opposite the ninth thoracic spine, the second lumbar opposite the tenth thoracic spine. The sacral segments correspond to the last dorsal and first lumbar spines (see Fig. 435, p. 520).

The nerve roots which arise below those of the first lumbar, and which go to form the cauda equina, are arranged in a right and a left bundle, with a median space between them. The highest roots occupy the most lateral position in the cauda, while the lowest are nearest the filum terminale.

To expose the spinal medulla by the operation of laminectomy the surgeon, after separating the muscles from the spines and laminæ, removes certain of the spinous processes along with their supra-spinous and inter-spinous ligaments. The next step consists in the removal of the necessary laminæ. This is not difficult in the cervical region where they are comparatively slender and do not overlap. In the thoracic region there is more difficulty, owing to the greater breadth of the laminæ and to their imbricated arrangement; in the lumbar region the difficulty arises from the greater depth and thickness of the laminæ. The bleeding comes mainly from (1) the posterior external vertebral veins, which form a plexus dorsal to the vertebral arches, and (2) from the internal vertebral plexus which occupies the fatty tissue between the dura and the spinal canal. After incising the dura mater and arachnoid cerebro-spinal fluid escapes. The anterior and posterior nerve roots are now exposed, and are seen to be separated by the dentate ligament which ends below in a fork-like manner opposite the first lumbar vertebra. As the first lumbar posterior root rests on the "fork," this structure serves as a guide to the nerve (Elsberg). Tumours which arise outside the cord, but within the dura, may be classified as anterior or posterior according as they lie in front of, or behind the dentate ligament. To reach an anterior tumour it is necessary to divide one of the tooth-like attachments of the ligament, and generally also one, or possibly two, adjacent posterior roots, after which the cord can be displaced backwards and towards the opposite side.

The **sub-dural space** extends down to the level of the second or third sacral spines. In performing the operation of *lumbar puncture* (Quincke) a fine trochar and cannula are introduced into the sub-arachnoid space below the level of the spinal medulla, the puncture being made $\frac{1}{4}$ to $\frac{1}{2}$ in. to one side of the interspinous ligament in the interval between the third and fourth or fourth and fifth lumbar spines. The fourth spine is at the level of the highest part of the crest of the ilium. The instrument should be directed medially towards the median plane and very slightly upwards. In the adult the distance of the dura mater from the surface is from 2 to 3 in., in the infant $\frac{3}{4}$ in.

Owing to the shape and arrangement of the articular surfaces of the vertebræ, dislocations without fracture are practically confined to the cervical region; they are commonest between the fifth and sixth vertebræ. The dislocation may be unilateral, but it is more frequently bilateral and incomplete. In both instances the cord may be only slightly bruised, in which case the paralysis will be only partial. In complete bilateral dislocations the cord is usually completely crushed, and when the lesion is at, or above, the level of the fourth cervical segment (origin of the phrenic nerves) death ensues rapidly from respiratory paralysis.

Fracture-dislocations of the vertebral column are commonest in the lower cervical and thoraco-lumbar regions; that is to say, where the movable cervical and lumbar regions join the more fixed thoracic region. The vertebral column above the injury is generally displaced forwards, so that the spinal medulla is often severely lacerated or completely torn across by the superior end of the portion of the column below the fracture. It is important to remember that, in consequence of the shortness of the spinal medulla as compared with the vertebral column, the origins of the spinal nerves are at a higher level than their exits from the vertebral canal. The distance between origins from the spinal medulla and exits through the intervertebral foramina becomes greater the further down the nerves are, the lowest nerve trunks running almost vertically downwards. The cervical nerves leave the vertebral canal *above* the vertebræ after which they are named (except the *eighth*, which is above the first thoracic vertebra); the thoracïc, lumbar, and sacral nerves, on the other hand, leave the canal *below* the correspondingly named vertebræ.

To understand the effect of **lesions of the spinal medulla**, it is necessary to be familiar with the sensory and motor distributions of the various spinal segments (see Figs. 600, p. 720, and 610, p. 736). Transverse lesions of the spinal medulla *above the fifth cervical spine* (that is, above the fibro-cartilage between the fourth and fifth cervical vertebræ) are quickly fatal, owing to paralysis of respiration, as the phrenic nerve arises mainly from the fourth segment. In transverse lesions of the cervical enlargement the *cutaneous insensibility* does not extend higher than a transverse line at the level of the second intercostal space. The diagnosis of the particular segment involved is arrived at by testing the motor and sensory functions of each segment. The sensory areas corresponding to the *lower four cervical* and the *first two thoracic segments* occupy the upper extremities, and are placed in numerical order from the lateral to the medial side of the limb. The sensory area corresponding to the *second*, *third*, and *fourth cervical segments* occupy the occipital region of the scalp, the back of the auricle, and the masseteric region, the whole of the neck, and the shoulders and upper part of the chest down to a horizontal line at the level of the anterior end of the third intercostal space. In a total transverse lesion of the spinal medulla in the *thoracic region*, the superior limit of the anæsthesia is horizontal, and reaches to the level of the terminations of the anterior rami of the spinal nerves which arise from the spinal segment opposite the vertebral injury. Hence the superior limit of the anæsthesia is at a much inferior level than that of the injured vertebra. For example, a fracture-dislocation at the level of the eighth thoracic vertebra involves the origin of the tenth thoracic nerve which ends at the level of the umbilicus. The sensory zone corresponding to the *fifth thoracic segment* is at the level of the nipples, that of the *seventh thoracic segment* is at the level of the xiphoid process, that of the *tenth* at the level of the umbilicus, while that of the *twelfth* reaches down, anteriorly, to the superior border of the symphysis. The sensory areas corresponding to the lumbar and sacral segments are seen in Figs. 619, p. 755, and 621, p. 763.

Goldthwait has shown that certain painful conditions, strains, and faulty postures connected with the lumbar and lumbo-sacral regions are pre-disposed to by, and associated with, architectural variations from what anatomists describe as the normal type.

The two well-marked variations from this normal type are (1) the congenital visceroptotic, narrow-backed, long-waisted, slender type of individual, and (2) the thick-set, broad-backed, heavy type.

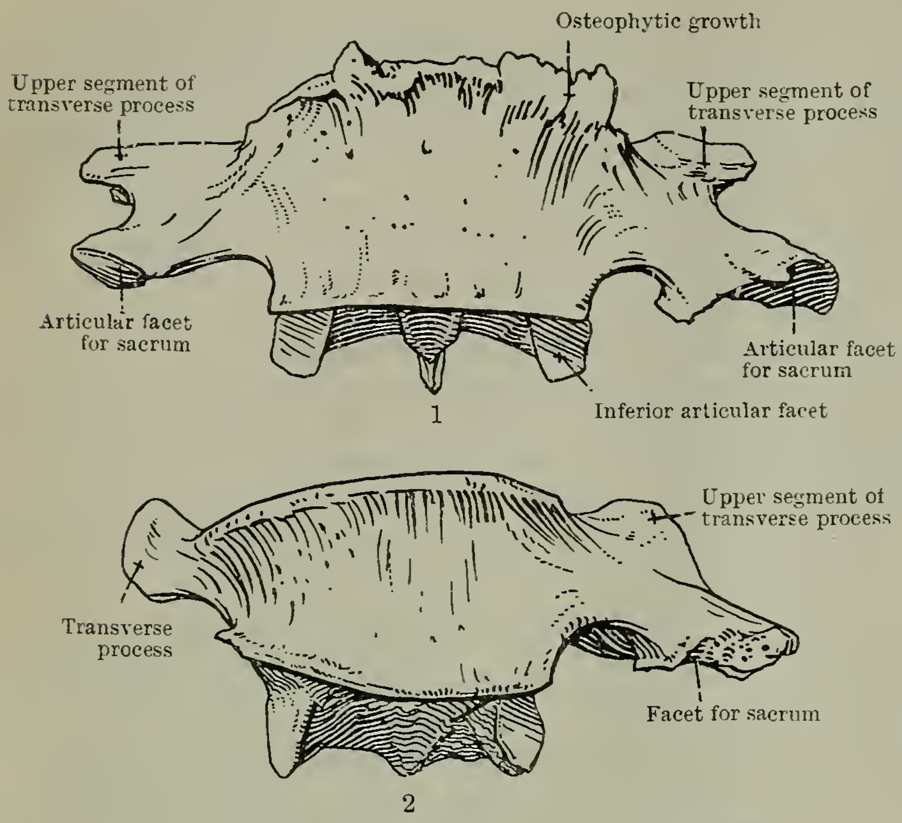
Osteophytic growth
Upper segment of transverse process
Upper segment of transverse process
Articular facet for sacrum
Articular facet for sacrum
Inferior articular facet
1
Upper segment of transverse process
Transverse process
Facet for sacrum
2

Fig. 1093.—Abnormal Fifth Lumbar Vertebræ.

In 1 both transverse processes articulated with the sacrum. In 2 only the left transverse process articulated with the sacrum.

In the visceroptotic type free motion takes place at the lumbo-sacral and thoraco-lumbar junctions as well as in the lumbar spine itself. The articular facets of the lumbar diarthrodial joints are less deep and less crescentic than in the normal type. The spine is, therefore, very flexible, and faulty attitudes are liable to occur. The most striking feature in this type is the exaggeration of the normal lumbar lordosis, produced principally by sharp angulation at the lumbo-sacral junction. From this region upwards the spine is comparatively straight as far as the lower cervical region, where a second sharp forward angulation takes place. This faulty attitude puts an extra strain on the sacro-iliac joint, and it is in this slender type of individual that relaxation and even displacement of the sacro-iliac joints are liable to be met with. Moreover the increased backward bending of the lumbar spine, combined with the tilting backwards of the sacrum, may result in the formation of painful bursæ or even of distinct articular facets between, more especially, the fourth and fifth lumbar and first sacral spines.

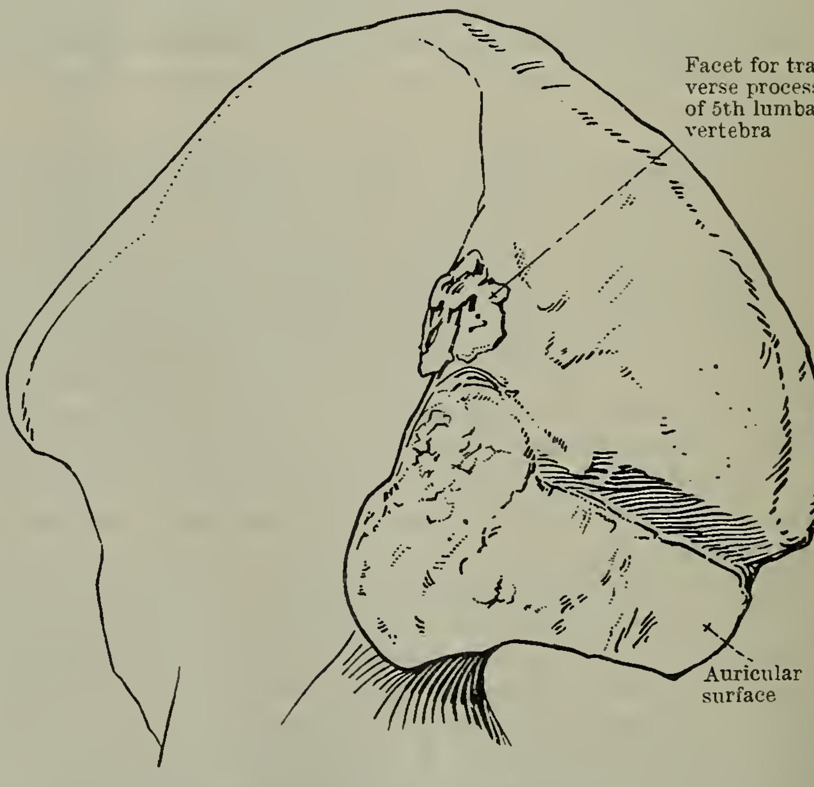

Fig. 1094.—Inner Surface of Ilium showing a Facet for the Enlarged Tip of the Fifth Lumbar Vertebra.

In the heavy, broad-backed, sthenic type of individual the lumbar vertebræ are broad and massive, the lumbar curve is comparatively slight as also is the forward inclination of the pelvis, and the axis of the sacrum approaches the perpendicular. The range of spinal movements is comparatively limited, so that a dropped and relaxed attitude of the body is anatomically more difficult to assume. In this type the greatest strain from faulty posture is thrown upon the diarthrodial joints at the junction of the fifth lumbar vertebra with the sacrum. It is in this type, therefore, that pain and disability due to lumbo-sacral strain is most commonly met with. In these individuals flexion or forward bending of the trunk takes place mainly at the hip joint, and on account of the greater depth and crescentic shape of the lumbar diarthrodial joints lateral bending takes place more especially in the lower thoracic region, where the facets of the joints are less deep and not so crescentic. In the lumbar region lateral flexion is impossible in the extended position on account of the locking of the diarthrodial joints. When the spine is bent forwards, lateral flexion is checked also by the quadratus lumborum and intertransverse muscles. A sudden unopposed action of the quadratus lumborum has been known to tear off the tips of one or more of the transverse processes. It is the depth and crescentic formation of the articular facets in the lumbar region which are the controlling factors in limiting lateral flexion in the lumbar region. If, however, the facet on one side is shallow and flattened transversely, the whole spine is liable to become listed over to that side.

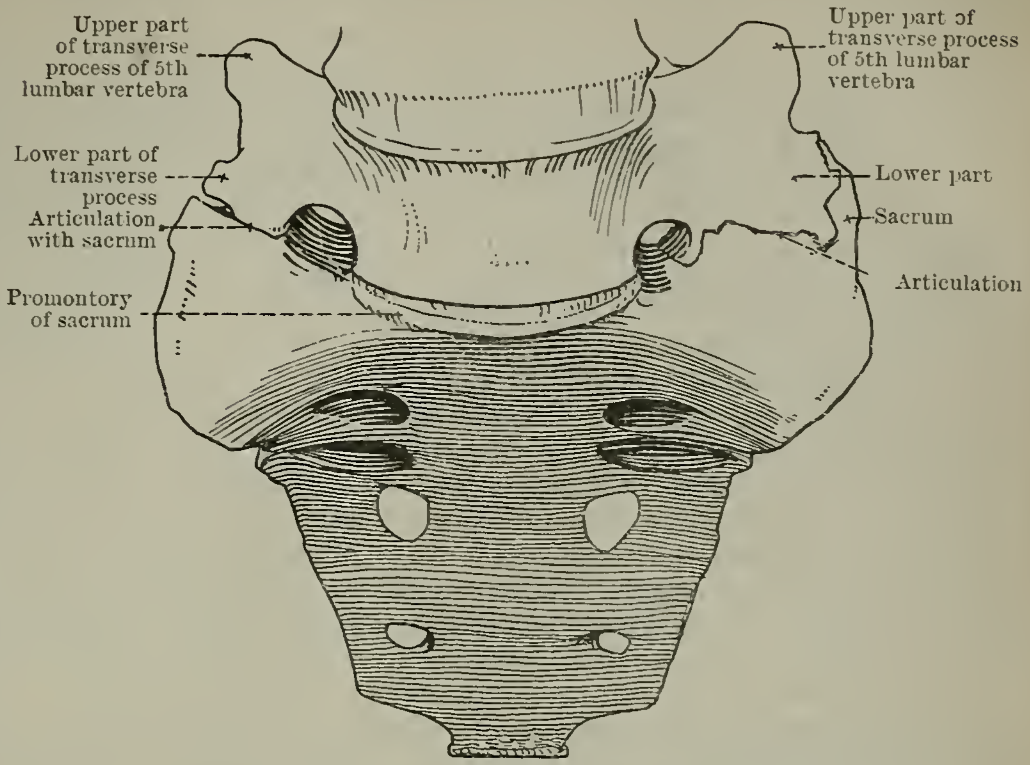
Upper part of transverse process of 5th lumbar vertebra
Lower part of transverse process
Articulation with sacrum
Promontory of sacrum
Upper part of transverse process of 5th lumbar vertebra
Lower part
Sacrum
Articulation

FIG. 1095.—SACRALISATION OF FIFTH LUMBAR VERTEBRA.

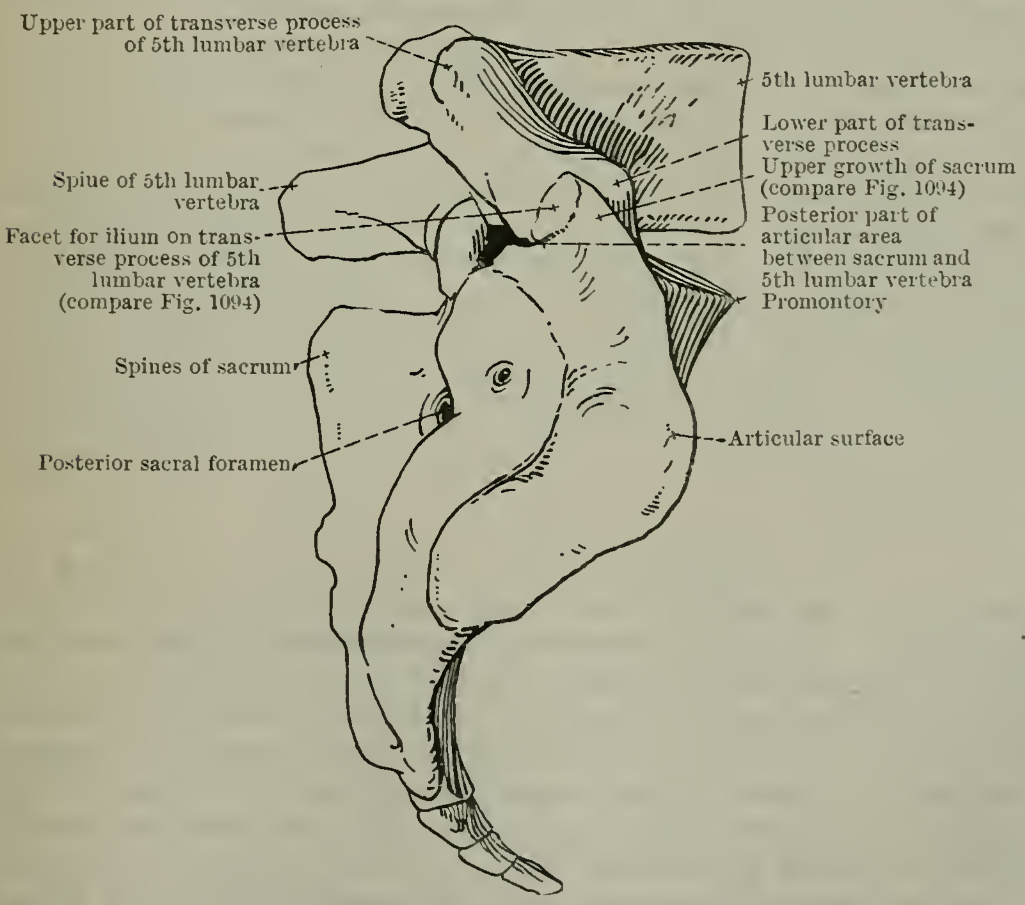
Upper part of transverse process of 5th lumbar vertebra
Spine of 5th lumbar vertebra
Facet for ilium on transverse process of 5th lumbar vertebra (compare Fig. 1094)
Spines of sacrum
Posterior sacral foramen
5th lumbar vertebra
Lower part of transverse process
Upper growth of sacrum (compare Fig. 1094)
Posterior part of articular area between sacrum and 5th lumbar vertebra
Promontory
Articular surface

FIG. 1096.—SACRALISATION OF FIFTH LUMBAR VERTEBRA. (Compare Figs. 1093, 1095.)

The most important anatomical variations which predispose to painful conditions and abnormal postures in the lumbo-sacral region are those connected with abnormalities in the transverse processes of the fifth lumbar vertebra. Normally, these processes are short and strong and give attachment to the strong ilio-lumbar ligaments which help to sling the trunk between the innominate bones. Sometimes these ligaments are more or less ossified on one or both sides. The comparatively short transverse processes of the fifth lumbar vertebra do not impinge against either the ilium or the sacrum during the movements of the spine. Sometimes, however, on one or the other side, this transverse process is much longer as well as much broader than normal, and when the extremity of such an elongated process, instead of being bluntly pointed, is expanded, or slightly bifid, it is liable to come in contact with the base of the sacrum, especially during lateral flexion of the spine. A bursa is always to be found between such a process and the top of the sacrum, when the former is not big enough or so situated as to form a true articulation with the sacrum, and one may form between it and the ala of the ilium (lumbo-iliac articulation). Such an articulation is, of course, developmental in origin, and by altering the statics of the spine predisposes to strain of the lower part of the back. Under such circumstances of irritation a bursitis or an arthritis of the abnormal joint not infrequently occurs. If the condition is unilateral the patient may take the pressure off the joint by listing over to the opposite side; the body of the fifth lumbar vertebra then becomes wedge-shaped, the base of the wedge being on the side of the abnormality. This is often the starting point of a scoliosis, and it may account also for the majority of cases of scoliosis associated with sciatica (scoliosis sciatica). Sometimes the transverse process of the fifth lumbar vertebra fuses not only with the base of the sacrum but also with the ilium so as to produce a complete unilateral or bilateral sacralisation of the vertebra. These "sacralisations" of the fifth lumbar vertebra, especially when unilateral and partial, are often associated with strain and osteo-arthritic changes in the lumbo-sacral and sacro-iliac joints. The presence of a lumbo-sacral transverse articulation, combined with osteo-arthritis of the sacro-lumbar joint on the same side, may result in a reduction in the size of the intervertebral foramen which transmits the anterior division of the fifth lumbar nerve. This foramen is bounded above by the lower border of the transverse process of the fifth lumbar vertebra, below by the base of the sacrum immediately medial to the psoas muscle, and laterally by the lateral lumbo-sacral ligament. Pressure on the nerve as it issues from this fibro-osseous foramen may account for the referred pain which is sometimes associated with these cases, while the branch of the fourth sacral nerve, which descends in front of the abnormal lumbo-sacral transverse articulation, is also liable to be pressed upon.

It is sometimes impossible to decide from a radiogram of the pelvis, taken in the strictly supine position, whether or not the transverse process of the fifth lumbar vertebra does actually articulate with the base of the sacrum. The difficulty is due to the circumstance that in the above position of the patient, the one usually adopted, the shadow of the posterior portion of the crest of the ilium is superimposed over the above-mentioned bones just where they would join if such an articulation existed. In order to throw the shadow of the ilium completely free of the transverse process of the fifth lumbar it is necessary to tilt the pelvis towards the opposite side; the radiographer can then say definitely whether or not this process is free from or articulates with the sacrum. Again, the manner in which the posterior part of the ilium overlaps the sacro-iliac joint makes it difficult for the radiographer to detect the presence of an osteo-arthritic or ankylosed condition of this joint. The most likely place to see these changes in a radiogram is at the lowest part of the joint shadow, where it is not overlapped by that which is cast by the posterior part of the ilium.

THE SHOULDER.

The bony landmarks of the shoulder must be systematically examined in all injuries about that region. The **medial extremity** of the **clavicle** is prominent; its articulation with the sternum forms essentially a weak joint, which is liable to be dislocated, especially from blows upon the lateral part of the shoulder which drive the medial end of the clavicle forwards against the weak anterior sterno-clavicular ligament. The **body** of the **clavicle**, subcutaneous throughout, is weakest at the junction of its two curves; it is in that region that the bone is so frequently fractured as the result of force transmitted through it to the trunk. The displacement of the lateral fragment varies according to whether the break takes place medial or lateral to the coraco-clavicular ligament; in the former case the weight of the upper extremity, acting through the coraco-clavicular ligament, pulls the lateral fragment downwards; when the fracture is lateral to the ligament, the lateral end of the clavicle rotates forwards, but there is no downward displacement. The **lateral end** of the **clavicle** is on a plane posterior to its medial end, so that the shoulder is braced backwards away from the thorax; hence in fractures of the clavicle, both medial and lateral to the coraco-clavicular ligament, the point of the shoulder rotates forwards and medially. The **acromio-clavicular articulation** is somewhat difficult to feel; the groove which corresponds to it runs in the sagittal direction, and lies 1¼ in. medial to the lateral border of the acromion, and immediately lateral to a slight prominence upon the lateral extremity of the clavicle. When the acromio-clavicular joint is dislocated the clavicle almost invariably over-rides the acromion, and the summit of the shoulder presents a somewhat conical or "sugar-loaf" appearance.

The **tip** of the **acromion** looks directly forwards, and lies a finger's breadth lateral to and a little in front of the lateral extremity of the clavicle. The **lateral border** of the **acromion** can readily be followed to its junction with the spine of the scapula, and the latter to its root, which is situated on a level with the third thoracic spine. The **medial border** of the **acromion** and the posterior border of the lateral end of the clavicle meet at an angle into which the point of the finger can be pressed. The **medial angle** of the **scapula**, covered by the trapezius and the supraspinatus muscles, is too deeply placed to be palpated distinctly. The **inferior angle**, and the **vertebral border**, from the root of the spine downwards, form visible prominences which are readily felt; the inferior angle overlies the seventh intercostal space on a level with the seventh thoracic spine, while the vertebral border lies a little medial to the angles of the ribs.

To elicit crepitus in a transverse fracture of the scapula below the spine, the surgeon stands behind the patient and grasps the upper fragment by placing the forefinger upon the coracoid and the thumb upon the spine, while, with the other hand, he grasps the inferior angle; the two fragments are then moved the one upon the other.

The **tip** of the **coracoid process** may be felt by pressing the finger firmly upon the anterior border of the deltoid at a point one inch below the junction of the middle and lateral thirds of the clavicle. Medial to the coracoid is a triangular depression which corresponds to the superior end of the interval between the clavicular fibres of the pectoralis major and deltoid muscles. Behind this triangular depression are the termination of the cephalic vein, a lymph gland, the first part of the axillary vessels, and the cords of the brachial plexus. By firm pressure in this situation the pulsation of the **axillary artery** can be felt, and by further pressure the circulation in the vessel can be arrested by compressing the artery against the second rib. The *first part* of the axillary artery may be cut down upon either by a transverse incision through the clavicular origin of the pectoralis major, or by a longitudinal incision in the interval between that muscular slip and the deltoid. The **companion vein** lies in front of, as well as to the thoracic side of, the artery, thus adding to the difficulty of exposing the vessel. In fractures of the middle third of the clavicle the subclavian vessels are protected by the soft pad formed by the subclavius muscle.

The **proximal extremity** of the **humerus**, covered by the deltoid, gives rotundity to the shoulder. The **greater tubercle** projects beyond the acromion, and constitutes the most lateral bony landmark of the shoulder. When the head of the bone is dislocated, the lateral border of the acromion then becomes the most lateral bony landmark, and the shoulder presents a square contour. The **lesser tubercle**, small but conical, can be felt through the deltoid. Pointing directly forwards, it lies one inch lateral to and a little below the level of the tip of the coracoid process. In examining the proximal extremity of the humerus for fracture, the tubercles should be grasped between the finger and thumb of one hand, while the flexed elbow is rotated with the other hand. The **head** of the **humerus** has the same direction as the medial epicondyle; its distal part can be palpated through the axilla, the arm being meanwhile abducted, to bring the head in contact with the inferior surface of the capsule. It is through this, the weakest part of the capsule, that the head is driven in the common varieties of dislocation of the shoulder, viz., those due to forcible abduction. The **proximal epiphysis** of the humerus includes the head and the greater part of the tubercles. The capsule is attached mainly to the epiphysis; hence, in children, we find that separation of the proximal epiphysis takes the place of dislocation. Disease in the proximal end of the diaphysis does not necessarily involve the cavity of the joint. The **intertubercular sulcus** of the humerus, which lies immediately lateral to the lesser tubercle, may be mapped out upon the surface by drawing a line, two inches in length, distally along the axis of the humerus from the tip of the acromion. When there is *effusion into the joint*, the arm becomes slightly abducted, and there is fulness in front, along the line of the long tendon of the biceps. With the elbow at the side the lower part of the capsule of the shoulder-joint is loose and folded upon itself to form a dependent pocket; if, after an injury, the arm is retained too long in this position, the patient may be unable to abduct the arm, in consequence of the formation of adhesions in and around the pouch.

To evacuate pus from the shoulder-joint, the integuments, deltoid, and capsule should be cut into by an incision passing vertically and distally from the tip of the acromion.

THE UPPER EXTREMITY.

THE AXILLA.

The **anterior fold** of the **axilla**, formed by the inferior border of the pectoralis major, extends from the fifth rib to the middle of the anterior border of the deltoid. With the arm abducted, the interval between the sternal and clavicular fibres of the pectoralis major is indicated by a slight groove extending distally and laterally from the medial end of the clavicle. The sternal fibres, along with the pectoralis minor, are removed in a complete operation for malignant disease of the breast, the pectoral branches of the thoraco-acromial artery being secured as they cross the interval between the sternal and clavicular portions of the greater pectoral. The **posterior fold** of the **axilla**, formed by the latissimus dorsi and the teres major muscles, is on a lower level than the anterior fold, and leaves the chest a little in front of the inferior angle of the scapula. Between the two folds, and running in the long axis of the limb, from the axilla to the middle of the arm, is the prominence of the **coraco-brachialis muscle**. The pulsations of the **third part of the axillary artery** may be felt in the furrow, immediately behind this prominence, at the junction of the anterior and middle thirds of the lateral wall of the axilla.

Female Mamma.—The breast tissue proper is arranged to form a central portion, the *corpus mammæ*, and a peripheral portion, made up of branching processes which radiate into the paramammary fat and become continuous ultimately with the connective tissue septa of the subcutaneous fatty tissue. The mamma, therefore, has no distinct capsule. In the young adult nullipara, the corpus mammæ is compact and well defined, and contains but little intramammary fat, while the peripheral processes are relatively small. In multipara, the corpus mammæ contains more fat, and the peripheral processes extend more widely into the paramammary fat.

The arrangement and extent of the parenchyma can be well seen by treating the breast with a 5 *per cent. solution of nitric acid.* If slices of the fresh organ are placed in this solution for a few minutes and then washed under running water, the albumen of the epithelial cells of the parenchyma is coagulated, while the connective tissue is rendered translucent and somewhat gelatinous. The *ultimate lobules* of the *parenchyma* now appear as little (1 to 2 mm.), dull, opaque, white, sago-like bodies, arranged in grape-like clusters around the finer branches of the ducts.

The parenchyma is prolonged into the peripheral processes, into the suspensory ligaments of Cooper, and into the loose retromammary cellular tissue and pectoral fascia. The breast tissue, therefore, has a much wider distribution than was formerly supposed. Vertically, it extends from the second rib to the sixth costal cartilage at the angle where it begins to ascend towards the sternum; horizontally, from a little medial to the lateral border of the sternum, opposite the fourth rib, to the fifth rib in the mid-axillary line. The *medial hemisphere* of the mamma rests almost entirely on the pectoralis major; at its lowest part it slightly overlies the upper part of the aponeurosis covering the rectus abdominis muscle. The *superior quadrant* of the *lateral hemisphere* rests upon the greater pectoral, on the edge of the lesser pectoral, and to a slight extent on the serratus anterior, upon which it extends upwards into the axilla as high as the third rib, where it comes into relation with the *thoracic* group of axillary lymph glands. The *remainder of the lateral hemisphere* rests almost entirely upon the serratus anterior, except the lowest part, which overlaps the digitations of the external oblique arising from the fifth and sixth ribs. It follows, therefore, that *fully one-third of the whole mamma lies inferior and lateral to the axillary border of the pectoralis major muscle.* The surgeon must cut beyond the above limits if he wishes to remove the whole of the mammary tissue.

The axillary fascia resists the spontaneous rupture of an axillary abscess, which, therefore, tends to spread upwards beneath the pectorals, and towards the root of the neck. To open the abscess the incision should be made upon the medial wall, behind, and parallel to, the lateral thoracic artery, which runs under cover of the anterior fold.

The **axillary lymph glands** vary greatly in size and number; many are no larger than a pin's head. In the female some of them undergo an adipose functional involution, whereby they come to resemble fat lobules. In health, one or two glands can usually be felt by thrusting the fingers upwards and medially beneath the anterior fold, the arm being only slightly abducted, so as not to stretch the axillary fascia. The *central group* (Leaf), embedded in the fat immediately beneath the axillary fascia, become inflamed in poisoned wounds of the upper extremity. The same group, along with the *pectoral group* (related to the medial wall of the axilla, at the inferior border of the pectoralis minor), are usually the first to become diseased in malignant affections of the breast. When the disease is more advanced the *posterior* (subscapular) and the *apical* (subclavicular) groups are generally affected as well; and Rotter has shown that in a considerable proportion of cases diseased glands are to be found in the *retro-pectoral fascia, i.e.* between the pectoralis major and minor and, above the latter muscle, on the first intercostal space in relation to the supreme thoracic artery. In operating for malignant disease of the breast, the surgeon removes, in addition to the whole breast and the greater part of the skin over it, both pectoral muscles (with the exception of the clavicular fibres of the pectoralis major), all the axillary lymph glands, and, as far as possible, all the fat and fascia, including the sheath of the axillary vein. It must be remembered that the distal part of the axillary vein lies immediately underneath the deep fascia of the lateral wall of the axilla; in cleaning the medial wall the long thoracic nerve must not be injured; and in removing the posterior group of lymph glands the thoraco-dorsal nerve, which accompanies the subscapular vessels, must be avoided, as it is doubly important to retain the action of the latissimus dorsi after removing the pectorals. The writer has so frequently met with disease in these retro-pectoral glands, that he is convinced of the necessity of removing the pectoral muscles.

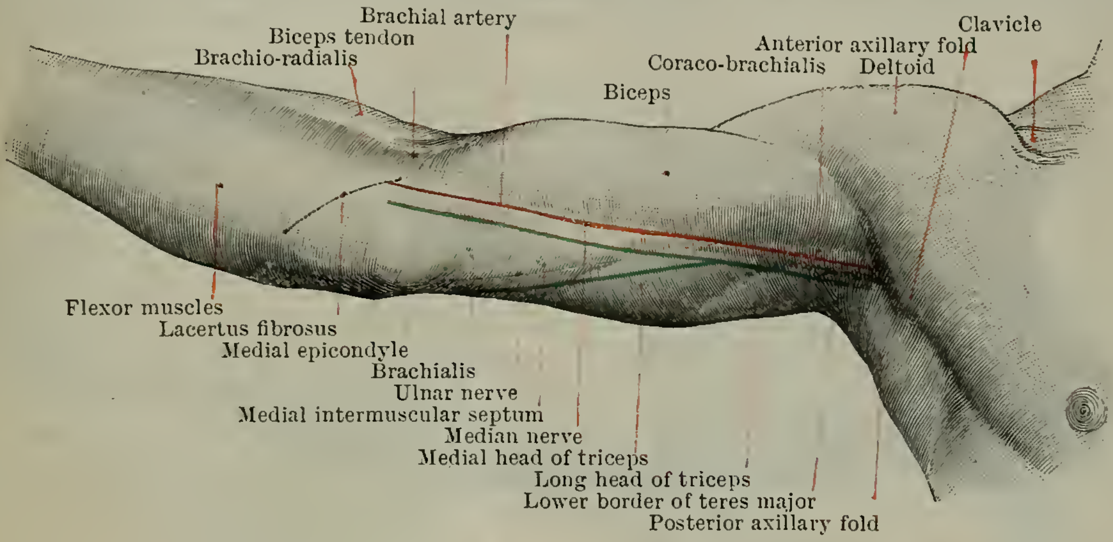

FIG. 1097.—AXILLA, MEDIAL ASPECT OF ARM AND ELBOW.

THE ARM.

The anterior and posterior borders of the **deltoid** may be traced from the shoulder girdle to the insertion of that muscle. The surface relations of the anterior border have already been referred to; the posterior border forms a well-marked and important landmark as it crosses the angle between the axillary margin of the scapula and the proximal part of the body of the humerus. By making an incision along this part of the posterior border of the deltoid, and retracting the edge of the muscle upwards and laterally, we expose the **surgical neck** of the **humerus**, and the quadrilateral opening in the posterior wall of the axilla, transmitting the posterior **circumflex artery** of the humerus and the **axillary nerve**; a little more distally is the radial nerve. The **coraco-brachialis**, the guide to the proximal half of the brachial artery, forms a prominence occupying the proximal half of the *medial bicipital furrow.* Traced distally the medial bicipital furrow widens out into an elongated triangle. This triangle, which may be termed the *medial supracondylar triangle,* becomes continuous, distally, with the medial part of the triangle in front of the bend of the elbow, and is limited posteriorly by the medial intermuscular septum, which may be felt as a cord-like band extending proximally from the medial epicondyle; the floor of the space is formed by the medial part of the brachialis. Within the triangle are the following important structures, enumerated from the lateral to the medial side, viz.: the **brachial artery**, the **median nerve**, the **distal part of the basilic vein**, the **medial cutaneous nerve of the forearm**, and the **superficial cubital lymph glands**, two or three in number. Extending proximally from the lateral epicondyle to the insertion of the deltoid is the lateral intermuscular septum, which is pierced at the junction of its proximal and middle thirds by the **radial nerve**. Between the lateral intermuscular septum and the lateral edge of the biceps is the ill-defined *lateral bicipital furrow*, the floor of which is formed by a strip of the brachialis, and, nearer the elbow, by the brachio-radialis and extensor carpi radialis longus.

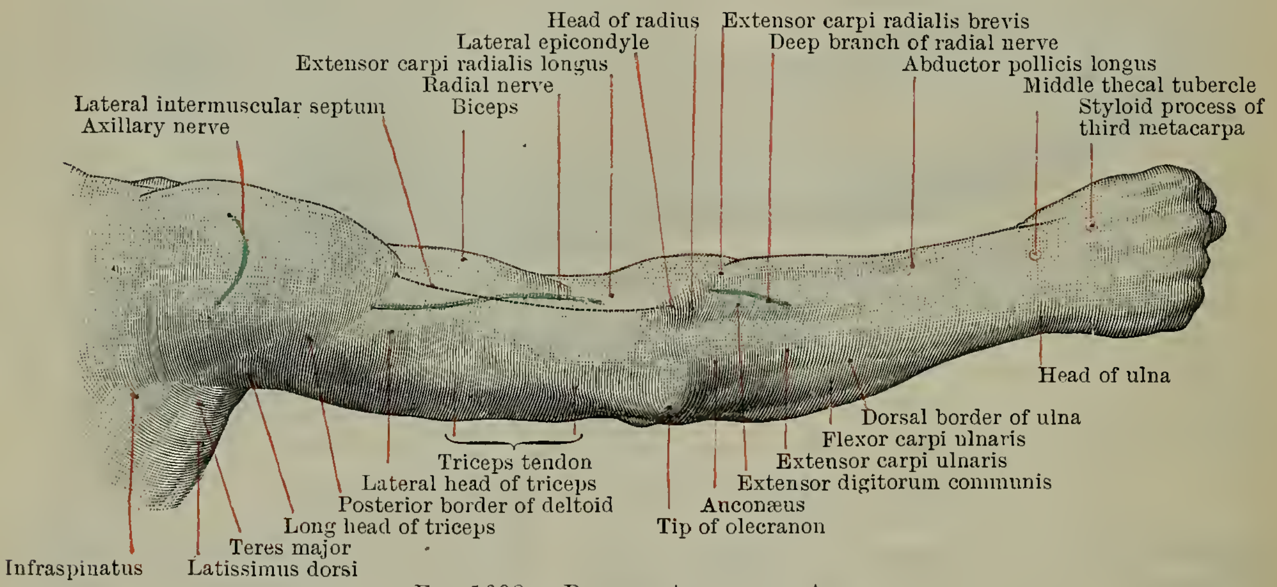

FIG. 1098.—DORSAL ASPECT OF ARM.

The posterior compartment of the arm is occupied by the **triceps**, the *long head* of which can be traced proximally to the axillary margin of the scapula, in front of the posterior border of the deltoid and behind the posterior fold of the axilla. The *lateral head* of the triceps, after emerging from under cover of the distal part of the posterior border of the deltoid, is continued obliquely along the lateral aspect of the arm as a well-marked muscular elevation. Proximal to the olecranon is the strap-like tendon of insertion of the triceps, which, when the elbow is fully flexed, forms an admirable posterior splint in supracondylar fractures of the humerus.

The **brachial artery**, slightly overlapped in the proximal half of the arm by the coraco-brachialis and in the distal half by the biceps, can be felt pulsating throughout the whole length of the anterior part of the medial bicipital furrow. The course of the vessel may be mapped out upon the surface by drawing a line from the medial border of the coraco-brachialis, at the level of the posterior fold of the axilla, distally to a point (opposite the neck of the radius) $\frac{1}{2}$ in. distal to the middle of the bend of the elbow. In ligaturing the vessel, the edges of the coraco-brachialis and biceps muscles, together with the median nerve, furnish valuable guides to the artery, the mobility of which is often a source of trouble in performing the operation.

The **basilic vein**, which is superficial to the deep fascia in the distal third of the arm, is visible in the medial supracondylar triangle and the distal part of the medial bicipital groove. The **cephalic vein** ascends a little anterior and medial to the lateral edge of the triceps to reach the interval between the deltoid and pectoralis major.

The surface guide for the **median nerve** is the same as that for the brachial artery. The **ulnar nerve** is indicated superficially by a line extending from the lateral wall of the axilla, immediately posterior to the prominence of the coracobrachialis, to the back of the medial epicondyle; in the proximal half of the arm the nerve lies close behind the brachial artery under cover of the basilic vein, while in the distal half it lies a little posterior to the medial intermuscular septum, partially embedded in the fibres of the medial head of the triceps. To map out the course of the **radial nerve**, first mark the point where it pierces the lateral intermuscular septum, viz., the junction of the proximal and middle thirds of a line extending from the insertion of the deltoid to the lateral epicondyle; from that point draw a line obliquely distally and forwards to the front of the lateral epicondyle, where the nerve divides into its superficial and deep branches. To map out the nerve as it lies in the radial groove, draw a line from the same point obliquely proximally across the prominence formed by the lateral head of the triceps to the junction of the posterior fold of the axilla with the arm. In fractures of the humerus in the neighbourhood of the insertion of the deltoid, the nerve is not infrequently lacerated, or so involved in the callus as to produce the condition known as "*drop-wrist*," the result of paralysis of the extensor muscles of the forearm. To cut down upon the nerve, commence the incision a little distal to the point where it pierces the lateral intermuscular septum, and carry it obliquely proximally and slightly backwards through the lateral head of the triceps.

The **shaft** of the **humerus**, nowhere subcutaneous, is most readily manipulated in the region of the insertion of the deltoid, proximally along the lateral head of the triceps, and distally behind the lateral supracondylar ridge. The **surgical neck**, situated between the tubercles and the attachments of the muscles inserted into the region of the intertubercular sulcus, is related to the lateral wall of the axilla, and is on a level with the junction of the proximal and middle thirds of the deltoid; at the same level are the circumflex vessels and the axillary nerve.

The shaft may be cut down upon with least injury to soft parts: (1) in its *proximal third, anteriorly*, by an incision extending distally through the anterior fibres of the deltoid, parallel, and a little lateral, to the intertubercular sulcus; the sheath of the biceps will thus be avoided, and the small, anterior circumflex artery will be the only vessel divided. (2) In the *proximal third, posteriorly*, by an incision through the posterior fibres of the deltoid, the bone being reached just lateral to the origin of the lateral head of the triceps, thus avoiding the radial nerve; the circumflex vessels and the axillary nerve will be exposed at the proximal part of the wound. (3) In the *distal third*, by an incision extending upwards from the back of the lateral epicondyle a little to the medial side of the lateral intermuscular septum.

THE ELBOW.

In injuries about the elbow the diagnosis rests mainly upon the relative positions of the bony points, which are, therefore, of great importance. The **epicondyles** of the humerus are both subcutaneous and upon the same level, the medial being the more prominent. In the extended position of the elbow the tip of the **olecranon** is on a level with a line joining the epicondyles; when the forearm is flexed the olecranon descends, and when full flexion is reached it lies 1 in. distal to the epicondyles, and in a plane anterior to the posterior surface of the distal end of the humerus. The **head** of the **radius**, which lies nearly 1 in. below the lateral epicondyle, is best manipulated from behind by placing the thumb upon it, while the semi-flexed forearm is being alternately pronated and supinated. Upon the lateral part of the posterior aspect of the extended elbow is a distinct dimple, which overlies the **radio-humeral articulation**; this dimple, along with the hollows on each side of the olecranon, becomes effaced in synovial thickenings and effusions into the joint. The **coronoid process** is situated too deeply to be distinctly felt. The **distal epiphysis** of the humerus includes the articular portion of the distal extremity and the lateral epicondyle; it is, therefore, small and almost entirely intra-articular, so that foci of disease in its neighbourhood soon invade the cavity of the joint. The medial epicondyle ossifies as a separate epiphysis which unites with the distal end of the diaphysis. In interpreting skiagrams of the elbow of children about six years of age and upwards, care must be taken not to mistake the centre of ossification in the lateral portion of the distal epiphysis of the humerus for a fracture. In the commonest dislocation of the elbow, viz., with backward displacement of both bones of the forearm, the normal relative position of the bony points is lost, whereas in a transverse supracondylar fracture the normal relations are maintained. In the child the head of the radius is relatively smaller, and less firmly kept in position by the annular ligament than in the adult, so that it is liable to be partially dislocated, giving rise to the condition known as "*pulled elbow.*"

To evacuate pus from the elbow-joint a vertical incision should be made over the dorsal aspect of the joint, immediately lateral to the olecranon.

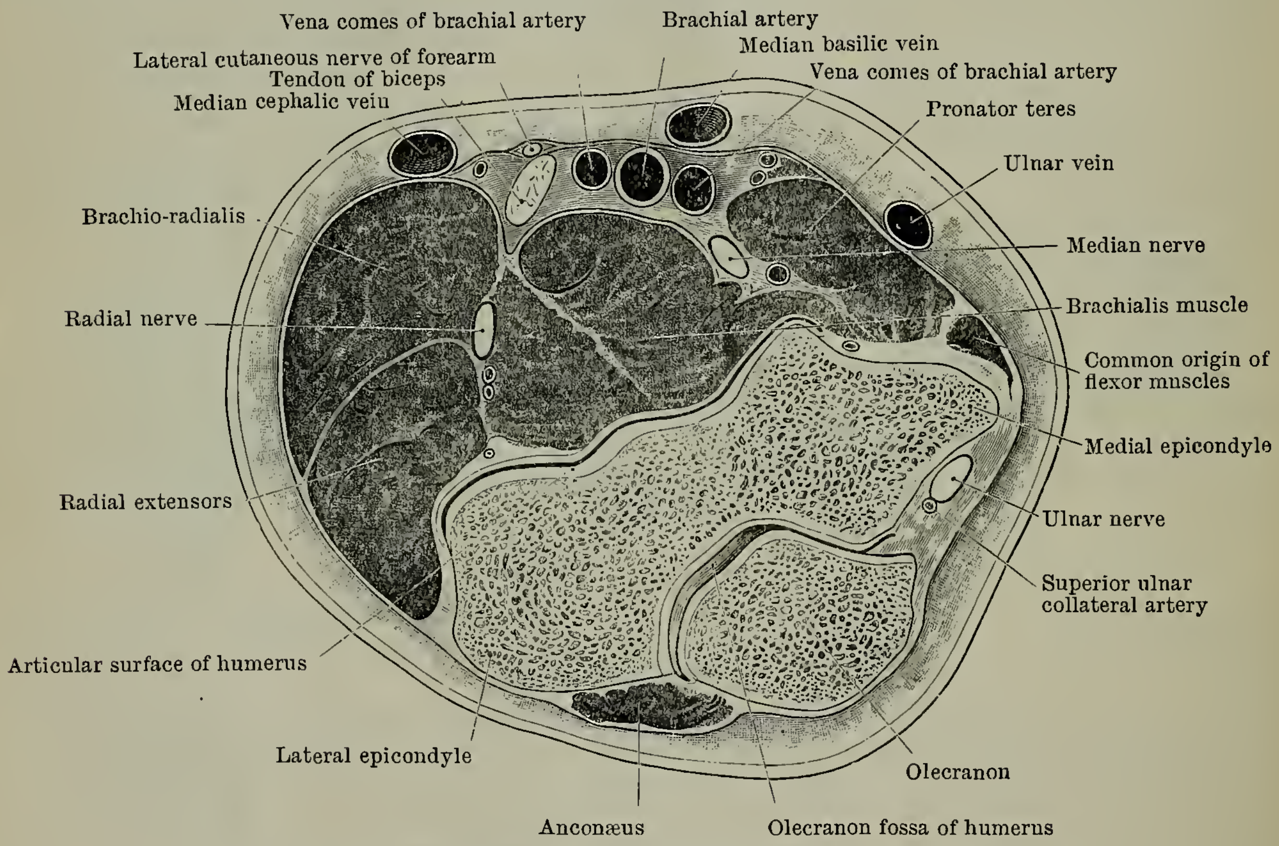

FIG. 1099.—TRANSVERSE SECTION THROUGH THE BEND OF THE ELBOW.

The **median vein** is seen to bifurcate into the median basilic and median cephalic veins $\frac{1}{2}$ in. distal to the middle of the bend of the elbow; opposite the same point, but beneath the deep fascia, is the **bifurcation** of the **brachial artery.** The **median basilic** and **median cephalic** veins diverge as they ascend one on each side of the biceps tendon; the larger of the two veins, viz., the median basilic, is usually selected for the operations of venesection and transfusion. When the elbow is flexed the **biceps tendon** can be traced vertically through the centre of the bend of the elbow almost to its insertion. Passing distally and medially from the medial edge of the tendon is the **lacertus fibrosus,** which separates the median basilic vein from the brachial artery. If the finger nail is insinuated beneath the medial edge of the lacertus fibrosus the point of the finger will rest upon and feel the pulsations of the brachial artery. The **median nerve** descends through the space a little medial to the brachial artery. The bifurcation of the **radial nerve** takes place in front of the lateral epicondyle under cover of the brachio-radialis. The **ulnar nerve** can be rolled beneath the finger upon the back of the medial epicondyle; its position renders it liable to injury in severe fractures about the elbow; and in excising the joint care must be taken not to injure the nerve.

THE FOREARM AND HAND.

The proximal half of the **radius** is deeply placed; the distal half, however, is easily palpated. The anterior border of its distal extremity is felt as a prominent transverse ridge, situated 1 in. proximal to the thenar eminence; immediately distal to the ridge is the **radio-carpal articulation.** The **tip** of the **styloid process,** situated nearly ½ in. more distal than that of the ulna, is deeply placed at the lateral side of the wrist, in the hollow between the extensor tendons of the first and second phalanges of the thumb. Upon the middle of the posterior surface of the distal end of the radius is the **dorsal radial tubercle,** which intervenes between the extensor pollicis longus and the short radial extensor of the wrist; the tubercle can be distinctly felt, and may be taken as a guide to the proximal end of Lister's dorso-radial incision for excision of the wrist. The dorsal border of the ulna is subcutaneous throughout, and may be felt along the interval between the flexor and extensor carpi ulnaris muscles. Upon the ulnar side of the dorsal aspect of the wrist, when the forearm is in the prone position, there is a well-marked rounded prominence formed by the **distal extremity** of the **ulna,** anterior to which is the **styloid process,** the deep groove between the two being occupied by the tendon of the extensor carpi ulnaris.

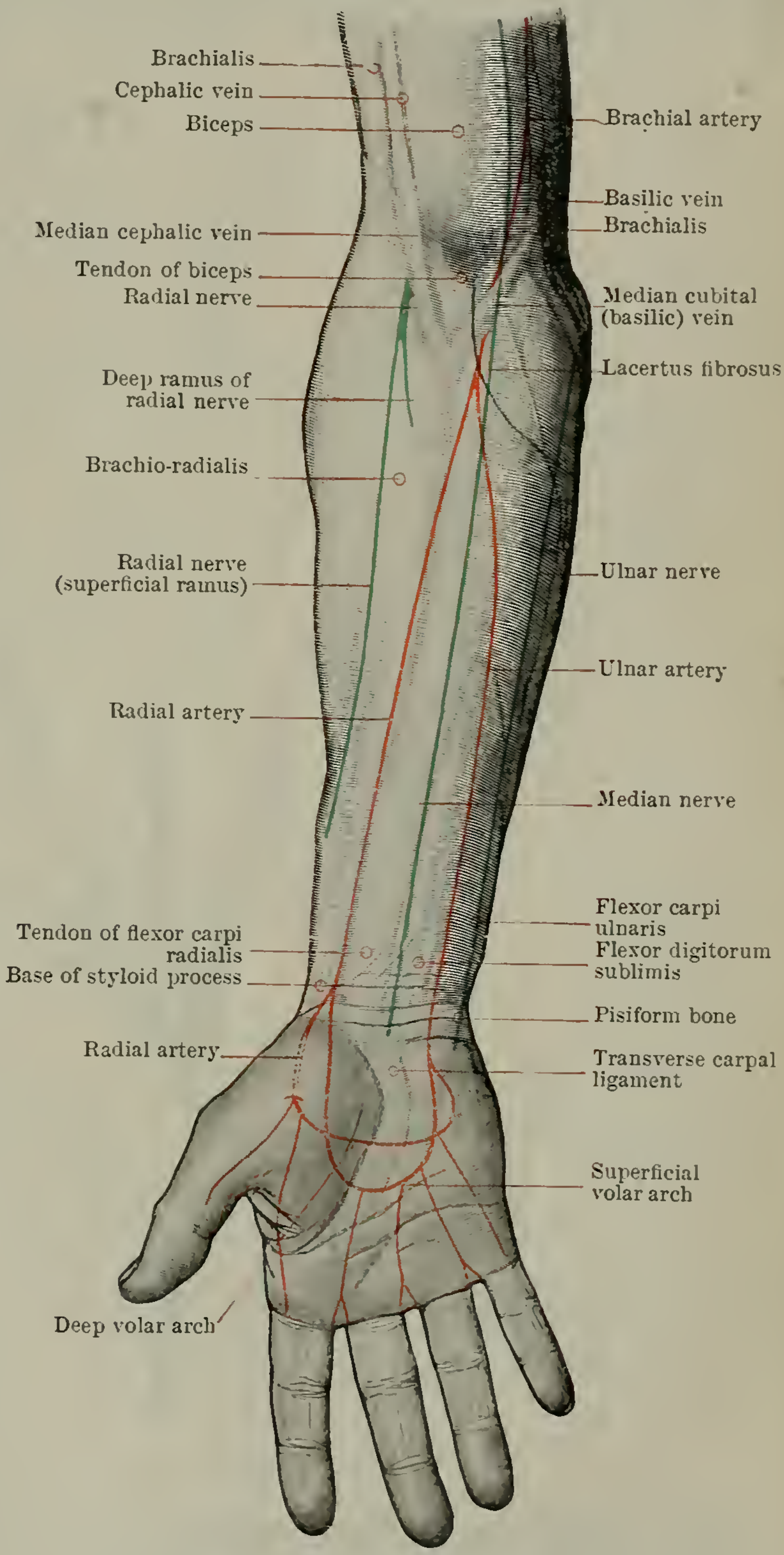

FIG. 1100.—BEND OF ELBOW, VOLAR SURFACE OF FOREARM, AND HAND.

The **carpal bones** are built up so as to form an arch, converted by the **transverse carpal ligament** into a tunnel for the transmission of the flexor tendons. At each extremity of the arch the two bony points to which the ligament is attached furnish important landmarks. These bony points are: *laterally,* the tuberosity of the navicular and the ridge of the greater multangular bone; *medially,* the pisiform and the hamulus of the os hamatum. The **tuberosity** of the **navicular** is felt immediately proximal to the root of the thenar eminence, midway between the tendons of the abductor pollicis longus and the flexor carpi radialis; ½ in. distal to the tuberosity of the navicular is the **ridge** of the **greater multangular bone,** felt deeply beneath the medial part of the thenar eminence. At the root of the hypothenar eminence, and crossed by the crease which separates the forearm from the hand, is the **pisiform bone**, proximal to which is the tendon of the flexor carpi ulnaris, passing to be inserted into it. The **hamulus** of the **os hamatum** is felt deeply beneath the radial side of the hypothenar eminence, and a full finger's breadth distal and lateral to the pisiform.

The bases of the **first**, **third**, and **fifth metacarpals**, all of which can be readily identified on the dorsal aspect, furnish a sufficient guide to the line of the carpo-metacarpal articulations. At the base of the **third metacarpal** is a tubercle, which can be felt projecting from its dorsal aspect at a point $1\frac{3}{4}$ in. vertically distal to the tubercle upon the back of the distal end of the radius. This metacarpal tubercle marks the insertion of the extensor carpi radialis brevis, the favourite site for the development of a "*ganglion*," which may frequently be ruptured by pressing it firmly against the tubercle. Anteriorly, the carpo-metacarpal articulations correspond to the distal border of the transverse carpal ligament.

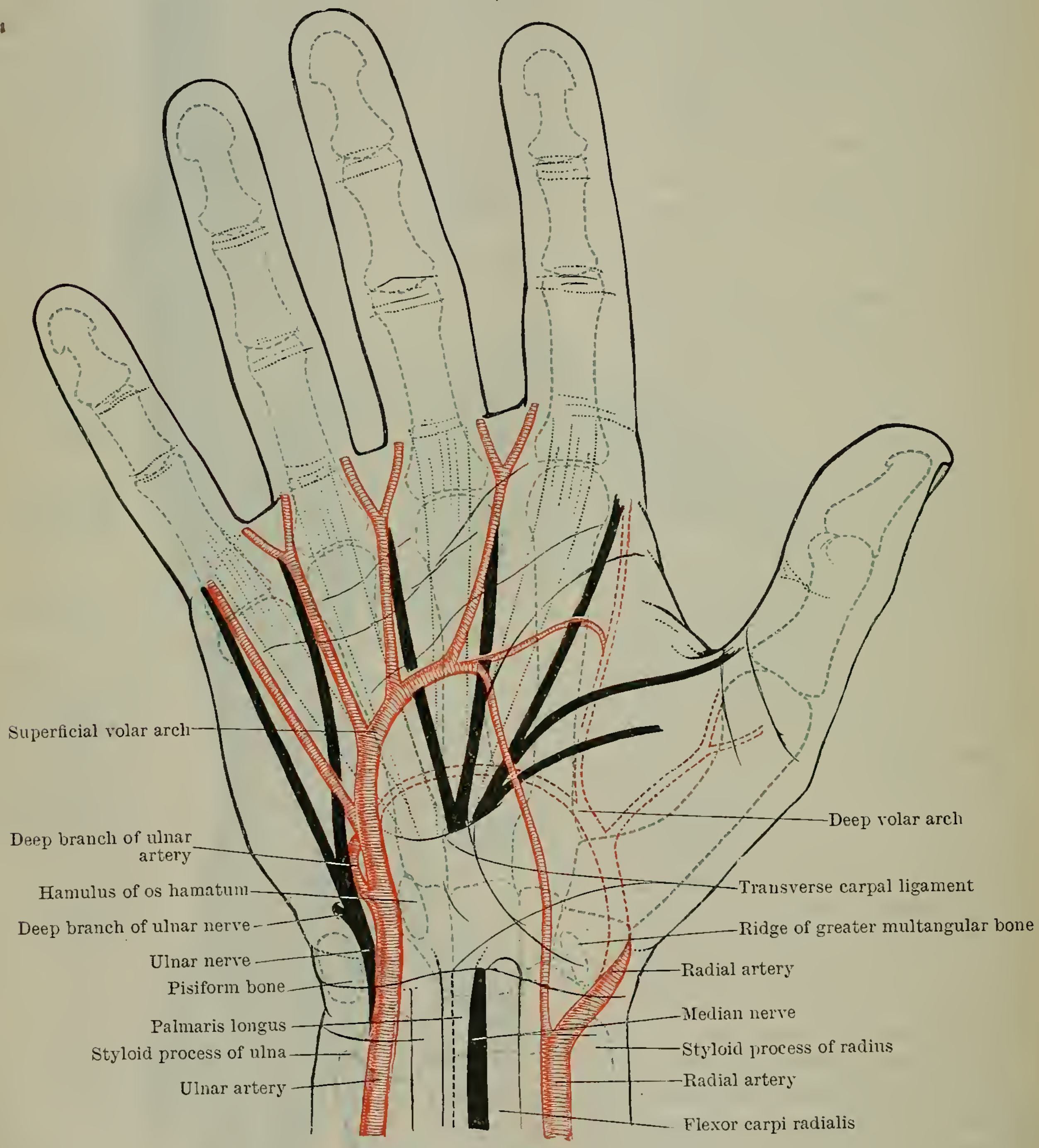

FIG. 1101.—PALM OF HAND.

The *prominences* of the *knuckles* are formed entirely by the heads of the metacarpal bones. Anteriorly, the **metacarpo-phalangeal articulations** are situated $\frac{3}{4}$ in. proximal to the level of the web of the fingers; posteriorly, the joints may be felt as a groove immediately proximal to the projecting ridge at the base of the first phalanges. A well-marked crease crosses obliquely over the anterior aspect of the metacarpo-phalangeal joint of the thumb. To cut into the **first interphalangeal joints** from the front, incise along the *most proximal* of the creases in front of the joints; whereas to cut into the **terminal joints**, incise along the *most distal* of the creases in front of the joints. Dorsally, the first and the terminal interphalangeal articulations are opposite the most distal of the various creases overlying the joints.

The most important *muscular* landmarks upon the front of the forearm are the brachio-radialis, the flexor carpi radialis, and the pronator teres. The **brachio-radialis** is thrown into prominence by flexing the semi-prone forearm against resistance. At the junction of the proximal and middle thirds of the forearm the **pronator teres** passes under cover of the brachio-radialis; between the two is the radial artery. The tendon of the **flexor carpi radialis** forms a prominent landmark descending along the middle of the volar aspect of the forearm towards the ridge of the multangulum majus; the tendon of the **palmaris longus**, when present, is seen to its medial side.

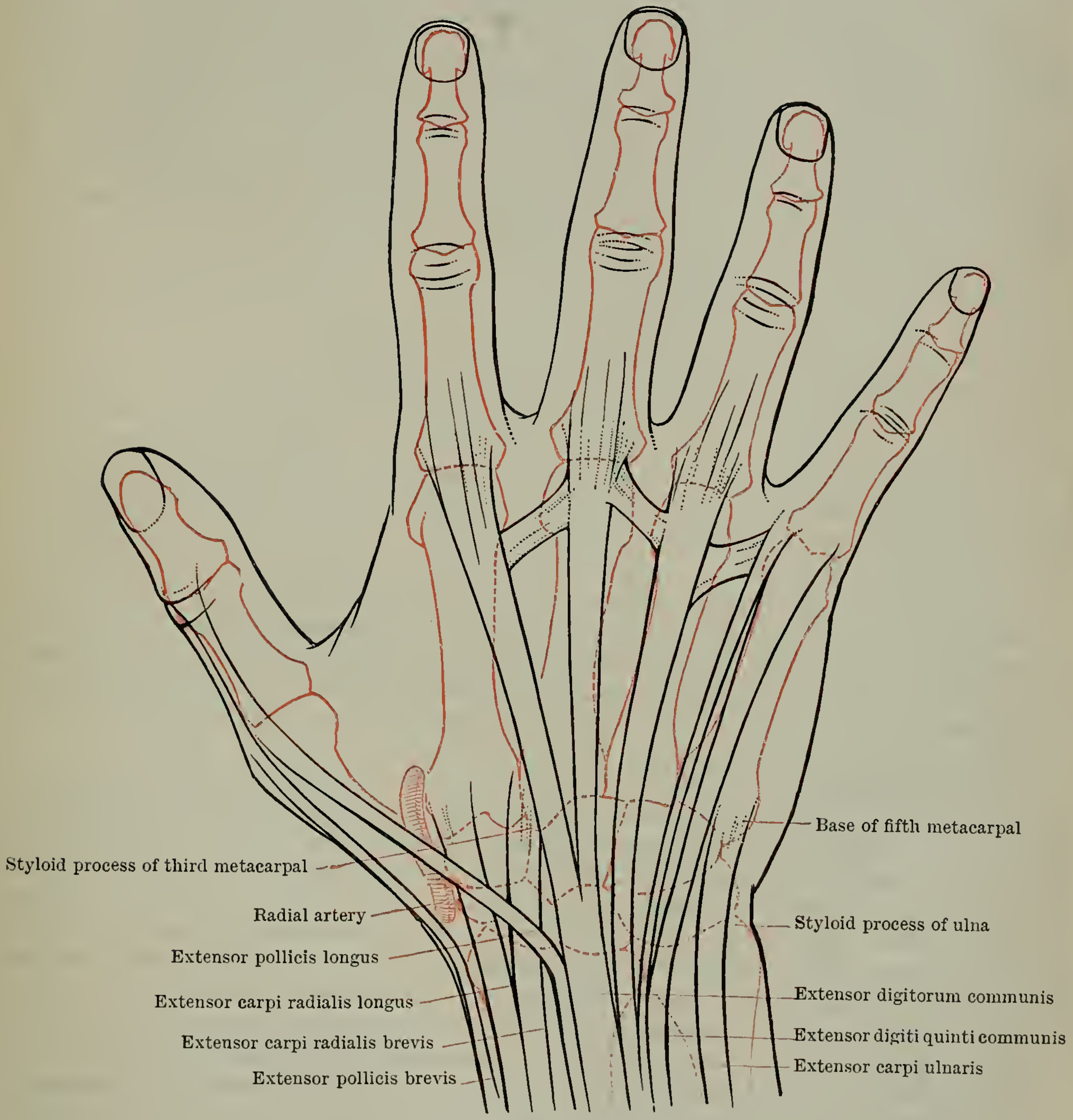
Base of fifth metacarpal
Styloid process of third metacarpal
Radial artery
Styloid process of ulna
Extensor pollicis longus
Extensor digitorum communis
Extensor carpi radialis longus
Extensor digiti quinti communis
Extensor carpi radialis brevis
Extensor carpi ulnaris
Extensor pollicis brevis

Fig. 1102.—Dorsal Aspect of Hand.

At the dorsum of the forearm the intermuscular septum between the radial and common extensors corresponds to the proximal part of a line extending from the lateral epicondyle of the humerus to the tubercle on the dorsum of the distal end of the radius. The **dorsal interosseous nerve**, at the point at which it emerges from the substance of the supinator muscle, will be found at the bottom of this septum, 2 in. distal to the head of the radius; below that point the septum is the best line along which to cut down upon the posterior surface of the radius. Winding across the distal third of the dorsal surface is an oblique prominence, caused by the abductor pollicis longus and extensor pollicis brevis muscles.

The flexor sheaths of the palm and of the digits are of surgical importance in consequence of their liability to suppurative inflammation. The **common flexor sheath** begins 1½ in. proximal to the transverse carpal ligament, under which it extends to a little beyond the middle of the palm. The **digital flexor sheaths** extend from the bases of the terminal phalanges to the level of the distal transverse crease of the palm, opposite the necks of the metacarpal bones, *with the exception of the sheath of the little finger*, which is continuous with the common flexor sheath of the palm. The **sheath of the flexor pollicis longus** extends from the base of the terminal phalanx proximally to a point about 1 in. proximal to the transverse carpal ligament; it frequently communicates with the common flexor sheath. From this anatomical arrangement it follows that suppuration in the sheaths of the little finger and thumb is specially liable to spread upwards into the palm, and thence underneath the transverse carpal ligament into the forearm.

The pulsations of the **radial artery** can readily be felt in the distal third of the forearm, midway between the lateral border of the radius and the tendon of the flexor carpi radialis. The course of the vessel is indicated upon the surface by a line extending from the bifurcation of the brachial (½ in. distal to the middle of the bend of the elbow) to the tubercle of the navicular, around which, and distal to the tip of the styloid process, the artery winds to the dorsum of the radial side of the wrist; in the latter situation the vessel, after passing deep to the extensor tendons of the thumb, dips into the palm through the proximal extremity of the first interosseous space. Incisions for opening or resecting the wrist are planned so as to avoid the vessel.

The proximal third of the **ulnar artery** is deeply placed, and takes a curved course from the bifurcation of the brachial towards the medial part of the volar surface of the forearm; the distal two-thirds of the vessel correspond to the distal two-thirds of a line drawn from the front of the medial epicondyle to the radial border of the pisiform bone. The course of the **ulnar nerve** corresponds to the whole of the above line.

The **median nerve** in the forearm may be mapped out by a line extending from a point midway between the centre of the bend of the elbow and the medial epicondyle, to a point midway between the styloid processes; in the distal third of the forearm the line follows the medial border of the tendon of the flexor carpi radialis. To evacuate pus spreading deeply up the front of the forearm, the incisions should be made on either side of the line corresponding to the median nerve. The superficial branch of the **radial nerve** winds to the dorsum of the forearm round the lateral border of the radius deep to the tendon of the brachioradialis, at the junction of the middle and distal thirds of the forearm.

The summit, or most distal part of the **superficial palmar arch**, corresponds to the mid-point of a line extending from the middle of the most distal transverse crease of the wrist to the root of the middle finger; a line drawn from the radial border of the pisiform bone across the hamulus of the os hamatum, and thence in a curved direction distally and laterally to this point, corresponds to the main or proximal part of the arch; the first and fourth digital branches overlie the fifth and third metacarpal bones respectively, while the second and third overlie the fourth and third interspaces respectively. The **deep arch** lies almost transversely, midway between the distal border of the transverse carpal ligament and the superficial arch. The **radialis indicis** corresponds to the radial border of the index-finger.

The **ulnar nerve** and the commencement of its two divisions lie immediately to the medial side of the superficial palmar arch, so that the pisiform and the hamulus of the os hamatum are the guides to the nerve. The **median nerve** emerges from under the transverse carpal ligament opposite the medial edge of the thenar eminence, while the digital branches to the thumb follow its distal margin.

Incisions for the removal of foreign bodies may therefore be made into the thenar with greater freedom than into the hypo-thenar eminence.

Incisions to evacuate deep-seated pus in the palm may be made in one or more of the following situations: (1) over the distal two-thirds of the second metacarpal bone; (2) over the distal half of the fourth metacarpal bone; (3) from the proximal part of the first incision an opening may be made through the first interosseous space on to the dorsum, care being taken to keep distal to the radial artery; (4) a longitudinal incision between the median and ulnar nerves, on the proximal side of the superficial palmar arch. At the wrist a longitudinal incision may be made immediately to the ulnar side of the palmaris longus tendon, thus falling between the lines of the median nerve and the ulnar artery. To open the **digital flexor sheaths**, incisions are made along the middle of the palmar surface of the fingers, opposite the first and second phalanges. The **proper digital vessels** and **nerves** pass distally along the sides of the fingers, nearer the flexor than the extensor surfaces. In cutting down upon the dorsal aspects of the phalanges, the incisions should be made to one or other side of the extensor tendon, preferably upon the ulnar side, to avoid division of the insertions of lumbrical muscles. The subcutaneous tissue of the palmar aspect of the terminal phalanges is connected by fibrous processes with the periosteum; hence the frequency of necrosis of the terminal phalanx in suppurative inflammations in this region.

THE LOWER EXTREMITY.

THE BUTTOCK.

The region of the hip or buttock extends from the crest of the ilium above to the gluteal fold below. The highest point of the **iliac crest**, situated a little posterior to its middle, is on a level with the fourth lumbar spine; the **anterior superior spine** of the **ilium** is directed forwards, and belongs to the groin, which it limits laterally; the **posterior superior spine**, situated at the bottom of a dimple or small depression, is on a level with the second sacral spine, and corresponds, therefore, to the middle of the **sacro-iliac joint**. Two and a half inches behind the anterior superior spine is a prominence upon the outer lip of the iliac crest; this prominence, which is termed the **tubercular point**, is the most lateral part of the crest, and has been referred to in dealing with the surface anatomy of the abdomen. A hand's breadth below the tubercle of the crest is the **greater trochanter** of the femur, the most lateral bony landmark of the hip; its anterior and posterior borders are best felt between the fingers and thumb, while the limb is slightly abducted to relax the ilio-tibial tract, and if the thigh is now rotated, it will be noted that the trochanter rotates round the segment of a circle, the radius of which is formed by the head and neck of the femur; in non-impacted fractures of the neck of the femur the trochanter rotates round the segment of a much smaller circle. *Nelaton's line*, drawn from the anterior superior spine to the most prominent part of the ischial tuberosity, crosses the hip at the level of the proximal border of the greater trochanter; this line is employed to ascertain the presence or absence of upward displacement of the trochanter. Chiene demonstrates the relative height of the trochanters by stretching two tapes across the front of the pelvis, one between the anterior superior spines, and the other between the proximal borders of the trochanters; the lower tape will converge towards the upper on the side of the upward displacement. A line prolonging the anterior border of the greater trochanter vertically upwards touches the iliac crest at the tubercular point. The **sciatic tuberosity**, in the erect posture, is overlapped by the distal border of the glutæus maximus; its most prominent part is felt a little proximal to the medial part of the gluteal fold. If the hip is rotated medially, the **lesser trochanter** of the femur may be felt by deep palpation proximal to the lateral end of the gluteal fold; it corresponds to the interval between the distal border of the quadratus femoris and the proximal border of the adductor magnus, and therefore, also, to the level of the medial circumflex artery of the thigh.

The **lower border** of the **glutæus maximus** lies a little above the **gluteal fold** medially, crosses it about its middle, and is continued distally and laterally to meet the proximal end of the furrow of the lateral intermuscular septum, at the junction of the proximal and middle thirds of the femur. The medial borders of the two great gluteal muscles are separated by the deep **gluteal cleft**, which extends upwards and backwards from the perineum to the level of the fourth sacral spine, where it opens out into the triangle upon the back of the sacrum. Anteriorly the buttock is limited by the prominence of the **tensor fasciæ latæ muscle**, which extends distally and somewhat backwards from the anterior end of the crest, to join the ilio-tibial tract distal to the root of the greater trochanter.

The superior **gluteal artery** reaches the buttock immediately below the upper border of the greater sciatic foramen, opposite a point corresponding to the junction of the upper and middle thirds of a line drawn from the posterior superior iliac spine to the upper border of the greater trochanter. To expose the vessel the incision should be made along this line, which has the advantage of running parallel to the fibres of the glutæus maximus, as well as parallel to the interval between the glutæus medius and piriformis muscles.

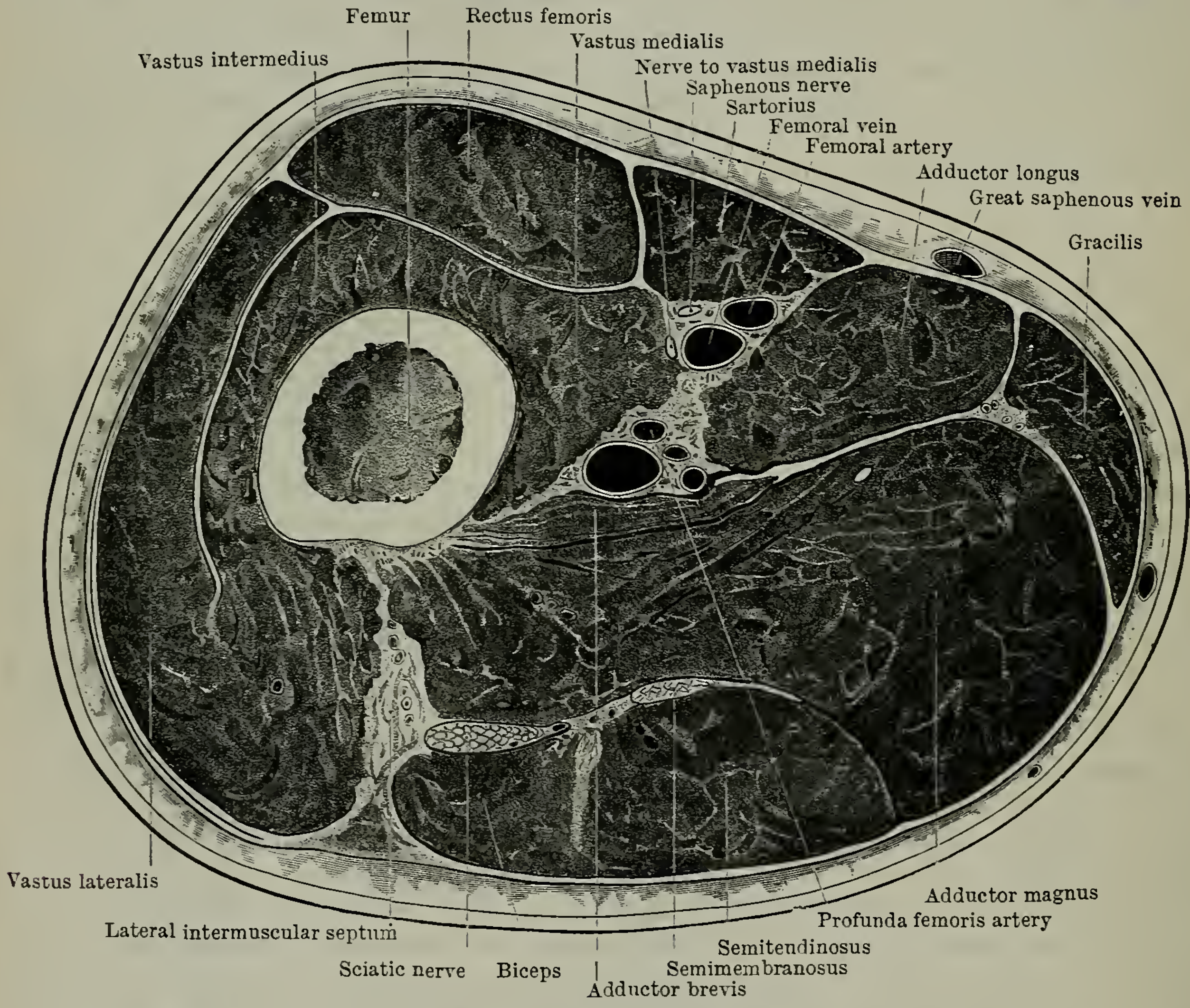

Fig. 1103.—Section through Thigh at the Level of the proximal part of the Adductor Canal.

The **sciatic nerve** enters the buttock at a point corresponding to the junction of the upper and middle thirds of a line drawn from the superior posterior iliac spine to the sciatic tuberosity; from this point the nerve passes downwards and slightly laterally upon the ischium to a point midway between its sciatic tuberosity and the greater trochanter. The **spine of the ischium** and the **pudendal vessels** are situated opposite the junction of the lower and middle thirds of the above line. The vessels and nerves which enter the buttock through the greater sciatic foramen *below the piriformis* may be exposed through an incision below and parallel to that above described for exposing the superior gluteal artery, viz., an incision corresponding to the middle two-fourths of a line extending from the upper end of the gluteal cleft to the root of the greater trochanter; the deep landmarks are the lower border of the piriformis and the root of the sciatic spine.

THE BACK OF THE THIGH.

The **hamstring muscles**, and especially the tendon of the biceps and semitendinosus, are thrown into prominence either by standing on tiptoes with the knees slightly flexed, or by flexing the leg against resistance. By throwing the hamstrings into action, the line of the **lateral intermuscular septum** of the thigh is indicated by a well-marked furrow, extending from the lower edge of the insertion of the glutæus maximus to the lateral aspect of the knee; behind this furrow is the **biceps femoris**, and in front of it is the large **vastus lateralis**, covered by the strong ilio-tibial tract of the fascia lata. The **shaft of the femur** may be cut down upon along the whole length of this furrow with least injury to the soft parts; the popliteal surface of the femur and deep-seated popliteal abscesses are most conveniently reached through the lower part of the same incision.

The course of the **sciatic nerve** corresponds to the proximal half of a line extending from a point midway between the sciatic tuberosity and the greater trochanter to the centre of the popliteal fossa. The nerve enters the thigh under cover of the lateral border of the biceps, whereas the **posterior cutaneous** nerve of the thigh which takes the same line, descends superficial to the biceps, between it and the fascia lata. In the operation of stretching the sciatic nerve it is cut down upon immediately distal to the lower border of the glutæus maximus. The surgeon, standing on the side of the patient opposite to the leg to be operated upon (Chiene), makes an incision in the line of the nerve through the integuments and fascia lata, and, sweeping the index-finger round the lateral border of the biceps, hooks up the nerve as it lies between that muscle and the adductor magnus.

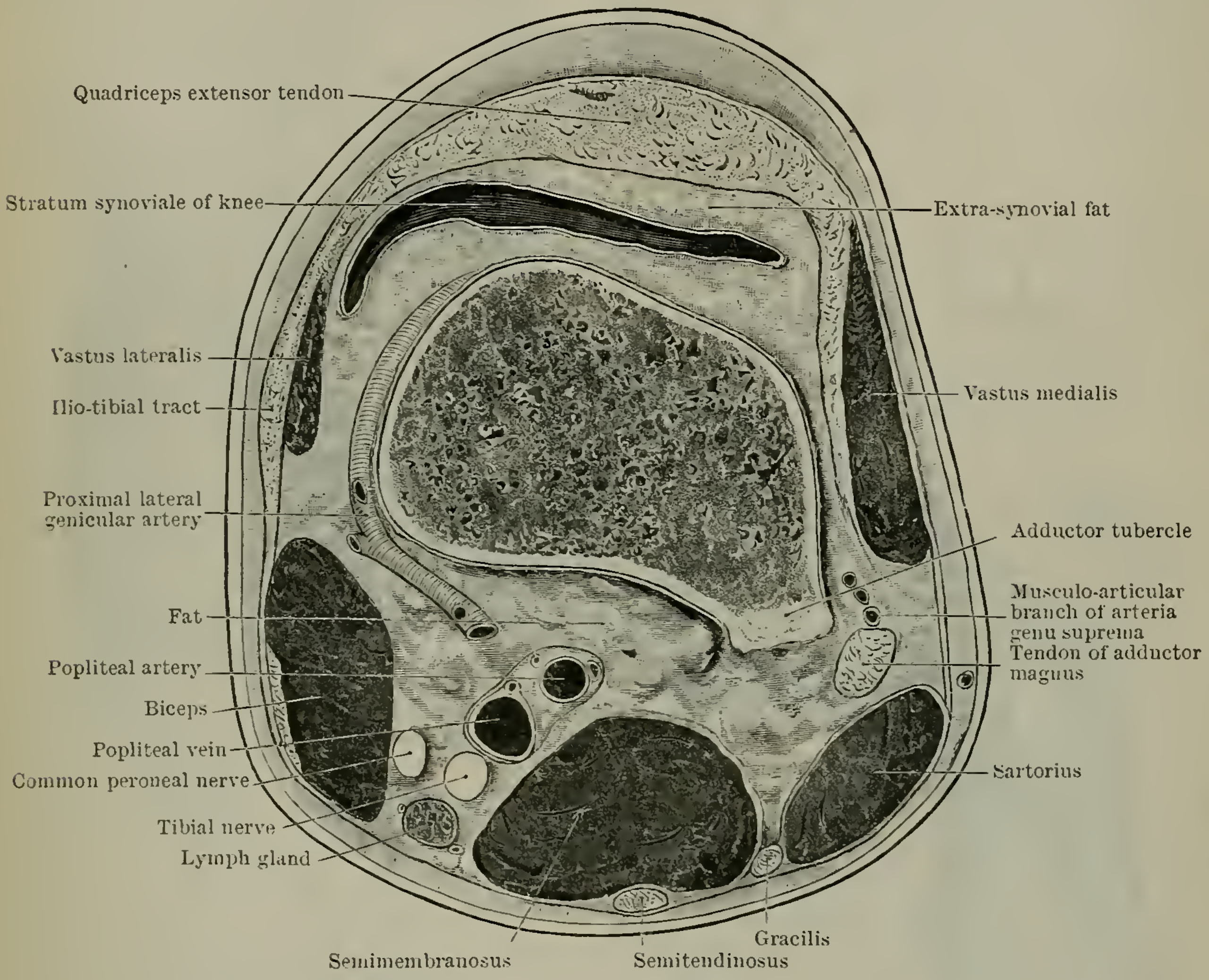

FIG. 1104.—SECTION THROUGH THE THIGH IMMEDIATELY PROXIMAL TO THE PATELLA.

The **common peroneal nerve** may be rolled under the finger as it passes distally immediately behind the tendon of the biceps and the head of the fibula; so close is the nerve to the tendon that the tendon should be divided, in cases where this is necessary, by the open method rather than subcutaneously.

Abscesses may reach the flexor compartment of the thigh from various sources, viz. : (1) from the posterior aspect of the hip-joint; (2) from the pelvis, through the greater sciatic foramen; (3) from one or other of the bursæ under the glutæus maximus; (4) from the front of the hip-joint, by passing backwards under the tensor fasciæ latæ; or by winding backwards beneath the neck of the femur, and through the interval between the quadratus femoris and the adductor magnus; (5) from the iliac fossa under the inguinal ligament into the fascial trigone, and thence to the back of the thigh by one or other of the routes already mentioned; (6) the pus may spread proximally from the popliteal surface of the femur, the knee, a popliteal gland, or from a bursa.

THE POPLITEAL FOSSA.

When the knee is extended the **popliteal fascia** is put upon the stretch, and obliterates the hollow of the popliteal fossa; by flexing the knee the fascia is relaxed, and the fingers may be pressed deeply into the proximal or femoral division of the fossa; as a rule, the pulsations of the popliteal artery can be felt. Deep to the **semitendinosus** is the fleshy **semimembranosus**, which bulges into the space and overlaps the proximal part of the popliteal artery. Between the semimembranosus and the medial head of the gastrocnemius is the most important **bursa** in the popliteal region; it not infrequently becomes distended with fluid, and then presents usually a more or less sausage-shaped outline; according to Holden, the bursa communicates with the cavity of the knee-joint in one subject out of five.

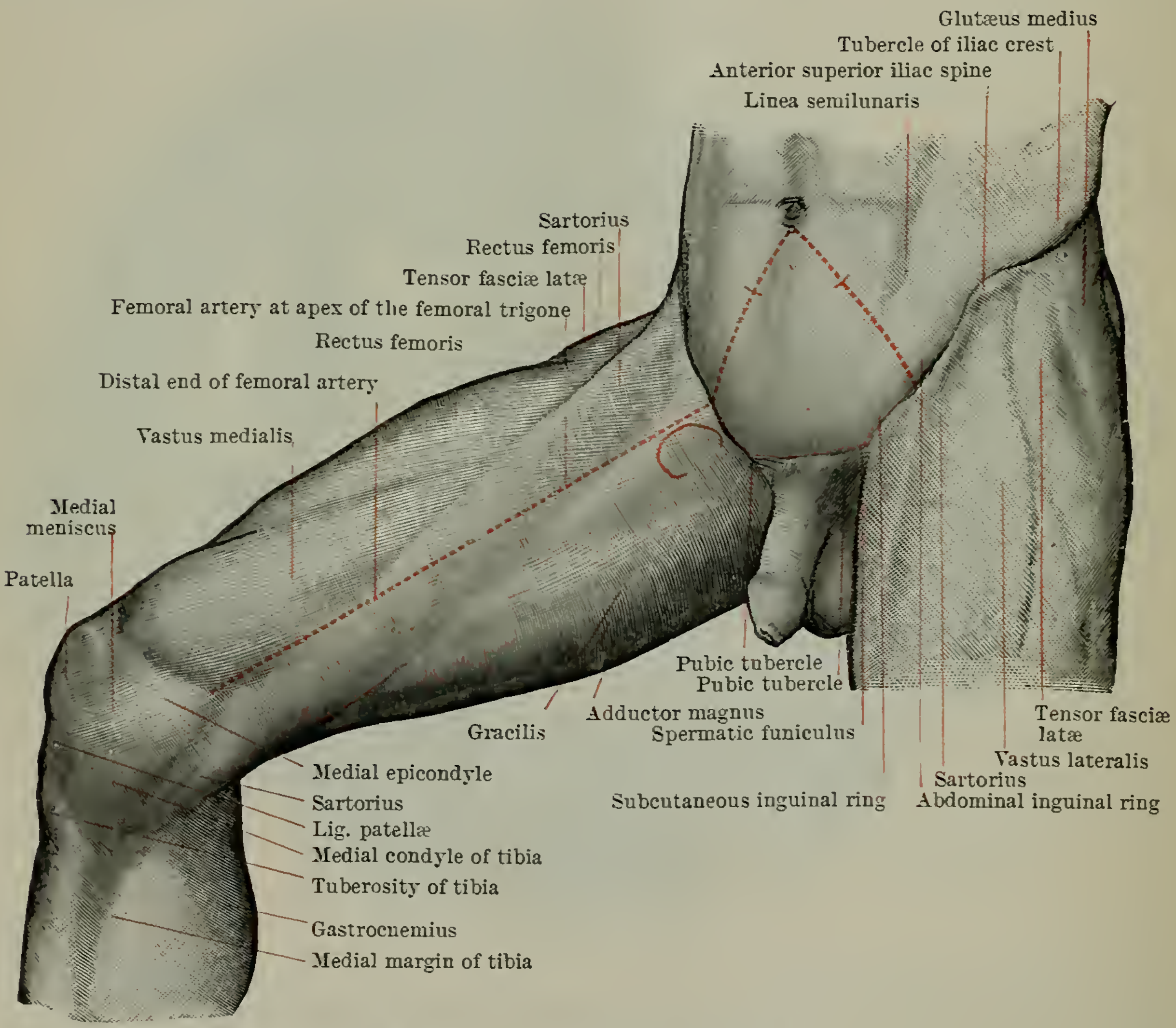

FIG. 1105.—THE THIGH AND GROIN.

To map out the line of the **popliteal vessels** and the **tibial nerve**, draw a line from a point a little medial to the proximal angle of the space to a point midway between the condyles of the femur, and thence distally along the middle of the space to the level of the distal part of the tuberosity of the tibia. The tibial nerve lies immediately under cover of the deep fascia; the artery is separated from the popliteal surface of the femur by a quantity of fat. The popliteal **lymph glands** lie deep to the popliteal fascia, one upon the tibial nerve, the others deeply in the space (Leaf).

THE FRONT OF THE THIGH.

Between the front of the thigh and the abdomen is the *fold of the groin*, at the bottom of which the **inguinal ligament** can be felt as a tense band, stretching from the anterior superior spine of the ilium to the pubic tubercle. The **anterior superior spine** looks directly forwards; comparative measurements of the inferior extremities are made by stretching a tape from it to the tip of one or other of the malleoli, care being taken that the pelvis is horizontal, and the limbs in corresponding positions. The **pubic tubercle** is felt under the proximal and lateral part of the mons Veneris and at a corresponding point in the male; between the tubercle and the symphysis is the **crest** of the pubis, the two crests together forming a rounded subcutaneous bony ridge. A line extending from the pubic tubercle horizontally laterally across the front of the thigh crosses the front of the hip-joint at the level of the inferior part of the head of the femur. The cord-like **tendon** of the **adductor longus** is readily felt, and a point about 1 in. below the pubic tubercle is selected for performing the operation of subcutaneous tenotomy of the tendon.

The centre of the **fossa ovalis** is situated 1½ in. distal and lateral to the pubic tubercle; it overlies the medial (hernial) and intermediate (venous) compartments of the femoral sheath; behind the lateral border of the opening is the arterial compartment of the sheath; crossing over the distal border is the termination of the great saphenous vein. A femoral hernia makes its way into the thigh below the proximal edge of the opening. The course of the **great saphenous vein** in the thigh is indicated by a line extending from the adductor tubercle of the medial epicondyle of the femur to the distal part of the fossa ovalis.

The **horizontal** or **subinguinal chain** of **lymph glands** can usually be felt along, and a little distal to, the line of the inguinal ligament; when the glands are inflamed the surgeon should not neglect to examine the buttocks and anus as well as the external genitals. The **vertical** or **femoral chain** lies in close relation to the upper end of the great saphenous vein. Deeper glands also are met with deep to the fascia cribrosa, close to the medial side of the femoral vein, and there is generally one in the femoral canal. To clear out the glands in the groin an incision should be made parallel to, and a finger's breadth distal to the whole length of the inguinal ligament.

To map out the course of the **femoral artery**, the thigh being slightly flexed and rotated laterally, draw a line from the mid-point between the anterior superior iliac spine and the symphysis pubis to the adductor tubercle at the proximal and posterior part of the medial epicondyle; rather less than the proximal third of this line corresponds to the femoral artery in the femoral trigone, while rather more than its middle third corresponds to the artery as it lies in the adductor canal. The seat of election for ligature of the vessel is at the apex of the femoral trigone. To compress the femoral, pressure should be made directly backwards against the ilio-pectineal eminence, and not against the head of the femur; to compress the femoral in the adductor canal, pressure should be made laterally against the medial surface of the shaft of the femur.

On the lateral aspect of the thigh the **fascia lata** is thick, aponeurotic, and loosely attached to the vastus lateralis; hence the tendency of abscesses to travel distally under cover of it towards the knee. The **sartorius**, which forms the most important muscular landmark of the thigh, may be thrown into prominence by maintaining the thigh unsupported, flexed, and slightly rotated laterally. Observe that in the proximal third of the thigh it forms the lateral boundary of the femoral trigone; in the middle third it is placed superficial to the adductor canal; while in the distal third it lies in front of the medial hamstrings. Lateral and adjacent to the proximal part of the sartorius is the prominence of the **tensor fasciæ latæ**, which, as it passes to its insertion, diverges from the sartorius; in the angle between the two the tendon of the rectus femoris may be felt as it overlies the distal part of the anterior aspect of the articular capsule of the hip.

The medial aspect of the distal half of the **shaft of the femur** may be conveniently cut down upon through the vastus medialis, where it comes to the surface between the sartorius and rectus muscles; the incision should be made in the direction of a line extending from a point midway between the medial border of the patella and the adductor tubercle, to the anterior superior iliac spine.

The front of the **hip-joint** may be reached through an incision from the anterior superior iliac spine distally, along either the medial or the lateral border of the sartorius; in the former case the deeper part of the dissection passes between the iliacus and the medial border of the rectus femoris, while in the latter case the joint is reached lateral to the rectus tendon, between it and the anterior borders of the glutæus medius and minimus muscles. The ascending branch of the **lateral circumflex artery** of the thigh crosses the capsule parallel to, and immediately above, the inter-trochanteric line. The **ilio-psoas** crosses the anterior and the medial part of the capsule; between the two is a **bursa**, which frequently communicates with the joint through the thin part of the capsule medial to the ilio-femoral ligament; it is by way of this communication that a psoas abscess occasionally gives rise to secondary tubercular disease of the hip-joint. One of the commonest situations to meet with an abscess in hip-joint disease is in the cellular tissue and fat under the tensor fasciæ latæ; or the pus may pass below and to the medial side of the neck of the femur, and thence along the course of the medial circumflex artery of the thigh to the back of the thigh. *To tap or explore the hip-joint*, the puncture should be made in the interval between the sartorius and the tensor fasciæ latæ, 2 to 3 in. distal to the anterior superior iliac spine; if the instrument is then pushed upwards, medially and posteriorly beneath the tendon of the rectus femoris, it will pass through the capsule a little above the inter-trochanteric line. Regarded from the point of view of **dislocation**, the regions of the acetabular notch and of the inferior part of the capsule are the weak points in the joint; it follows, therefore, that abduction favours dislocation by bringing the head of the femur into relation with these two weak areas.

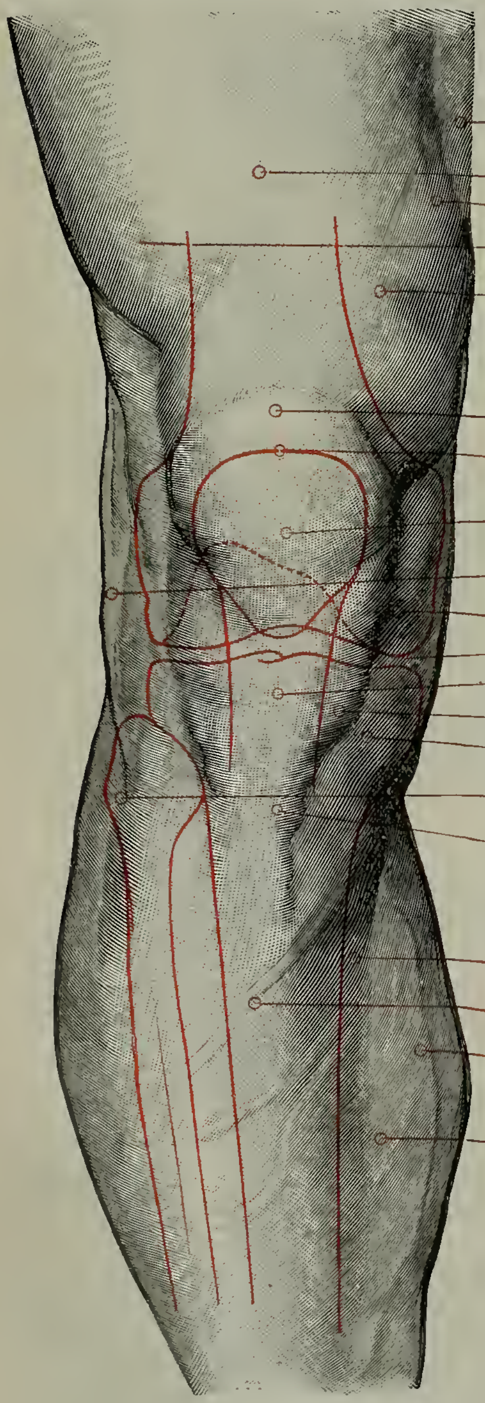

FIG. 1106.—ANTERIOR ASPECT OF KNEE.

THE KNEE.

With the knee extended and the quadriceps relaxed, the **patella** can be readily outlined and moved from side to side upon the femoral condyles. When the quadriceps is contracted its tendon springs forwards and is felt as a tense band above the patella; while the **lig. patellæ**, which has become tense and prominent, may be traced to the distal part of the tuberosity of the tibia. In front of the distal part of the patella and of the proximal part of the lig. patellæ is the **pre-patellar bursa**, into which effusion takes place in the condition known as housemaid's knee. Deep to and on each side of the ligamentum patellæ is a well-circumscribed pad of fat, palpation of which gives rise to a feeling closely resembling true fluctuation. In extension, only the distal pair of articular facets of the patella are in contact with the trochlear surface of the femur. In semiflexion the middle pair of facets rests upon the trochlea; in this position the medial margin of the medial condyle, the proximal border of the medial condyle of the tibia, and the distal part of the patella are all distinctly visible, and together bound a triangular depression, which overlies the line of the joint and contains the anterior part of the **medial meniscus**; it is in this triangle that the surgeon searches for a displaced or thickened medial meniscus, for a loose body, and for "lipping" of the edge of the articular cartilage in chronic osteo-arthritis. A similar, but less well-defined, triangle may be felt immediately lateral to the distal edge of the patella. When the quadriceps is thrown into sudden or violent contraction, as in preventing oneself from falling backwards, the patella may be transversely fractured at the moment of partial flexion. In full flexion almost the whole of the trochlear surface of the condyles is exposed to palpation, covered, however, by the stretched quadriceps tendon.

The proximal part of the medial surface of the medial condyle is overlapped by the muscular prominence of the distal fibres of the **vastus medialis.** Leading proximally from the medial condyle is a slight furrow, corresponding to the interval between the distal part of the vastus medialis and the sartorius; at the bottom of the furrow the cord-like **tendon of the adductor magnus** may readily be felt, and followed to its insertion into the **adductor tubercle**; the latter, situated at the junction of the medial supra-condylar ridge with the proximal and posterior part of the medial condyle, marks the level of the **epiphyseal cartilage.** Anteriorly and posteriorly the epiphyseal cartilage lies just proximal to the highest part of the articular cartilage.

Disease of the distal end of the body of the femur generally invades the popliteal surface of the femur and the popliteal fossa rather than the cavity of the knee-joint. In *Macewen's operation for knock-knee*, the incision (through which the osteotome is introduced to divide the femur) is carried down to the bone through the vastus medialis a little proximal to the medial condyle, a finger's breadth proximal to the summit of the trochlea, to avoid injury to the epiphyseal cartilage, and the same distance in front of the adductor tendon, to avoid injury to the musculo-articular branch of the arteria genu suprema.

Distal to the medial condyle is the subcutaneous **medial condyle of the tibia,** across which the tendons of the sartorius, gracilis, and semitendinosus pass to their insertions. Between those tendons and the medial head of the gastrocnemius is a groove which winds distally and forwards from the popliteal space; an incision along this groove will expose the **great saphenous vein** and **saphenous nerve** and the superficial or saphenous branch of the arteria genu suprema.

On the lateral side of the knee is the **ilio-tibial tract**, which, after crossing and obscuring the line of the joint, is attached to the **lateral condyle of the tibia.** By semiflexion of the knee the posterior border of the tract is thrown into relief, and a well-marked furrow intervenes between it and the prominent tendon of the biceps; the distal part of the shaft of the femur and the popliteal surface may be reached through an incision along this furrow. Under cover of the ilio-tibial tract, as it crosses the line of the joint, are the **lateral meniscus**, the **distal lateral genicular artery**, and the **fibular collateral ligament.** The **head of the fibula**, and the **tendon of the biceps** passing to be inserted into it, are rendered distinctly visible by semiflexing the knee; the former lies on a level with the tuberosity of the tibia, 1½ in. posterior and a little distal to the most prominent part of the lateral condyle of the tibia. Immediately distal to the head of the fibula is the termination of the **common peroneal nerve**, which is liable to be contused from blows, and in fractures of the neck of the fibula.

The **synovial layer** of the knee-joint extends distally, anteriorly, as far as the level of the proximal border of the tibia; posteriorly, it dips distally for a short distance behind the popliteal notch of the tibia, to form a small cul-de-sac, the close relation of which to the popliteal artery must be borne in mind in performing the operation of excision of the knee. Anteriorly, the synovial layer extends proximally beneath the quadriceps in the form of a pouch, which reaches nearly two inches proximal to the articular surface of the femur; posteriorly, there is no extension of the synovial cavity proximal to the condyles; at the sides of the knee the synovial layer covers the anterior third of the superficial surface of each condyle.

In **effusion into the knee-joint** the hollows become obliterated, the patella is floated up, and fluctuation may be obtained proximal, distal, and to either side of the patella.

To pass a tube through the knee-joint for drainage, two short vertical incisions should be made—one on each side of the joint at the level of the proximal part of the patella, and a finger's breadth behind its lateral edges. In **arthrectomy** of the knee for tubercular disease, the subsynovial fat facilitates the separation of the supra-patellar pouch from the distal and anterior part of the shaft of the femur; to expose the **pouches posterior to the condyles**, the cruciate ligaments must be divided.

THE LEG.

The medial surface of the **tibia** is subcutaneous throughout; hence the seat of a fracture of the shaft is, as a rule, easily felt, and the distal extremity of the proximal fragment is liable to perforate the skin. The skin over the distal half of this surface is the commonest seat of varicose and callous ulcers, which are frequently prevented from healing by adhesion of the floor of the ulcer to the periosteum.

The **shaft of the fibula**, situated on a plane posterior to that of the tibia, is, with the exception of the triangular subcutaneous surface proximal to the lateral malleolus, deeply placed amongst the muscles. To examine the fibula, the surgeon should stand on the opposite side of the patient and manipulate the bone along the line of the intermuscular septum between the peronæi and the muscles of the calf.

The greater fulness of the antero-lateral surface of the leg, as compared with its medial surface, is due to the presence of the **extensor** and **peroneal groups of muscles**. When those groups are thrown into action, the individual muscles are mapped out upon the surface by the grooves corresponding to their intermuscular septa. The **posterior peroneal septum** is seen as a well-marked furrow, extending from the posterior aspect of the head of the fibula to the hollow behind the lateral malleolus; in front of it are the **peronæi muscles**, the *longus* giving rise to a prominence on the proximal half of the leg, while the *brevis* is prominent on the distal half; behind the septum is a prominence formed by the lateral border of the **soleus**, which projects beyond the border of the **gastrocnemius**.

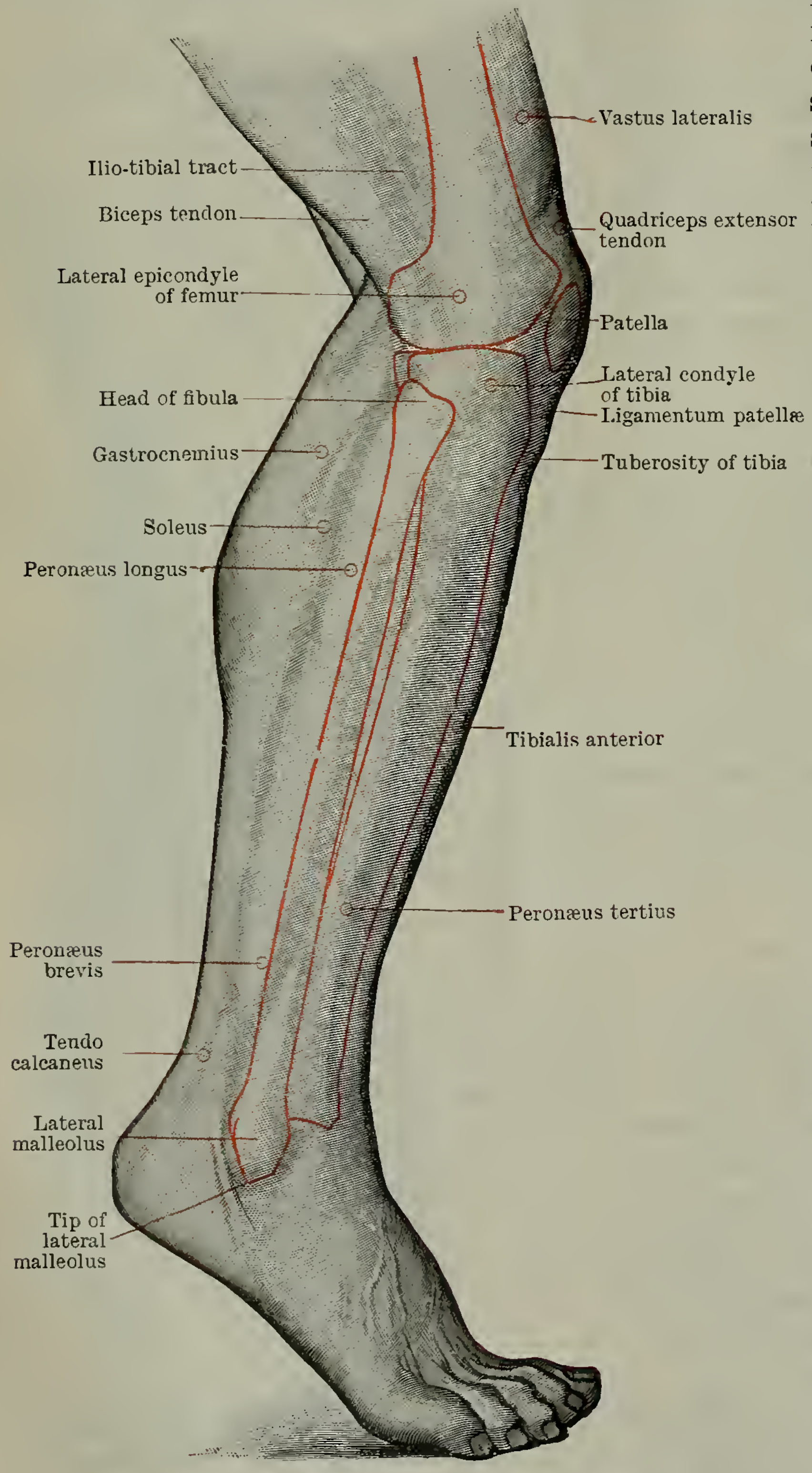

FIG. 1107.—LATERAL ASPECT OF KNEE AND LEG.

It is along the line of the posterior peroneal intermuscular septum that incisions should be made to expose the fibula; to avoid the superficial peroneal nerve, however, the incision must not extend to a more proximal level than one inch distal to the head of the fibula.

The furrow between the extensors and the two peronæi, the **anterior peroneal septum**, is much less distinct, and runs in a line from the anterior border of the head of the fibula to the anterior border of the lateral malleolus; the **cutaneous portion of the superficial peroneal nerve** corresponds to the distal half of this line. At the junction of the middle and distal thirds of the leg the extensor muscles incline medially over the anterior aspect of the tibia.

The **anterior tibial artery** reaches the front of the interosseous membrane 2 in. distal to the tuberosity of the tibia; in the proximal two-thirds of its course it lies upon the interosseous membrane, while in its distal third it winds on to the front of the tibia, to terminate at a point opposite the ankle-joint, midway between the two malleoli. *Incisions to expose the vessel* should strike the lateral border of the tibialis anterior, which corresponds to a line drawn from a point midway between the lateral condyle of the tibia and the head of the fibula, to the termination of the vessel.

When the muscles of the calf are thrown into action, a groove is seen between the two heads of the **gastrocnemius**, the fleshy fibres of which extend a little distal to the middle of the leg. The fleshy fibres of the **soleus** extend to the junction of the middle and distal thirds of the leg, and project beyond the margins of the gastrocnemius. The narrowest part of the **tendo calcaneus** is situated opposite the bases of the malleoli, and it is there that the tendon is divided in the operation of tenotomy. The **small saphenous vein**, which lies a little to the lateral side of the tendon, gradually reaches the middle of the calf, along which it runs proximally to the middle of the popliteal fossa. The **great saphenous vein** and the **saphenous nerve** lie along the medial margin of the tibia.

The course of the **posterior tibial artery** is mapped out by drawing a line from the distal angle of the popliteal fossa, at the level of the distal border of the tuberosity of the tibia, to a point midway between the medial malleolus and the tendo calcaneus. *To expose the vessel* in the proximal half of the leg, an incision is made parallel to and ½ in. posterior to the medial margin of the tibia; after retracting the medial border of the gastrocnemius and dividing the tibial origin of the soleus, the artery is found lying on the tibialis posterior. In exposing the artery below the soleus, divide two layers of deep fascia and keep the knife directed towards the tibia.

The **peroneal artery** is given off 3 in. distal to the head of the fibula; incisions to expose the vessel are made in the direction of a line extending from the posterior border of the head of the fibula to a point midway between the lateral malleolus and the tendo calcaneus.

THE FOOT AND ANKLE.

The tip of the **lateral malleolus** is situated ¼ in. distal and ¾ in. more posterior than that of the **medial malleolus**. Proximal to the lateral malleolus is the triangular subcutaneous surface of the fibula, the apex of which corresponds to the distal end of the extensor-peroneal intermuscular septum.

The **line of the ankle-joint** can be felt on either side of the extensor tendons, and when the foot is extended the anterior part of the proximal articular surface of the **talus** forms a visible prominence distal to the anterior crest of the distal end of the tibia. The small posterior surface of the talus is felt distal and posterior to the medial malleolus, at the anterior part of the hollow between it and the heel. In *effusions into the ankle-joint* the hollows in front and behind the malleoli are obliterated, and the extensor tendons are raised from the front of the joint.

A finger's breadth distal to the tip of the medial malleolus is the **sustentaculum tali**; 1¼ in. in front of the sustentaculum, and midway between the dorsal and plantar margins of the medial aspect of the foot, is the **tuberosity of the navicular** (the medial landmark in Chopart's amputation), which is generally visible, and always distinctly palpable. The **calcaneo-taloid joint** lies immediately above the sustentaculum, while close above it the **tendon of the tibialis posterior** may be rendered visible, as it extends from behind the tip of the medial malleolus to the tuberosity of the navicular. An inch and a half in front of the tuberosity of the navicular is the **joint between the first cuneiform and the first metatarsal**; the ridge at the base of the first metatarsal furnishes a good guide to the articulation. The first **metatarso-phalangeal joint** lies a little in front of the middle of the ball of the great toe.

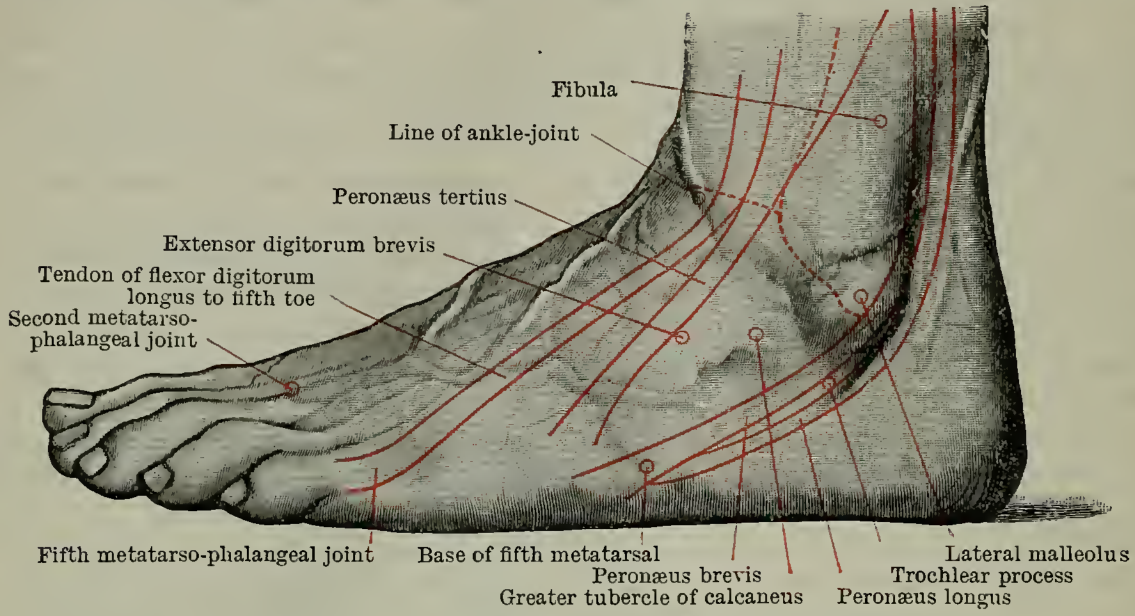
Fibula
Line of ankle-joint
Peronæus tertius
Extensor digitorum brevis
Tendon of flexor digitorum longus to fifth toe
Second metatarso-phalangeal joint
Fifth metatarso-phalangeal joint
Base of fifth metatarsal
Peronæus brevis
Greater tubercle of calcaneus
Lateral malleolus
Trochlear process
Peronæus longus

Fig. 1108.—Lateral Aspect of Foot and Ankle.

A finger's breadth vertically below the tip of the lateral malleolus is the **trochlear process** of the calcaneus, and midway between the two is the **calcaneo-taloid joint**; the trochlear process is, when present, a trustworthy guide to the level at which the **two peronæi tendons** cross the lateral surface of the calcaneus. The **greater process** of the **calcaneus** is felt in the triangular interval between the tendons of the peronæus brevis and tertius; the **calcaneo-cuboid joint**—the lateral landmark in Chopart's amputation—is placed a little in front of the mid-point between the tip of the lateral malleolus and the base of the fifth metatarsal bone. To open the lateral **tarso-metatarsal articulations**, the knife, entered behind the projecting base of the fifth metatarsal bone, should be directed forwards as well as medially. On the dorsum of the foot the tarsal joints are obscured by the extensor tendons. The **synovial layer** of the **ankle-joint** is prolonged on to the neck of the talus, and care must be taken to avoid opening the ankle-joint in performing Chopart's amputation.

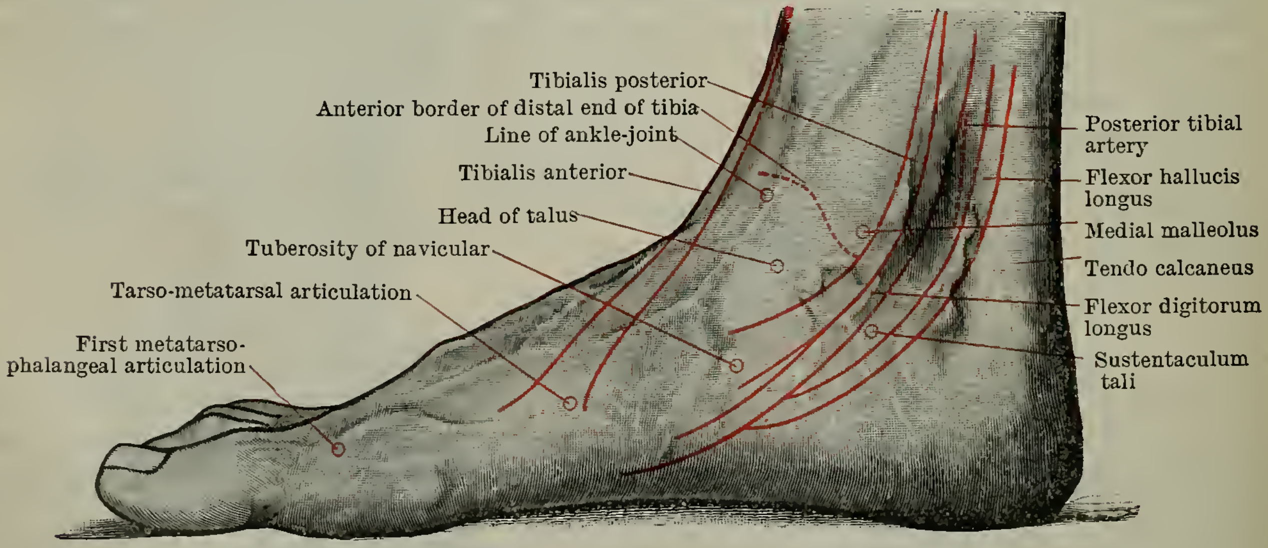

Fig. 1109.—Medial Aspect of Foot and Ankle.

The line of the **tarso-metatarsal joints** extends nearly 1 in. further forwards on the medial than on the lateral border of the foot; between these points the joint-line takes a zigzag course on account of the second metatarsal bone extending backwards between the first and third cuneiform bones. The joint between the second metatarsal and second cuneiform is nearly ½ in. behind that between the first metatarsal and first cuneiform, and nearly ¼ in. behind that between the third metatarsal and the third cuneiform. The strong transverse interosseous ligament (*Lisfranc's ligament*), which connects the lateral surface of the first cuneiform with the base of the second metatarsal, must be divided in the tarso-metatarsal amputation of Lisfranc. In order to preserve the insertions of the two tibial and the three peroneal muscles, it is advisable, when possible, instead of disarticulating at "Lisfranc's joint," to saw through the metatarsal bones just in front of their bases.

The **metatarso-phalangeal articulations** are situated 1 in. behind the web of the toes. In disarticulating a toe, the transverse metatarsal ligament, which unites the heads of the metatarsal bones, should not be injured.

The **tendon** of the **tibialis posterior** may be felt, and, by inverting the foot, seen, as it extends from behind the tip of the medial malleolus to the tuberosity of the navicular; it crosses the talus immediately above the sustentaculum tali.

In the commonest form of club-foot, viz., *talipes equino-varus*, the tuberosity of the navicular is approximated to the medial malleolus, so that tenotomy of the tendon should be performed through a puncture a little distal to the tip of the medial malleolus; if the knife, after dividing the tendon, is carried down to the bone, the **plantar calcaneo-navicular ligament** will be divided and the **talo-navicular joint** opened, a procedure which is called for before the foot can be brought into good position.

Crossing the front of the ankle-joint, from medial to lateral side, are the following tendons, viz.: the **tibialis anterior**, the largest and most prominent; the **extensor hallucis longus**, the **extensor digitorum longus**, and the **peronæus tertius**. The **extensor digitorum brevis** gives rise to a fleshy pad which overlies the dorsal aspect of the calcaneo-cuboid joint. When the foot is everted, the tendon of the **peronæus brevis** may be seen extending from the tip of the lateral malleolus to the base of the fifth metatarsal bone; immediately below it is the tendon of the **peronæus longus**, which, as it winds round the cuboid, is obscured by the fleshy fibres of the abductor digiti quinti muscle. The **abductor hallucis muscle**, although described along with the sole, forms a fleshy pad along the medial border of the foot below the sustentaculum tali.

An incision, extending from the tuberosity of the navicular to the middle of the medial border of the heel, will expose the various tendons, vessels, and nerves, as they pass from the medial malleolus into the sole, beneath the abductor hallucis.

The **dorsalis pedis artery** may be mapped out on the surface by drawing a line from a point opposite the ankle-joint, midway between the tips of the two malleoli, to the posterior end of the first interosseous space; the vessel may be compressed against the medial column of the tarsal bones. The **great saphenous vein** and the **saphenous nerve** lie between the anterior border of the medial malleolus and the tendon of the tibialis anterior; the **small saphenous vein** and the **nervus suralis** take the same course as the tendon of the peronæus brevis.

The **medial plantar vessels** and **nerves** lie along the **medial intermuscular septum**, which corresponds to a line drawn from the inferior surface of the medial tubercle of the calcaneus to the interval between the first and second toes. The **lateral plantar vessels** and **nerves** may be exposed by an incision along the **lateral intermuscular septum**, which runs in a line extending from the middle of the inferior surface of the heel to the fourth toe (Kocher); to map out the course of the **plantar arch**, draw a line across the sole from the medial side of the base of the fifth metatarsal bone to the proximal end of the first interosseous space.

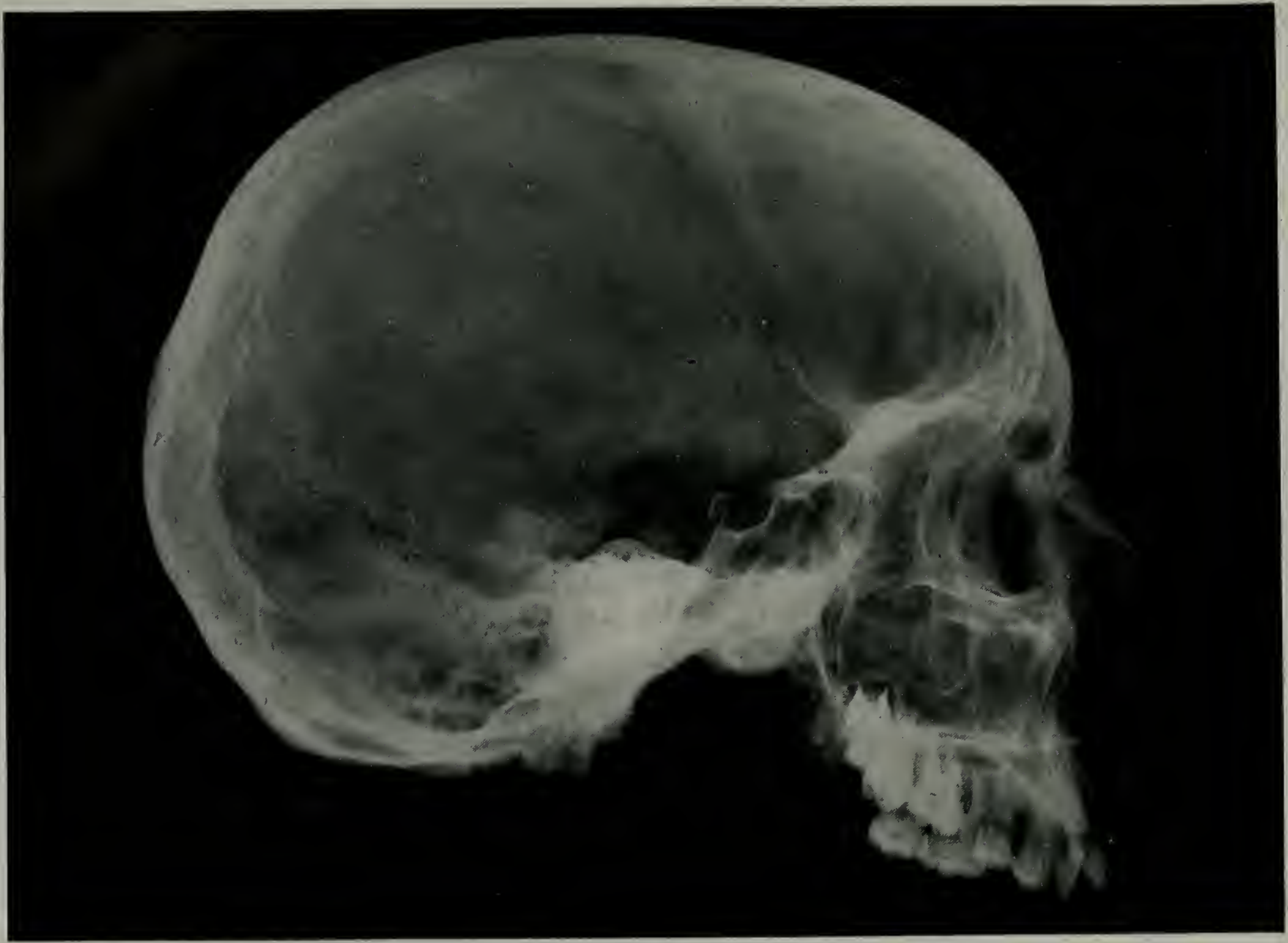

PLATE I.

Skiagram of Skull from the side, showing Frontal Sinuses, Maxillary Sinuses, and Sphenoidal Sinus, also the Hypophyseal Fossa.

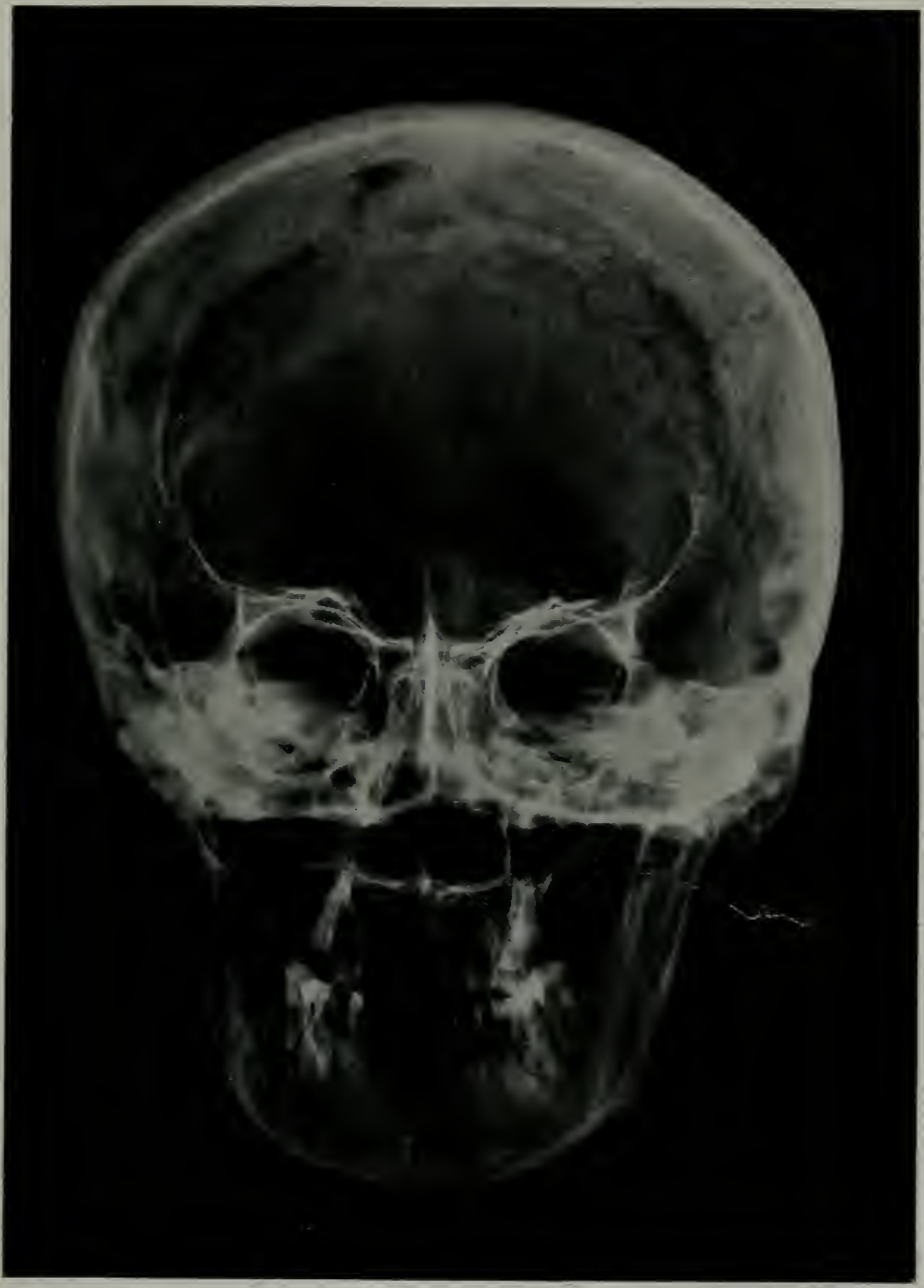

PLATE II.

Skiagram of Skull from the front, showing the Frontal Sinuses, the Ethmoidal Air-Cells, and the Maxillary Sinuses.

INDEX.

INDEX.

NOTE.—Figures in heavy type refer to the pages on which structures are most exhaustively described.

Abdomen, 91, **1148**
  in child, 1398
  abscesses, 1404, 1412, 1418, 1422, 1428, 1430, 1454
  apertures, 1150
  contents, 1153, **1156**
  subdivision, 91
  surgical anatomy, 1398, 1427
Abdomen proper, 91, **1149**
  bones, 94, 101
  cavity, 1148, 1149
    arteries, 882, 929
    lymph glands, 1027
    lymph vessels, 1030
    nerves, 700, 701, 727, 785, 789
    planes and regions, 1151, 1401
    surgical anatomy, 1401, 1428
    veins, 987
  walls, 437, 475
    arteries, 914, 927, 928, 929, 936, 937, 941, 949, 951
    fasciæ, 369, 372, 437, 475, 1150, 1399
    formation, 28
    incisions, 1400, 1406, 1429
    lymph glands, 1023, 1029
    lymph vessels, 1023, 1030, 1032
    muscles, 440, 476
    nerves, 718, 746, 747, 749
    relation to primitive streak, 28
    surgical anatomy, 1398, 1427
    veins, 990
Abduction at joints, 305
Abnormalities. *See also* **Variations**
  of aorta, 884, 932, 933, 937, 1037, 1038
  of arches of palm, 923, 924, 925
  of **arteries**—
    arcuate, 958
    axillary, 914, 917, 925
    basilar, 908
    brachial, 230, 917, 919, 925
    bronchial, 914, 927
    carotid, common, 885, 889, 907, 1038, 1039
      external, 890, 899, 1039
      internal, 902, 1039
    carpal, 923
    cerebral, anterior, 905
      posterior, 908
    cervical, deep, 915, 929
      transverse, 911, 912
Abnormalities—*continued*
  of **arteries**—*continued*
    circumflex, humeral, 917
      iliac, 950, 955
      of thigh, 950, 955
    cœliac, 931, 937
    colic, 932, 936
    communicating, posterior, 902
    coronary, 885
    deep cervical, 915, 929
    digital, 923, 925
    dorsalis indicis radialis, 923
    dorsalis pedis, 958, 959, 963
    dorsalis penis, 946, 950
    epigastric, inferior, 949, 950, 955
    femoral, 946, **955**
    gastric, 932, 936, 939
    gastro-duodenal, 931, 935
    gastro-epiploic, 935
    gluteal, 946
    hæmorrhoidal, 943, 946
    hepatic, 932, 933, 935, 936
    hyoid, 890, 899
    hypogastric, 930, 939, **946**
    iliac, common, 930, 939, 946
      external, 884, 930, 950
    ilio-lumbar, 939, 946
    innominate, 885, 886, 914
    intercostal, 907, 915, 927, 928, 929
    interosseous, 917, 919, 923, 924, 925
    lumbar, 930, 938
    mammary, internal, 914, 927
    maxillary, external, 890
    median, 923, 924, 925
    mesenteric, inferior, 932, 933, 935, 936
      superior, 932, 933, 935, 936, 937
    metacarpal, 923
    ophthalmic, 904
    ovarian, 931
    palatine, ascending, 890, 899
    perforating, of hand, 923
      of peroneal, 958
    peroneal, 957, 958
    phrenic, inferior, 930, 937
    plantar, 959, 960, 963
    popliteal, 946, **957**, 961
    princeps pollicis, 923
    profunda brachii, 917
    profunda femoris, 955

- **Abnormalities**—*continued*
  - of **arteries**—*continued*
    - profunda penis, 946
    - pudendal, internal, 946
    - pulmonary, 884, 1037
    - radial, 917, 919, 923, 925
    - recurrent radial, 923
    - recurrent ulnar, 919, 925
    - renal, 930, 931, 933, 936, 937, 946
    - sacral, lateral, 939, 946
      - middle, 930, 939
    - scapular, transverse, 911
    - spermatic, internal, 930, 931, 939
    - splenic, 932, 935, 936
    - sterno-mastoid, 890, 899
    - subclavian, 885, 889, 910, 915, 927, 929, 1038
    - subscapular, 917
    - suprarenal, 931
    - sural, superficial, 957
    - tarsal, lateral, 958
    - thyreo-cervical, 911, 912, 914
    - thyreoid, inferior, 907, 927
      - superior, 890
    - thyreoidea ima, 885
    - tibial, 957, 958, 963
    - transverse cervical, 911, 912
    - transverse scapular, 911
    - ulnar, 917, 919, 923, 924
    - ulnar collateral, 917, 919
    - ulnar recurrent, 919, 925
    - vertebral, 885, 907
    - volaris indicis radialis, 923
  - of atrium, left, 966
  - of carpal arches, 923
  - of cisterna chyli, 1032
  - of coronary sinus, 966, 967
  - of ductus thoracicus, 1032
  - of heart, 876, 966, 1034, 1035, 1036, 1037
  - of plantar arch, 960
  - of right lymph duct, 1032
  - of second thoracic nerve, 743
  - of thoracic duct, 1032
  - of thyreo-cervical trunk, 911, 912, 914
  - of transverse sinus, 981
  - of **veins**—
    - azygos, 967, 988
    - cardiac, 966
    - cava inferior, 967, 988
      - superior, 966, 988
    - cephalic, 973
    - comites, of lower limb, 998
    - coronary sinus, 966, 967
    - facial, posterior, 975
    - femoral, 998
    - gluteal, 994
    - of heart, 966
    - hemiazygos, 967, 988
    - hepatic, 988
    - hypogastric, 991
    - iliac, 988, 991
    - innominate, 966, 967
    - intercostal, 967
    - jugular, 971, 973
    - lumbar, 988
    - occipital, 973
    - ovarian, 988
    - popliteal, 998
    - profunda femoris, 998
    - renal, 988
    - saphenous, 994
    - spermatic, 988
- **Abnormalities**—*continued*
  - of **veins**—*continued*
    - subclavian, 987
    - suprarenal, 988
    - testicular, 988
  - of venæ cavæ, 966, 967, 988
  - of venæ comites of lower limb, 998
  - of volar arches, 923, 924, 925
- **Abscess** of abdomen, 1404, 1412, 1418, 1422, 1428, 1430, 1454
  - anal, 1422
  - axillary, 1441
  - iliac, 1418, 1422
  - ischio-rectal, 1422
  - lumbar, 1418, 1428
  - in neck, 1376, 1378
  - perinephric, 1418, 1430
  - popliteal, 1451
  - psoas, 1418, 1430, 1454
  - retro-cæcal, 1412
  - retro-pharyngeal, 1376
  - of scalp, 1347
  - subphrenic, 1404, 1412
  - of thigh, 1452
- Acervulus, 1341
- **Acetabulum**, 249, 251, 253, **254**, 260, 341
  - changes with erect attitude, 259
  - in female, 258
  - proper position, 253
  - relation to obturator externus, 259
  - structure, 255
- Achromatic figure, 10, 11
- Achromatin, 8
- Acid, carbonic, 862
- Acini of glands, 1127
- Acinus, 1126
- "Acoustic," 125
- Acro-cephaly, 296
- Acro-megaly, 614
- Acromion, 218, **220**, 377, 378
  - relation to greater tubercle, 226
  - separate, 223
  - surface and surgical anatomy, 1439
- Actions of muscles, 366
- Adamantine, 84, 182, 1110, **1111**
    - development, 1232, 1233
    - formation, 1234
  - of milk teeth, 1116
- Adam's apple. *See* Prominence, laryngeal
- Adduction at joints, 305
- Adenoids, 1137, 1376
- **Aditus**, 87
  - ad antrum, 828
    - surgical anatomy, 1359
  - laryngis, 1068
    - closure and opening, 1075
    - muscles acting on, 1072
    - in pharyngeal wall, 1141
    - surgical approach, 1378
- Adrenin, 1321, 1322
- Æquator. *See* Equator
- Affenspalte, 658
- Age ascertained from skull, 185
- Age estimated in fœtus, 82
- Agger nasi, 172, 212, **797**
- Air-cells, ethmoidal. *See* **Sinus**
- Air-cells of lung, 1097
  - mastoid. *See* **Cells, air**
- Air-sacs of lung, 1097
- Air-sinus. *See* **Sinus, air**
- Akanthion, 133, 295
- **Ala**, 87

- Ala—*continued*
  - cinerea. *See* **Trigonum** N. vagi
  - of nose, 793
  - of sacrum, 103, 105
    - in pelvic brim, 257
  - of sphenoid. *See* Wing
  - of vomer, 145, 146, 169, **209**
- Ali-sphenoid, 205
- Allantoic diverticulum, 43, 44, 53, 57
- Allantois, 43
- Allelomorphs, 22, 23
- **Alveoli**, 87
  - of glands, 1126, 1127
  - of jaws, development, 1233
  - of lung, 1097
  - of mandible, 177
    - relative thickness of walls, 180
  - of maxilla, 128, 144, 212
- Alveus hippocampi, 625
- Ameloblasts, 1223
- Amitotic division of cells, 9
- Amnion, 31, 42, 43, 58
  - cavity, 44, 59, 66
- Amniotic ectoderm, 26, 31
- Amphiarthroses, 302
- **Ampulla** of ductus deferens, 1277
  - of lacrimal ducts, 819
  - of lactiferous ducts, 1319
  - phrenica of œsophagus, 1146
  - of rectum, 493, **1215**
  - of semicircular canals, 838
  - of semicircular ducts, 841
  - of uterine tube, 1297
  - of Vater, 1194
    - surgical anatomy, 1406
- Amygdala. *See* **Tonsil**
- Analogy, 2
- Anaphase of cell division, **11**, 13, 18
- **Anastomosis**, crucial, 946, 954
  - of portal and systemic veins, 999, 1148, 1222
  - post-central, 1053
  - post-costal, 1053
  - post-neural, 1053
  - post-transverse, 1053
  - pre-costal, 1053
  - pre-laminar, 1053
  - ventral, 1053
- Anatomy, 1
  - surface and surgical, 1347
  - systematic, 3, 4
  - topographical, 4
- ANGEIOLOGY, 3, 861
- Angioblasts, 69
- **Angle** or **Angulus**—
  - of acromion, 221
  - cardio-hepatic, 1098
  - cephalo-auricular, 822, 823
  - of eye, 816
  - facial, 297
  - of femur, 265
  - filtration, 804, 805, 807
  - inferior lateral, of sacrum, 103, 105
  - infracostal, 1398
  - infrasternal, 120
  - of iris, 804, 805, 807
  - of mandible, 129, 179, **180**
    - at birth, 180, 184
    - in old age, 180
    - surgical anatomy, 1366
  - of mouth, 1101
  - naso-facial, 793
- **Angle** or **Angulus**—*continued*
  - pubic, 253
    - ossification, 255
  - of rib, 117
    - anterior, 118
  - sacro-vertebral, 107
    - changes with erect attitude, 258
  - of sacrum, inferior lateral, 103, 105
  - of scapula, 219
    - inferior, level, 99, 122, 219
      - relation to latissimus, 371
    - medial, level, 1433
  - of sphenoid, 204
  - sternal, 114, 122
    - level, 115, 1389
    - variations, 116
- Animal cells. *See* **Cell**
- Animals, diphyodont, heterodont, homodont, polyphyodont, 1235
- Ankle bone. *See* Talus
- **Annulus**. *See also* **Ring**
  - fibrocartilagineus of ear, 829
  - fibrosus of fibro-cartilages, 309
  - hæmorrhoidalis, 1219
  - tendineus communis of orbit, 679, 682, 692
  - tympanicus, 201, 825
  - umbilicalis. *See* **Umbilicus**
- **Ansa** hypoglossi, 705, **726**
  - relation to fascia, 448
  - lenticularis, 611
    - connexion with corpus striatum, 637
  - peduncularis, 611
  - subclavia, **782**, 784
- Anteflexion and anteversion of uterus, 1302
- "Anterior," definition, 5
- ANTHROPOLOGY, PHYSICAL, 294
- Antibrachium. *See* **Forearm**
- Antihelix, 822
- Antitragus, 79, **823**
- **Antrum**, 87
  - cardiacum of œsophagus, 1146
  - maxillary (Highmore). *See* **Sinus**
  - pyloric, 1161, 1163
  - **tympanic**, 126, **161**, 198, 826, **830**
    - at birth, 161, 830
    - in child, 1359, 1362
    - operation to open, 1362
    - relation to sigmoid sinus, 165
      - to suprameatal triangle, 139
    - surface and surgical anatomy, 1359
- **Anus**, 94, 104, 1220
  - distance from peritoneum, 1217, 1226, 1424
  - imperforate, 1223
  - lymph vessels, 1423
  - surgical anatomy, 1421
  - veins, 992, 1222
- **Aorta**, 880
      - in birds and reptiles, 884, 1038
    - abnormalities, 884, 1037, 1038
    - development, 61, 71, 72, 73, 1035, 1037, 1038
    - morphology, 1056
    - nerve supply, 785, 786, 791
    - orifice, 869, 872, **874**
  - abdominal, 473, 476, **882**
    - abnormalities, 932, 933, 937
    - branches, 884, **929**
    - nerve supply, 786, 791
    - relation to abnormal iliac vein, 988
    - surface and surgical anatomy, 1417
  - **arch of**, 881
      - in birds and reptiles, 1038

Aorta—*continued*
arch of—*continued*
primitive. *See* **Arch**
abnormalities, 1038
branches, 882, **885**
variations, 885
development, 1038
level, 1433
relation to manubrium, 115
surface anatomy, 1396
ascending, 880
abnormalities, 1037
blood supply, 885
branches, 881, **884**
development, 1035
relation to sternum, 115
surface anatomy, 1396
descending, 880, 882
development, 73, 1038, 1039
abdominal. *See* **A.**, **abdominal**
thoracic, 882
branches, 882, **927**
thoracic, 880
nerve supply, 785
descending. *See* **A.**, **descending**
Aorta, primitive, 71
dorsal, 61, 72, 73
branches, 1039
derivatives, 1037
ventral, 72
derivatives, 1037
Apertures—
of abdomen, 1150
atrio-ventricular. *See* **Orifice**
externa aquæductus cochleæ, 168, 200
aquæductus vestibuli, 167, 200
of larynx. *See* **Aditus** laryngis
of nose, 173
of pelvis, 257
in female, 258
inferior, 257
superior, **257**, 412, 1149
piriformis, 125, 132, 133
at birth, 184
relation to maxilla, 128
to nose, 168
slope, 169
variations, 214, 297
of thorax, 120
tympanica canaliculi chordæ, 828
of ventricle, fourth, 669
development, 41, 554
lateral, 669
relation to nerves, 550
median, 669
Apex columnæ posterioris, 525
of head of fibula, 271
of heart, 868
bifid, 1036
of lung, 120, 1091
level, 118, 1433
surgical anatomy, 1390
Aponeurosis, 253
epicranial. *See* Galea
intercostal, 438
of latissimus dorsi, 369
lumbar. *See* **Fascia**
of obliquus externus, 115, 260, 373, **477**, 484, 485
internus, 115, 122, 260, **480**, 482, 484
palatine, 145, **466**, 1108
palmar, 385, 386
Aponeurosis—*continued*
pharyngeal, 147, **466**
plantar, 278, **424**, 433, 434
prostatico-peritoneal, 493
of transversus abdominis, 115, 122, 260, **481**, 484
Apparatus, auditory, nervous, 605
connexion with optic, 606
digestorius, 1101
lacrimal, 818
surgical anatomy, 1368
respiratory, 1061
uro-genital, 1245
Appendages of fœtus, 58
of skin, 852
Appendices of epididymis, 1271
epiploicæ, 1201, **1202**
of testis, 1272
development, 1310, **1316**
vesicular, 1298
development, 1310
APPENDICULAR SKELETON, 91, 217, 247
Appendix ventriculi laryngis, 1071
vermiform. *See* **Process**
Aquæductus cerebri, 543, 550, 580, **583**, 615
development, 41, 590
cochleæ, **168**, **839**, 840
vestibuli, 167, 837
Arachnoid, 154
development, 41
of brain, 668
granulations, 154, **670**, 978
of spinal medulla, 519, 668
in sacral canal, 104, 106
Arbor vitæ cerebelli, 576
Arc, longitudinal, of skull, 296
Arcades, arterial, 935
Arch, Arches. *See also* **Arcus**
alveolar, 212
of **aorta**, 881
in birds and reptiles, 1038
abnormalities, 1038
branches, 882, **885**
variations, 885
development, 1038
level, 1433
relation to manubrium, 115
surface anatomy, 1396
aortic, primitive, 72, 73
derivatives, 1037
morphology, 1056
of atlas, anterior, 97
development, 123
homology, 112
relation to skull, 148
posterior, 97
axillary, 374
nerve supply, 732, 738, 744
relation to axillary artery, 917
of azygos vein, 966, 1433
branchial, 47, 49, 51, 53
arteries, 73, 1037, 1056
cartilages, derivatives, 181, 183, 314, 835, 1098
muscles derived from, 497
nerves of, 497, 710
carpal, dorsal, **922**, 924, **925**
volar, 922, 924, **925**
abnormalities, 923
coraco-acromial, **222**, 322
of cricoid cartilage, 1063
dental, 1118

- **Arch, Arches**—*continued*
  - femoral, deep, 407
    - superficial, 407, 478
  - of foot, **287**, 359, **364**, 437
  - glosso-palatine, 464, 1107, **1109**
    - surgical anatomy, 1374
  - **hyoid** (branchial), 47, 49, 51
    - artery, 73, 1037, 1038, 1056
    - cartilage, 183
    - muscles, 497
    - nerve, 497, 710
  - lumbo-costal, lateral, 109, 122, **473**
    - medial, 109, **473**
  - **mandibular**, 47, 49, 51, 53, 54
    - artery, 72, 1037, 1038, 1056
    - cartilage, 181, 314, 835
    - muscles, 497
    - nerve, 497, 710
  - palmar. *See* **A.**, volar
  - pharyngo-palatine, 466, 1109, **1138**
    - surgical anatomy, 1374
  - plantar, 959
    - abnormalities, 960
    - surface and surgical anatomy, 1459
  - pubic, 253, **256**
    - in female, 258
    - in pelvic outlet, 257
  - superciliary, **130**, **132**, 190
    - relation to brain, 155
    - seen from the side, 137
    - in women, 186
  - tarsal, of eyelids, 818
  - temporo-maxillary, 217
  - tendinous, of pelvic fascia, 491
  - of vena azygos, 966, 1433
  - venous, dorsal, of foot, 996
        - of hand, 985
      - development and morphology, 1058
    - transverse, of sole, 996
  - vertebral, 94
    - development, 123
    - homology and variations, 112
  - visceral. *See* **A.**, **branchial**
  - **volar**, 924, 926
      - abnormalities, 923, 924, 925
      - development and morphology, 1056
      - surface and surgical anatomy, 1448
    - deep, 926
    - superficial, 924, **926**
  - **zygomatic**, **125**, 128, **138**, 141
    - level, 169
    - relation to brain, 161, 1349
      - to cavernous sinus, 158
      - to coronoid process, 180
    - seen from above, 130, 297
      - from below, 144
      - from the side, 138, 139
    - surface anatomy, 1349
    - variations, 217
- **Arcus.** *See also* **Arch**
  - senilis, 805
  - tendineus m. solei, 430
- **Area**—
  - acoustic, 653
  - acustica of fourth ventricle, 552
    - relation to vestibular nucleus, 603
  - aortic, 1396
  - association, of cortex, 642
  - auditory, 653
  - axial, of limbs, 771
  - bare, of liver, **1186**, 1188, **1190**, 1225
    - of stomach, 1164, 1229, 1231
- **Area**—*continued*
  - bucco-pharyngeal, 32
  - of cardiac dulness, 1391
  - cochleæ, 838, 839
  - cribrosa of kidney, 1252
  - embryonic, 26, 27, 31
    - development, 7
    - at different dates, 77
    - differentiation of, 27
    - pericardial region of, 32
    - relation of neural fold and primitive streak, 28
  - extra-embryonic, 31
  - facialis of meatus, 200
  - gastricæ, 1168
  - of medulla (Flechsig), 564
  - mitral, 1396
  - motor, of cerebrum, 649
    - character of cortex, 661
    - surface anatomy, 1349, 1350
  - olfactoria, 620
  - parasplenalis, 662
  - parastriata, 658, 659
  - parieto-occipital, 662
  - pericardial, 32
    - inversion of, 42
  - peristriata, 658, 659
  - piriformis, 621, **622**
    - connexion with amygdaloid nucleus, 638
      - with olfactory bulb, 645
  - postrema of fourth ventricle, 552
  - precentralis anterior, 664
    - intermedius and posterior, 664
  - precordial, 1394
  - pulmonary, 1396
  - quadrate, of temporal bone, 151, **152**, 200
  - sensory, of cerebrum, 648
    - character of cortex, 661
  - striata of occipital lobe, 656
    - relation to calcarine fissure, 657
  - subcentralis, 663
  - temporalis polaris, 655
  - tricuspid, 1396
  - vestibularis inferior et superior, 200, 839, 840
    - of fourth ventricle, 552
  - visual, 656
    - arterial supply, 909
- Areola mammæ, 1318
- Arlt, sinus of, 820
- **Arm (upper)**, 217
  - arteries, 918
  - fasciæ and muscles, 381
  - incisions, 1443
  - lymph glands, 1015
  - lymph vessels, 1018
  - nerves, 724, 732
  - in pronation and supination, 238
  - surface and surgical anatomy, 1441
  - veins, 985
- Armpit, 217
- **Arteries**, 861
        - development, 68, 71, 1032, 1037
        - morphology, 1052
        - structure and tissues, 863
        - vascular and nervous supply, 866
      - aberrant. *See* **Vas** and **Vasa**
      - arteriarum, 866
      - intersegmental, 72, 73, 1039
        - somatic, 1052
        - visceral, 1055
      - nutrient, 86

- **Arteries**—*continued*
    - presegmental, 72, 73, 1039
    - segmental, 1052
    - splanchnic, 1052, 1055
    - systemic, 880
    - vitelline, 61, 71, 73
- **Arteries, articular**—
    - of acromio-clavicular joint, 912
    - of ankle joint, 958, 961
    - of carpal joints, 925
    - of elbow joint, 920, 921, 924
    - of hip joint, 944, 953
    - of intercarpal joints, 925
    - of intertarsal joints, 959, 961, 962
    - of knee joint, 955, 956, 961
    - of mandibular joint, 896, 897
    - of radio-carpal joint, 925
    - of shoulder joint, 912, 918
    - of sterno-clavicular joint, 912, 917
    - of tarsal joints, 959, 961, 962
    - of tibio-fibular joint, 961
    - of wrist joint, 925
- **Arteries, cutaneous**, 851
    - in superficial fascia, 367
    - of anterior tibial, 961
    - of deep circumflex iliac, 949
    - of dorsal interosseous, 924
    - of dorsalis pedis, 961
    - of inferior epigastric, 948
    - of inferior gluteal, 946
    - lateral, of intercostal, 928
    - of plantar, 958, 959
    - of popliteal, 957
    - of posterior ramus of intercostal, 928
    - of posterior tibial, 958
    - of superior epigastric, 914
- **Arteries, nutrient, of bones**, 86
    - of clavicle, 912
    - of femur, 955
    - of fibula, 958
    - of hip-bone, 941, 942, 944
    - of humerus, 918, 920
    - of radius, 924
    - of ribs, 915
    - of tibia, 958
    - of ulna, 924
- **Arteries of organs and regions**—
    - of abdomen, 882, 929
    - of abdominal wall, 914, 927, 928, 929, 936, 937, 941, 949, 951
    - of acoustic meatus, 826, 895, 896, 897
    - of amygdaloid nucleus, 904
    - of anal canal, 944, 1221
    - of arm, 918
    - of arteries, 866
    - of auditory tube, 832, 893, 895, 899
    - of auricle of ear, 824, 894, 895, 896
    - of back of neck, 894, 912, 915
    - of back of trunk, 912, 915, 928, 938
    - of bile duct, 933
    - of bladder, 493, 942, 943, 944, 1041, 1269
    - of brachia conjunctiva and pontis, 908
    - of brain, 904, 905, 907
        - relation to membranes, 671
    - of branchial arches, 73, 1037, 1056
    - of bronchi, 73, 914, **927**, 1056, **1095**
    - of bulb, 943, 945
        - surgical anatomy, 1419
    - of buttock, 942, 944, 946, 953, 954
    - of cæcum, 935, 1202, 1207
    - of caudate nucleus, 904, 905
    - of cerebellum, 907, 908
- **Arteries of organs and regions**—*continued*
    - of cerebrum, 670, **904**, **905**, 908, 1355
    - of chorioid of eye, 807, 903
    - of chorioid plexuses, 904, 907, 908
    - of clitoris, 945, 1309
    - of cochlea, 847, 908
    - of colon, 935, 936, 1172, 1202
    - of commissura anterior, 904
    - of conjunctiva, 818
    - of corpora cavernosa, 945, 946, 1285, 1309
    - of corpora quadrigemina, 908
    - of corpus callosum, 905
    - of corpus mamillare, 908
    - of corpus striatum, 904, 905
    - of diaphragm, 914, 929, 936
    - of ductus deferens, 942, 943, 1279, 1281
        - in wall of duct, 1279
    - of duodenum, 933, 935, 1180
    - of dura mater of skull, 157, 159, 161, 166, 894, 895, 897, 898, 903, 904, 907
    - of ear, 824, 836, 847; *and see* **Aa.**, auditory, auricular, meningeal (middle), petrosal, of pterygoid canal, stylomastoid and tympanic
    - of epididymis, 931
    - of ethmoidal sinus, 899, 904
    - of external acoustic meatus, 826, 895, 896, 897
    - of extremities. *See* A. of limbs
    - of eyeball, 802, 803, 807, 809, 812, **903**
        - in inflammation, 1368
    - of eyelids, 818, 898, 903, 904
    - of face, 892, 896, 898, 903
        - surgical anatomy, 1370
    - of filum terminale, 941
    - of fingers, 922, 923, 926
    - of foot, 958, 961
    - of forearm, 920, 923
    - of fornix cerebri, 904, 905, 908
    - of frenulum linguæ, 892
    - of frontal sinus, 904
    - of gall bladder, 933, 1193
    - of geniculate bodies, 909
    - of gluteal region, 942, 944, 946, 953, 954
    - of hand, 921, 922, 923, 925
    - of head, 891 *et seq.*
    - of heart, 876, 884, 885
    - of hyoid arch, 73, 1037, 1038, 1056
    - of hypophysis cerebri, 902, 1338
    - of ileum, 934, 935, 1172
    - of inferior extremity. *See* **A.** of lower limb
    - of internal capsule, 904, 905
    - of internal ear, 847, 895, 908
    - of internal jugular vein, 894
    - of intestines, 934, 935, 1172, 1202, 1207
    - of iris, 809, 903
    - of jejunum, 934, 935, 1172
    - of kidney, 930, 1254
    - of labium majus, 945, 952, 953, 1307
    - of lacrimal gland, 819, 898, 903
    - of lacrimal sac, 820, 898
    - of larynx, 465, **891**, **911**, 1378
    - of leg, 955, 957, 960
    - of lentiform nucleus, 904, 905
    - of ligamentum teres femoris, 944, 953
    - of ligamentum teres uteri, 931, 943, **948**
    - of limbs, 909, 947
        - development and morphology, 1041, 1056, 1057
    - of lips, **893**, 1105
        - surgical anatomy, 1370

Arteries of organs and regions—*continued*
- of liver, 914, 932, **933**, 935, 937, 1191
- of lower limb, 942, 943, 946, 947
  - development and morphology, 1041, 1057
- of lung, 878, 927, 1095, 1097
- of lymph glands, 1003
- of mamma, 912, 914, 918, 928, 1320
- of mandibular arch, 72, 1037, 1038, 1056
- of mastoid air-cells, 895
- of maxillary sinus, 800, 898, 899
- of meatus, external acoustic, 826, 895, 896, 897
- of mediastinum, 914, 927
- of medulla oblongata, 907
- of medulla spinalis, 907, 911, 928, 1040, 1053
  - relation to pia mater, 673
- of meninges of brain, 157, 159, 161, 166, 894, 895, 897, 898, 903, 904, 907
- of mid-brain, 904, 908
- of naso-lacrimal duct, 820
- of neck, 886 *et seq.*, 905, 909
- of nose, 799, 893, 899, 904
- of nostril, 800
- of œsophagus, 911, 927, 932, 937, 1148
- of olfactory bulb, 904
- of omentum, 933
- of optic tract, 904
- of orbit, 897, 898, 903
- of ovary, **931**, 943, 1297
- of palate, 892, 895, 899, 1108, 1375
- of palm of hand, 921, 923, 925
- of pancreas, 932, 933, 935, 1198
- of parathyreoid gland, 1333
- of parotid duct, 896
- of parotid gland, 895, 896, 897, 1131
- of peduncles of cerebrum, 904, 908
- of pelvis, 931, 936, 938, 941
- of penis, 945, 946, 952, 1285
- of pericardium, 914, 927
- of perineum, 945
- of pharynx, 892, 893, 895, 899, **1143**
- of pineal body, 908
- of pleura, 914
- of pons, 908
- of processus vermiformis, 935, 1207
  - surgical anatomy, 1411
- of prostate, 943, 1288
- of pterygoid canal, 899, 902
- of pterygoid muscles, 898
- of rectum, 936, 939, 943, 944, 1221
- of retina, 812, 903
  - development, 820
- of round ligament of femur, 944, 953
- of round ligament of uterus, 931, 943, **948**
- of scalp, 894, 895, 896, 897, 903, 904
  - within scalp, 1347
- of sciatic nerve, 946, 1041
- of sclera, 803
- of scrotum, 945, 952, 953, 1282
- of semicircular canals, 895
- of seminal vesicle, 943, 1279
- of septum pellucidum, 904
- of sigmoid sinus, 894
- of skin, 367, 851
- of sole of foot, 958, 962
- of sphenoidal sinus, 800, 899
- of spinal medulla, 907, 911, 928
  - development and morphology, 1040, 1053
  - relation to pia mater, 673
- of spleen, 932, 1056, 1343, 1344, 1408

Arteries of organs and regions—*continued*
- of sternomastoid, 890, 891, 894, 899
- of stomach, 932, 933, 935, 1169
- of sublingual gland, 892, 893, 1133
- of submaxillary gland, 893, 1132
- of superior extremity. *See* **A.** of upper limb
- of suprarenal gland, 929, 930, 937, 1328, 1329
  - development and morphology, 1055
- of teeth, 898
- of tela chorioidea, 908
- of testicle, **930**, 943, 1281
  - within testicle, 1273, **1274**
  - surgical anatomy, 1413, 1421
- of thalamus, 904, 905, 908
- of thigh, 943, 946, 950
- of thorax, 878, 880, 884, 912, 927
- of thumb, 922, 923
- of thymus, 914, 1336
- of thyreoid gland, 886, 887, 891, 911, 1331
  - abnormalities, 885, 907, 927
  - development and morphology, 1056
  - surgical anatomy, 1377, 1379, 1382
- of toes, 958, 959, 962
- of tongue, 463, 464, **891**, 1123, 1124
  - surgical anatomy, 1381, 1382
- of tonsil (palatine), 892, 893, 895, 1140
- of trachea, 911, 914
- of trigeminal nerve, 897, 902, 908
- of tuba auditiva, 832, 893, 895, 899
- of tuba uterina, 931, 943, 1298
- of tympanic antrum and cavity, 836; *and see* **Aa.**, meningeal (middle), petrosal, of pterygoid canal, stylomastoid and tympanic
- of tympanic membrane, 829, 895, 897
- of uncus, 904, 909
- of upper limb, 909
  - development and morphology, 1041, 1056
- of urachus, 942
- of ureter, 930, 931, 942, 943, 1258, 1416
- of urethra, 945
- of uterine tube, 931, 943, 1298
- of uterus, 931, 943
  - in pregnancy, 1303
  - surgical anatomy, 1426
- of vagina, 943, 1306
- of velum medullare anterius, 908
- of vena cava inferior, 937
- of vermiform process, 935, 1207
  - surgical anatomy, 1411

Arteries, named
- acetabular, of medial circumflex, 953
  - of obturator, 944
- acromial, of posterior circumflex, 918
  - of thoraco-acromial, 917
  - of transverse scapular, 912
- alveolar, inferior, 458, **898**
    - relation to spheno-mandibular lig., 315
  - superior, anterior, 898
    - posterior, 898
      - relation to maxillary sinus, 176
- anastomotic, of inferior gluteal, 946
- angular, 893
  - in incisions for abscess, 1368
- anonyma. *See* **A.**, innominate
- aorta. *See* **Aorta.**
- appendicular, 935, 1207
  - surgical anatomy, 1411
- arciformes of kidney, 1254

Arteries, named—*continued*
  arcuate, of foot, 962
    abnormalities, 958
  ascending cervical. *See* **A.**, cervical
    of circumflex iliac, 949
      surgical anatomy, 1401
    of lateral circumflex, 953
    palatine. *See* **A.**, palatine
    pharyngeal, 149, 162, **895**
    of profunda brachii, 920
    of transverse cervical, 912
      abnormality, 912
  atrial (of heart), 885
  auditory, internal, 167, 847, **908**
  auricular, anterior, 896
    deep, 897
    of occipital, 894
    posterior, 150, 449, 824, **894**
      relation to antrum, 1355
  axillary, 915
      first and second parts, 916
      third part, 917
    abnormalities, 914, 917, 925
    development and morphology, 1039, 1041, 1056
    surface and surgical anatomy, 1439, 1440
  azygos, of vagina, 943
  basal. *See* **A.**, central
  basilar, 549, **908**
    abnormalities, 908
    development, 1040
    in operation on hypophysis, 1365
    relation to skull, 164
      to sphenoidal sinus, 177
  brachial, 918
    abnormalities, 230, 917, 919, 925
    development, 1041
    nerve supply, 734
    surface and surgical anatomy, 1441, 1443, 1444
  bronchial, 927
      abnormalities, 914, 927
      development and morphology, 73, 927, 1056
      within lung, 1095
    of internal mammary, 914
  buccal, 893
  buccinator, 456, **898**
  of bulb, 943, 945
    surgical anatomy, 1419
  calcanean, 424, 959
  calcarine, 909
  capsular, of liver, 1191
  cardiac. *See* **A.**, coronary
  carotico-tympanic, 902
  carotid, *common*, 887, 889
        abnormalities, 885, 889, 907, 1038, 1039
        development, 1038
        relation to sixth vertebra, 96
        surface and surgical anatomy, **1382**, 1384, 1396
      left, 887
      right, 887, **889**
    external, 889
      abnormalities, 890, 899, 1039
      branches, 890, **891**
      development, 1038
      nerve supply, 782
      relation to mandible, 180
      surface and surgical anatomy, 1382
    internal, 899

Arteries, named—*continued*
  carotid—*continued*
    internal—*continued*
      abnormalities, 902, 1039
      branches, 902
      in carotid groove, 158
      connexion with carotid gland, 1326
      development, 1038
      in foramen lacerum, 162
      when needling mandibular nerve, 1367
      nerve supply, 782
      relation to auditory tube, 152
        to ear, 151
        to foramen lacerum, 159
        to sphenoidal sinus, 176
        to tonsil, 1140
      in tumour of hypophysis, 1365
  carpal, dorsal, of radial, 922
        abnormality, 923
      of ulnar, 924
    volar, of radial, 921
      of ulnar, 924
  cavernous, 902
  central, of brain, 904, 905
      antero-lateral, 905, 1355
      antero-medial, 904
      postero-lateral, 909
      postero-medial, 908, 909, 1355
  centralis retinæ, 903
    development, 820
    within eyeball, 812
  cerebellar, inferior, anterior, 908
      posterior, 907
    superior, 908
  cerebral, anterior, 670, **904**
      abnormalities, 905
      relation to terminal nerve, 678
    middle, 670, **905**, 1355
    posterior, 908, 1355
      abnormality, 908
  "of cerebral hæmorrhage," 905, 1355
  cervical, ascending, 911
      development and morphology, 1055
    deep, 915
      abnormalities, 915, 929
      development and morphology, 1055
    superficial, 912
    transverse, 911
      ascending branch, 369, 912
        abnormality, 912
      descending branch, 369, 372, 911, **912**
        abnormalities, 911, 912
  chorioidal, anterior, 904
    posterior, 908
    of fourth ventricle, 907
  ciliary, 903
      piercing sclera, 803
      within eyeball, 807, 809
    anterior, 903
    posterior, long and short, 903
      piercing fascia bulbi, 802
  circumflex, of heart, 885
    humeral, anterior, 918
      posterior, 918
        abnormality, 917
        surface and surgical anatomy, 1442, 1443
    iliac, deep, 949
        abnormalities, 950, 955
      superficial, 951
    scapular, 219, 379, **918**
    of thigh, lateral, 953

Arteries, named—*continued*
  circumflex—*continued*
    of thigh, lateral—*continued*
        abnormality, 955
        surface and surgical anatomy, 1454
      medial, 953
        abnormality, 950, 955
        surface and surgical anatomy, 1449
  clavicular, of thoraco-acromial, 917
  coccygeal, 946
  cœliac, 931
    abnormalities, 931, 937
    development and morphology, 73, 1040, 1056
    surface and surgical anatomy, 1417
  colic, left, 936
      abnormalities, 936
      relation to internal hernia, 1179
      surgical anatomy, 1413
    middle, 935
      abnormalities, 932, 936
      surgical anatomy, 1413
    right, 935
  collateral, of intercostal, 928
      of first and second, 915
    medial, of profunda brachii, 920
    ulnar, inferior, 920
      superior, 381, **920**
        abnormalities, 917, 919
  comitans nervi ischiadici, 946
      development and morphology, 946, 1041
    nervi mediani. *See* **A.**, median
    nervi phrenici. *See* **A.**, pericardiaco-phrenic
  communicating, of brain, anterior, 904
      posterior, **904**, 908
        abnormality, 902
    of peroneal, 958
    of posterior tibial, 958
    volar, 924
    of volar arch, 926
  coronary, of heart, in heart substance, 876
        abnormalities, 885
      left, 885
      right, 884
    of stomach. *See* **A.**, gastric, *left*
  cortical, of brain, 905, 908
  costo-cervical. *See* **Trunk**
  crico-thyreoid, 891
    surgical anatomy, 1379
  cystic, 933, 1193
  deep auricular, 897
    cervical. *See* **A.**, cervical
    circumflex iliac. *See* **A.**, circumflex
    of clitoris, 945, 1309
    of dorsalis pedis, 962
    external pudendal, 953
    femoral. *See* **A.** profunda femoris
    of medial circumflex, 953
    of penis. *See* **A.** profunda penis
    of tongue. *See* **A.** profunda linguæ
    of ulnar, 924
  deferentialis, 942, 943, 1279, 1281
    in ductus deferens, 1279
  deltoid, of thoraco-acromial, 917
  descending aorta. *See* **Aorta**
  descending, of circumflex scapular, 918
    of lateral circumflex, 953
    of occipital, 894
    of posterior circumflex, 918
    of transverse cervical, 911, **912**
  diaphragmatic. *See* **A.**, phrenic
  digital, of foot, dorsal, 962

Arteries, named—*continued*
  digital, of foot—*continued*
      plantar, 958, 959, 962, 963
    of hand, 922, 926
        development and morphology, 1056
      dorsal, 922, 926
        abnormalities, 923
      volar, common, 926
          abnormalities, 925
        proper or special, 926
          surgical anatomy, 1449
  dorsalis clitoridis, **945**, 1309
    indicis radialis, 922
      abnormalities, 923
    linguæ, **892**, 1124
    nasi, 904
    pedis, 427, **961**
      abnormalities, 958, 959, 963
      development, 1041
      surface and surgical anatomy, 1459
    penis, 945, 1285
      abnormalities, 946, 950
    pollicis, 922
  "end," of spleen, 1344
  epigastric, *inferior*, 407, 485, **948**
      abnormalities, 949, 950, 955
      development and morphology, 1040, 1054
      relation to ductus deferens, 1276
      seen through peritoneum, 1224
      surface and surgical anatomy, 1398, 1401, 1425
    superficial, 952
    superior, 473, **914**
      development and morphology, 1040, 1054
      surgical anatomy, 1401
  ethmoidal, anterior and posterior, 904
    in ethmoidal canals, 136, 157
  facial. *See* **A.**, maxillary, *external*
  facial, transverse, 896
  femoral, 407, 415, 948, **950**
      abnormalities, 946, **955**
      development and morphology, 1040, 1041, 1057
      nerve supply, 751, 752, 753
      relation to hip-bone, 254
      surface and surgical anatomy, 1453
    common, 951
    deep. *See* **A.** profunda femoris
    superficial, 951
  fibular, of anterior tibial, 961
    of posterior tibial, 957
  frontal, *of brain*, ascending, 905
      lateral, inferior, 905
      medial, anterior, 904
        intermediate, 905
        posterior, 905
    of ophthalmic, 904
      exit from orbit, 135
      in rhinoplasty, 1348
      surface anatomy, 1348
    of superficial temporal, 897
  gastric, *left*, **932**, 1169
      abnormalities, 932, 936, 939
      development and morphology, 1056
      surgical anatomy, 1409
    right, **933**, 1169
      development and morphology, 1056
      surgical anatomy, 1409
    short, 933, 1169
    of superior mesenteric (anomalous), 935

Arteries, named—*continued*
  gastro-duodenal, **933**, 1177, 1196
    abnormalities, 931, 935
    surgical anatomy, 1406, 1409
  gastro-epiploic, left, **933**, 1169
    right, **933**, 1169
      abnormalities, 935
      surgical anatomy, 1409
  genicular, 956
  genu suprema, 955
    surface and surgical anatomy, 1455
  gluteal, 942, 946
      abnormalities, 946
      surface and surgical anatomy, 1450
    inferior, 946
      development and morphology, 1040, 1041, 1057
      in fœtus, 939
    superior, 942
  hæmorrhoidal, *inferior*, 944
      in anal canal, 1222
    middle, 943
      abnormality, 943
      in rectum, 1222
    superior, 936
      abnormality, 946
      in rectum, 1221
  helicine, of penis, 1285
  hepatic, **933**, 1191
      abnormalities, 933, 935, 936
      development and morphology, 1056
      left, 933
        abnormalities, 932, 933
      right, 933
    accessory, 932, 933
    of inferior phrenic, 937
    of superior epigastric, 914
  hyaloid, 814
    development, 820
  hyoid, of lingual, 892
    of superior thyreoid, 891
      abnormalities, 890, 899
  hypogastric, 490, **940**
    abnormalities, 930, 939, **946**
    development and morphology, 1040, 1056
    in fœtus, 939
  ileal, 935, 1172
  ileo-cæcal, **935**, 1207
  ileo-colic, **935**, 1202, 1207
  iliac, circumflex. *See* **A.**, circumflex
    common, 939
      abnormalities, 930, 939, 946
      development and morphology, 1040, 1056
      level, 1434
      surgical anatomy, 1414, 1417
    external, 948
      abnormalities, 884, 930, 950
      development and morphology, 1040, 1041, 1057
      nerve supply, 751
      surface and surgical anatomy, 1417
    internal. *See* **A.**, hypogastric
    of ilio-lumbar, 941
  ilio-lumbar, 941
    abnormalities, 939, 946
  infra-hyoid, of superior thyreoid, 891
    abnormalities 890, 899
  infra-orbital, 135, 452, **898**
    exit from foramen, 133
  infra-scapular, 918
  infraspinous, of transverse scapular, 912

Arteries, named—*continued*
  innominate, 886
      in lower animals, 886
    abnormalities, 885, 886, 914
    in child, 1379
    development, 1038
    surface and surgical anatomy, 1379, 1396
  intercostal, *anterior*, 914
    posterior, of aorta, 927
        abnormalities, 907, 929
          of first, 927, 928
        development and morphology, 1039, 1053, 1054
        in subcostal groove, 117
      of superior intercostal, 915
    superior or *suprema*, 915
      abnormalities, 907, 915, 929
      development and morphology, 1040, 1054
  interlobar, of kidney, 1254
  interlobular, of kidney, 1254
  interosseous, *common*, 924
      abnormalities, 917, 919, 923, 925
      homology, 1057
    dorsal, 924
      abnormalities, 925
      development and morphology, 1056
      homology, 1057
      nerve supply, 742
    volar, 924
      abnormalities, 924, 925
      development and morphology, 1041, 1056
      homology, 1057
  intersegmental, 72, 73, 1039
    somatic, 1052
    visceral, 1055
  interventricular, of heart, 885
  intestinal, 935
    in wall of gut, 1172
  intralobular, of spleen, 1344
  jejunal, 935, 1172
  labial, of face, **893**, 1105
      surgical anatomy, 1370
    of vulva, anterior, 952, 1307
      posterior, 945, 1307
  lacrimal, 134, 135, 139, **903**
  laryngeal, inferior, 465, **911**
    superior, 465, **891**
      in pharyngotomy, 1378
  lenticulo-optic, 905
  lenticulo-striate, 905
  of ligamentum teres uteri, 931, 943, **948**
  lingual, 463, 464, **891**, 1124
      surgical anatomy, 1381, 1382
    of inferior alveolar, 898
  lumbalis ima, 938
  lumbar, 937
      abnormalities, 930, 938
      development and morphology, 1039, 1053, 1054
    of ilio-lumbar, 941
  macular, 813
  malleolar, lateral, anterior, 961
    medial, anterior, 961
      posterior, 958
  mammary, internal, **912**, 1320
      abnormalities, 914, 927
      development and morphology, 1040, 1054
      nerve supply, 784
      surface and surgical anatomy, 1389

- **Arteries, named**—*continued*
  - **mammary**, internal—*continued*
      - when tapping pericardium, 1396
    - lateral, 914
  - marginal, of heart, 885
  - masseteric, of external maxillary, 893
    - of internal maxillary, 180, 456, **898**
  - mastoid, 894
  - **maxillary**, *external*, 179, **892**
      - abnormalities, 890
      - relation to tonsil, 1140
      - surface and surgical anatomy, 1366, 1381
    - *internal*, 141, 142, 456, 458, **897**
      - development, 1039
      - in excision of condyle, 1366
      - relation to mandible, 180
        - to spheno-mandibular lig., 315
  - median, 924
    - abnormalities, 923, 924, 925
    - development and morphology, 1041, 1056
    - homology, 1057
  - mediastinal, anterior, 914
    - of aorta, 927
  - **meningeal**, *accessory*, 147, **898**
    - *anterior*, 157
      - of ethmoidal, 157, 904
      - of middle meningeal, 157, 898
      - of ophthalmic, 903
    - *of lacrimal*, 903
    - *middle*, 147, 152, **897**
        - anomalous ophthalmic branch, 904
        - inside skull, 154, 161, 166
        - relation to skull, 159
          - to spheno-mandibular lig., 315
        - surface and surgical anatomy, 1353
        - torn, 159
      - anterior terminal branch, 898
        - surface anatomy, 139, 1349, 1350, 1353
      - posterior terminal branch, 898
    - *posterior*, 166
      - of ascending pharyngeal, 149, 162, 166, **895**
      - of internal carotid, 902
      - of middle meningeal, 166, 898
      - of occipital, 166, **894**
      - of vertebral, 166, **907**
  - mental, 179, **898**
  - **mesenteric**, *inferior*, 936
      - abnormalities, 932, 933, 935, 936
      - development and morphology, 73, 1040, 1056
      - surface and surgical anatomy, 1417
    - *superior*, 934
      - abnormalities, 932, 933, 935, 936, 937
      - connexion with umbilicus, 1040
      - development and morphology, 61, 73, 1040, 1056
      - relation to pancreas, 1195
      - surface and surgical anatomy, 1404, 1417
  - metacarpal, dorsal, 922, 925
      - abnormalities, 923
      - first, 922
      - second and third, 922, 925
    - volar, 926
  - metatarsal, dorsal, 962
    - plantar, 959
      - first, 962
  - musculo-articular, 955
  - musculo-phrenic, 473, **914**
  - mylo-hyoid, 898
  - nasal, dorsal, 904
    - lateral, 893

- **Arteries, named**—*continued*
  - nasal—*continued*
    - posterior, lateral, 899
      - septal, 899
    - of retina, 813
  - naso-palatine. *See* **A.**, spheno-palatine
  - neural, of intercostal, 928
    - of superior gluteal, 942
  - nutrient, 86
  - obturator, 254, **943**
      - relation to distended bladder, 1264
        - to ductus deferens, 1276
        - to ovary, 1295
    - abnormal, 946, 949, 955
  - occipital, 136, **893**
      - in back of neck, 444
      - on mastoid temporal, 150
    - of posterior auricular, 895
  - œsophageal, 1148
      - development and morphology, 73, 1056
    - of aorta and bronchial, 927
    - of inferior phrenic, 937
    - of inferior thyreoid, 911
    - of left gastric, 932
  - omental, of gastro-epiploics, 933
  - omphalo-mesenteric, 935
  - ophthalmic, 903
    - abnormalities, 904
    - in optic foramen, 136, 158
  - orbital, of brain, lateral, 905
      - medial, 904
    - of middle meningeal, 897
  - ovarian, 931, 1297
      - abnormalities, 931
    - development and morphology, 1040, 1055
    - surgical anatomy, 1426
  - **palatine**, ascending, **892**, 971
        - abnormalities, 890, 899
      - greater (or descending), 145, 899
        - surgical anatomy, 1375
      - lesser, 145, 899
    - of ascending pharyngeal, 895
  - palpebral, 818, 903, 904
  - pancreatic, 932, 933, 1198
  - pancreatica magna, 932
  - pancreatico-duodenal, inferior, 935, 1198
    - superior, 933, 1180, 1198
  - parietal, of brain, 905
    - of superficial temporal, 897
  - parieto-occipital, 909
  - parieto-temporal, 905
  - pectoral, of thoraco-acromial, 917
  - **perforating**, of foot, 959, 962
    - of hand, distal, 922, 926
      - proximal, 922, 926
        - abnormality, 923
    - of internal mammary, 914
    - of peroneal, 353, 958
      - abnormality, 958
    - of profunda femoris, 415, **954**
      - fourth, 953, 954
  - pericardiaco-phrenic, 914
  - pericardial, 914, 927
  - perineal, 945
    - transverse, 945
  - perinephric, 930, 931
  - peritoneal, of spermatic, 931
  - peroneal, 957
    - abnormalities, 957, 958
    - development and morphology, 1041, 1057
    - homology, 1057
    - nerve supply, 763

Arteries, named—*continued*
peroneal—*continued*
surface and surgical anatomy, 1457
petrosal, superficial, 163, 836, **897**
pharyngeal (of internal maxillary), 146, **899**
ascending, 149, 162, **895**
phrenic, inferior, 936
abnormalities, 930, 937
superior, 929
plantar, lateral, 958
abnormalities, 960, 963
development, 1041
surface and surgical anatomy, 1459
medial, 958
abnormality, 959
development, 1041
surface and surgical anatomy, 1459
polaris superior, 1343
pontine, 908
popliteal, 264, 948, **955**
abnormalities, 946, **957**, 961
development and morphology, 1041, 1057
nerve supply, 762
surface and surgical anatomy, 1452
post-central, of intercostal, 928
prelaminar, of intercostal, 928
presegmental, 72, 73, 1039
prevertebral, of ascending pharyngeal, 895
princeps pollicis, **923**, 926
abnormalities, 923
profunda auricularis, 897
brachii, 381, 384, **920**
abnormality, 917
cervicis. *See* **A.**, cervical, deep
of clitoris, 945, 1309
of dorsalis pedis, 962
femoris, 415, **953**
abnormalities, 955
iliaca circumflexa. *See* **A.**, circumflex
linguæ, 891, 1124
position in tongue, 1123
surgical anatomy, 1373, 1374
of medial circumflex, 953
penis, 945, 1285
abnormality, 946
pudendæ externæ, 953
of ulnar, 924
of pterygoid canal, 163, 899
from internal carotid, 902
to pterygoid muscles, 898
pubic, of inferior epigastric, 949
of obturator, 944
pudendal, accessory, 946
external, deep, 953
superficial, 952
internal, 490, **944**
abnormality, 946
surgical anatomy, 1418, 1450
pulmonary, 878
abnormalities, 884, 1037
blood supply, 885
development and morphology, 1035, 1056
orifice, 869
surface anatomy, 1396
branches, 879, 880
arterial supply, 927
development and morphology, 1038, 1056
in roots of lungs, 1095
within lungs, 1097
left, 880

Arteries, named—*continued*
pulmonary—*continued*
branches—*continued*
right, 879
relation to sternum, 115
pyloric. *See* **A.**, gastric, right
radial, 388, 403, **920**
abnormalities, 917, 919, 923, 925
development and morphology, 1041, 1056
homologue (absent), 1057
nerve supply, 741
surface and surgical anatomy, 1448
first part, 921
second and third parts, 922
in volar arch, 926
at wrist, 238
radial recurrent. *See* **A.**, recurrent
radialis indicis. *See* **A.** volaris indicis radialis
recurrent, of deep volar arch, 925, 926
interosseous, 924
radial, 921
abnormalities, 923
tibial, anterior and posterior, 961
ulnar, dorsal and volar, 924
abnormalities, 919, 925
renal, 930
abnormalities, 930, 931, 933, 936, 937, 946
development and morphology, 1040, 1055
surface and surgical anatomy, 1417
within kidney, 1254
accessory, **930**, 939
surgical anatomy, 1416
retinæ centralis. *See* **A.** centralis
of round ligament of uterus, 931, 943, **948**
sacral, lateral, 105, 106, 941
abnormalities, 939, 946
middle, 105, **938**, 1222
abnormalities, 930, 939
development and morphology, 73, 1039, 1055
saphenous, 408, 955
great, 955
small, 957
scapular, circumflex, 219, 379, **918**
transverse, 912
abnormality, 911
scrotal, anterior, 952, 1282
posterior, 945, 1282
segmental, 1052
septal, of superior labial, 893
sigmoid, 936
surgical anatomy, 1414
spermatic, external, 948
internal, **930**, 1281
abnormalities, 930, 931, 939
development and morphology, 1040, 1055
surgical anatomy, 1413, 1421
in testis, 1273, 1274
spheno-palatine, 142, 169, **899**
spinal, 907, 928
development and morphology, 1040, 1053
relation to pia mater, 673
of ascending cervical, 911
of ilio-lumbar, 941
of intercostal, 928
of lateral sacral, 941

Arteries, named—*continued*
- spinal—*continued*
  - of lumbar, 938
  - of vertebral, 907
- splanchnic, 1052, 1055
- **splenic**, **932**, 1343
  - abnormalities, 932, 935, 936
  - development and morphology, 1056
  - in gastric ulcer, 1408
  - within spleen, 1344
- stapedial, 835, 1039
- sterno-mastoid, 891, 894
    - abnormalities, 890, 899
  - of occipital, 894
  - of superior thyreoid, 891
- striate, lateral and medial, 905
- stylo-mastoid, 150, 830, 836, 847, **895**
- **subclavian**, 118, 468, **909**, **910**
    - abnormalities, 885, 889, 910, 915, 927, 929, 1038
    - development and morphology, 1038, 1039, 1054
    - level, 1433
    - nerve supply, 782
    - relation to fascia, 447
    - surface and surgical anatomy, 1385, 1390, 1439
  - left and right, 909, 910
- subcostal, 473, **929**
- sublingual, 892
- submaxillary, 893
- submental, 893
- subscapular, of axillary, 918
    - abnormality, 917
  - of transverse scapular, 912
- suprahyoid, of lingual, 892
- supra-orbital, 132, 903
  - surface anatomy, 1348
- suprarenal, 929, 930, 937, 1328
    - abnormalities, 931
    - development and morphology, 1055
    - within gland, 1329
  - inferior and middle, 930
  - superior, 937
- supraspinous, 912
- suprasternal, 912
- sural, 956
  - superficial, 957
    - abnormality, 957
- systemic, 880
- tarsal, lateral, 962
    - abnormality, 958
  - medial, 962
- **temporal**, of brain, 905
    - anterior, 908
    - posterior, 909
  - of lacrimal, 903
  - of retina, 813
  - of scalp, deep, 139, **898**
    - middle, 139, 197, **896**
    - *superficial*, 139, 824, **895**
      - in anæsthesia, 1349
      - cirsoid aneurysm of, 1347
      - relation to mandible, 180
      - surface anatomy, 1349
- terminalis, inferior and superior, 1343
- testicular, 930. *See also* **A.**, spermatic, internal
- thoracalis suprema, 917
- thoracic, lateral, 918
  - surgical anatomy, 1441
- thoraco-acromial, 373, 377, **917**
- thoraco-dorsal, 918
- thyreo-cervical. *See* **Trunk**
- **thyreoid**, inferior, 911
    - abnormalities, 907, 927
    - surgical anatomy, 1377
  - superior, 891
    - abnormalities, 890
    - development and morphology, 1056
    - surgical anatomy, 1382
- thyreoidea ima, 886
  - abnormality, 885
  - development and morphology, 1056
- **tibial**, anterior, 353, **960**
    - abnormalities, 957, 958, 963
    - development and morphology, 1041, 1057
    - homology, 1057
    - surface and surgical anatomy, 1457
  - posterior, 423, **957**
    - abnormalities, 957, **958**
    - development and morphology, 1041, 1057
    - homology, 1057
    - nerve supply, 763
    - surface and surgical anatomy, 1457
- tonsillar, of external maxillary, 893, 971
- tracheal, 901
- **transverse** cervical. *See* **A.**, cervical
  - facial, 896
  - of lateral circumflex, 953
  - of medial circumflex, 954
  - perineal, 945
  - scapular. *See* **A.**, scapular
- tubal, of ovarian, 931
  - of uterine, 943
- **tympanic**, anterior, 152, 897
  - inferior, 836, 895
  - of internal carotid, 151, 836, 902
  - posterior, 895
  - superior, 897
- **ulnar**, 389, **923**
    - in volar arch, 926
  - abnormalities, 917, 919, 923, 924
  - development and morphology, 1041, 1056
  - homologue (absent), 1057
  - nerve supply, 737
  - surface and surgical anatomy, 1448
- ulnar collateral. *See* **A.**, collateral
- ulnar recurrent. *See* **A.**, recurrent
- **umbilical**, 59, 60, 71, 939, 942
    - development, 1040
  - *obliterated*, 940, 942, 1224
    - development, 1041
    - relation to distended bladder, 1264
      - to ductus deferens, 1276, 1277
- uterine, 943
    - in pregnancy, 1303
    - surgical anatomy, 1426
  - of ovarian, 931
- vaginal, 943, 1306
  - of liver, 1191
- ventricular, of heart, 885
- **vertebral**, 905, 906
    - on arch of atlas, 97, 313, 444
    - in foramen magnum, 148
    - in foramina transversaria, 96, 97
    - relation to skull, 164
  - abnormalities, 885, 907
  - development and morphology, 1040, 1054, **1055**
  - nerve supply, 784
  - surgical anatomy, 150, 1384, 1387

Arteries, named—*continued*
  vesical, inferior, 493, 943, 1269
      middle, 942
      superior, 493, 940, **942**, 1269
        development, 1041
    of obturator, 944
  visceral, intermediate or lateral, 1052
  vitelline, 61, 71, 73
  volar, superficial, of radial, 921, 926
  volaris indicis radialis, 923, 926
    abnormalities, 923
    surgical anatomy, 1448
  xiphoid, 914
  zygomatic, of lacrimal, 903
  zygomatico-orbital, 896
Arteriolæ rectæ of kidney, 1254
Arterioles, 861
  capillary, 865
Arthrectomy of knee, 1456
Arthrodia, 303
Arthrology, 3, 301
Articulations, 83, 301. *See also* **Joints**
  coxæ. *See* **Joint**, hip
  cubiti. *See* **Joint**, elbow
  genu. *See* **Joint**, knee
  humeri. *See* **Joint**, shoulder
Asterion, 140, 141, 296
Astragalus. *See* **Talus**
Asymmetry, 4
Atlas vertebra, 97
    development, 123
    fusion with occipital, 196
    homologies, 112
    ossification and variations, 111
    relation to skull, 148, 149
  lateral mass, 97, **98**, 149
  transverse process, 97, 149
    surgical anatomy, 1383
Atresia ani, 1223
Atrium, 171
  of heart, 861, 866, **869**
      development, 72, 1033
      structure, 875
    left, 871
      abnormality, 966
    right, 869
  of lung, 1097
  of middle meatus, 171, 172, 173, **797**
  tympani, 826
Atrophy of organs and tissues, 9
Attachments of muscles, 365
Attic. *See* Recess, epitympanic
Attitude, erect, 4, 107, 258, 340, 349, 1165
  kneeling, 267
  sitting, 249, 251
Attraction sphere, 8
Auerbach's plexus, 1172
Auricle of atrium, 869
      surface anatomy, 1394
    left, 871
    right, 870
  of ear, 822
    arteries, 824, 894, 895, 896
    development, 48, 58, 79, 81
    lymph vessels, 824, 1012
    muscles, extrinsic, 449
    nerves, 690, 723, 824
    surgical anatomy, 1355
    veins, 824, 973
Auris interna. *See* **Ear**, internal
Auscultation, triangle of, 369, 371, 372, 1428
Axial skeleton, 91, 94
Axilla, 217
  abscess, 1441
  fascia, 369, 373
  lymph glands, 1016
  surface and surgical anatomy, 1440
Axis of eyeball, 135, 801
  of optic nerves, 801
  of orbit, 135
  of pelvis, 257
Axis vertebra. *See* **Vertebra, cervical**, second
Axis-cylinder. *See* Axon
Axis-ligament of malleus, 835
Axon, 508, 509, 511
  of sensory cells, 512

Back, arteries of, 912, 915, 928, 938
  fasciæ of, 368, 437
  muscles of, 369, 438
  nerves of, 717, 718
  surgical anatomy of, 1427
  veins of, 967, 990
Back of skull, 136
Backbone. *See* **Column**, vertebral
Ball-and-socket joints, 303
Banderella of Giacomini, 627
Bands of Baillarger, 642
  of Meckel, 834
  moderator, 873
  tooth, 1233
Bar, branchial and pharyngeal. *See* **Arch**, branchial
Barbula hirci, 823
Base of brain, 541
  of heart, 867
    in child, 868
  of mandible, 178
  of skull, exterior, 142
      interior, 155
    weak areas, 1349
Base-line of skull, 1350
Basi-occiput, 148, 193. *See also* **Occipital bone**
Basion, 148, 295
Basi-otic bone, 195, 196
Basis cerebri, 541
  cranii externa, 142
      posterior region, 147
    interna, 155
  of life, 8
  pedunculi, 582
    constituents, 590
Bed of nail, 852
  of stomach, 1163
Belly, 248. *See also* **Abdomen**
Beraud, valve of, 820
Bertin, bones of, 205
Betz, cells of, 649
Bifurcation of aorta, 880, 882
    abnormalities, 884
  of trachea, 1077
Bigelow, ligament of. *See* **Lig.**, ilio-femoral
Bile, 1180
Bi-manual examination of pelvis, 1427
Bismuth meal, 1165, 1407
Bladder, gall. *See* **Gall-bladder**
Bladder, swim, of fishes, 862
Bladder, urinary, 1258, 1265
      neck, level, 1260
    female, 1258, 1265
      examination of interior, 1427
    male, 1258
  in abdominal incisions, 1400
  arteries, 493, 942, 943, 944, 1041, 1269

- **Bladder**—*continued*
  - at birth, 258, 1265
  - capacity, 1264
  - in child, 258, 1265, 1400
  - communication with rectum, 1223
  - cystoscopic examination, 1419
  - descent into pelvis, 258
  - development, 52, 53, 1310, **1313**
  - distended, 1227, 1258, 1262, 1265, 1267, 1268, 1278, 1302, 1420
    - relation to peritoneum, 1223
  - distorted, 1420
  - empty, 1258, **1261**, 1265, 1266, 1268, 1278, 1302, 1420
  - fixation, 1268
  - hypertrophy, 1420
  - interior, 1264
  - lymph glands, 1023
  - lymph vessels, 1026, 1269
  - nerve supply, 785, 786, 791, 1269
  - relation to extraperitoneal tissue, 491
    - to peritoneum, 1223, 1226, 1258, 1263, 1265, **1266**
    - to pubis, 253
  - structure, 1268
  - surgical anatomy, 1400, 1425
  - veins, 492, 493, 992, 993, 1058, 1269
- Blastula, 26, 58
- Blind spot of eye, 809
- Blisters, plane of formation, 851
- Blood, 861
  - circulation, 861
    - fœtal, 1050
  - oxygenation in different animals, 862
- Blood corpuscles. *See* **Corpuscles**
- Blood islands, 69
- Blood vessels, 3. *See also* **Arteries, Veins**
  - primitive, development, 71
- **Body, Bodies.** *See also* **Corpus**
    - subdivisions, 91
  - accessory, of spermatids, 21
  - ano-coccygeal, 106, 494, 1214, 1218
  - aortic, 1324
    - development, 1326
  - cell, 8
  - chromaffin, 1323
    - development, 27, 36, 1326
  - ciliary, 807
    - development, 38
  - coccygeal. *See* Glomus
  - of corpus callosum. *See* **Trunk**
  - cortical, 1326
    - accessory, 1326
  - epithelial. *See* **Gland**, parathyreoid
  - of femur, 263, 264, 265
    - obliquity and variations, 266
  - of fibula, 272
  - geniculate, 581, 607, 609
      - arteries, 909
      - development, 39, 606
      - function, 518, 584
    - *lateral*, 609
      - connexion with occipital lobe, 618
        - with optic tract, 617
      - structure, 611
    - *medial*, 581
      - connexion with cochlear nuclei, 604
        - with corpus quadrigeminum inferius, 616
        - with lateral lemniscus, 583, 605
        - with medial lemniscus, 589
        - with optic tract, 616
- **Body, Bodies**—*continued*
  - geniculate—*continued*
    - *medial*—*continued*
      - connexion with temporal lobe, 605
  - of humerus, 227
  - of hyoid bone, 182
  - hypothalamic. *See* **Nucleus**
  - of mandible, 129, **177**
    - at birth, 185
  - of maxilla, 128, 134, **211**
    - in front of skull, 132, 134
    - in nose, 171
    - relation to ethmoid, 176
  - Pacinian, 857
    - on ulnar nerve, 735
  - paraterminal, 623
    - connexion with commissures, 626
    - function, 625
  - parathyreoid. *See* **Gland**
  - perineal, 1218, 1306
  - **pineal**, 581, 607, **612**, **1340**
      - peduncle, 609
    - arteries, 908
    - development and morphology, 39, 606, 1341
    - structure, 1341
    - veins, 977
  - polar, 12, 14, 24
      - disappearance, 19, 25
    - first, 18
      - division of, 19
    - second, **19**, 23
  - post-branchial, 49, 1332, **1337**
  - of pubis, 249, **253**, 259, 260
  - of radius, 236
  - **restiform**, 542, 547, **548**, 551, 557
      - in cerebellum, 577
      - in pons, 567
    - constituents, 563
    - relation to acoustic nerve, 602
      - to cochlear nuclei, 602
  - of rib, 117
  - satellite, of glomus coccygeum, 1325
  - of scapula, 219
  - of spermatids, accessory, 21
  - of sphenoid, 126, 128, 202. *See also* **Sphenoid bone**
  - stalk. *See* Stalk, allantoic
  - of sternum, 114, 121
  - of stomach, 1158, **1161**
  - suprarenal. *See* **Gland**
  - of talus, 279
  - thyroid. *See* **Gland**
  - of tibia, 268, 271
  - of ulna, 233
  - ultimo-branchial, 49, 1332, **1337**
  - of uterus, 1299
  - of vertebra, 94, 95, 108
    - development, 123
    - homology, 112
  - vitreous, 813
    - development, 820
  - Wolffian, **1311**, 1040
- Boils in acoustic meatus, 1355
- **Bone**, 84
    - characters, 84
    - compact, 84
    - constituents, 84
    - development, 88
    - ossification, 88
    - spongy, 84, 85, 89
    - structure, 84
    - subperiosteal, 89

Bone—*continued*
  corpuscles, 84, 89
  lamellæ, 84, 89
  marrow, 70, 83
      origin, 89
    red and yellow, 84, 86
  rudiment, 88
Bones, 83, 94
    articular parts, 83, 86
    articulation, 83
    blood supply, 86
    "cartilage," 88, 188
    characters, 84, 85, 86
    classification, 84
    dried, characters, 86
    flat, 85
    "growing end," 90
    growth, 89
    irregular, 85
    living, characters, 85
    long, 84
      growth, 90
    maceration, 86
    "membrane," 88, 188
    number, 91
    in old age, 84
    pneumatic, 85
    primordial, 188
    "in recent state," 85
    secondary, 188
    sesamoid, **85**, 91. *See also* **Sesamoid bones**
    short, 85
    uses, 83
  of abdomen, 94, 101
  carpal, 85, 217, **238**. *See also* **Carpus**
  of face, 130, 177
  of foot, 248, **275**
  of hand, 217, **238**
  of limbs, 91, 217, 247
      measurements, 299
    lower, 247
    upper, 217
  of nose, 168
  of pelvis, 102, 249, 255
  of skull, 85, 125, 189
    at birth, 183
    growth, 90
  tarsal, 85, 248, 275. *See also* **Tarsal bones**
  of thorax, 99, 106, 113, 116, 119
  of wrist, 85, 217, **238**
Boundaries of abdomen proper, 1149
Bow, hypochordal, 112, 123
  vertebral, 123
Brachium. *See* **Arm** (upper)
Brachium conjunctivum, 543
    arteries, 908
    in cerebellar notch, 574
    in cerebellum, 576, 577
    connexions, 577, 578, 586
    decussation, 586
    development, 38
    in hypothalamus, 611
    in mid-brain, 586
    in pons, 550, 569, 570
    relation to mesencephalic root, 600
      to trochlear nerve, 601
  pontis, 542, 549, 566
    arteries, 908
    in cerebellum, 576, 577
  quadrigeminum inferius, 581
      relation to lateral lemniscus, 583
Brachium quadrigeminum—*continued*
    superius, 581
      constituents, 585
Brachycephaly, 295
Brachyfacies, 297
Brachykerkia, 299
Brachyknemia, 299
Brachy-urania, 298
Brain, 3, 5, 124, **540**. *See also* **Cerebrum**, **Hemisphere**, **Pons**, etc.
    primitive, 37, 513
      cavities, derivatives, 41
      flexures, 515
  arteries, 904, 905, 907
    relation to membranes, 671
  base, 541
  connexions, 542
  development, 36, 37, 38, 501, 513, 550, 553, 570, 578, 590, 606, 618, 623, 625, 626
  explanation of growth and position, 513
  general appearance, 540
  gray matter, 513, 576
  lymph channels, 1011
  nature of, 513
  summary of parts, 542
  surface and surgical anatomy, 155, 161, 165, 1350
  veins, 672, 975, 976, 977, 978
    relation to membranes, 671
  weight, 664
  white matter, 513, 576
    development, 41
Brain of carnivores, 3
Brain-sand, 1341
"Breaking" of voice, 1076
Breast. *See* Mamma
Breast-bone. *See* **Sternum**
Bregma, 130, 295, 1348
Bregmatic bone, 191
Bridge of nose, 127, 793
Brim of pelvis, 257
Bronchi, 1061, **1081**
  arteries, 73, 914, **927**, 1056, **1095**
  cartilages, 88, 1081, 1097
  development, 46, 50, 1099
  in root and in lung, 1095
  structure, 1097
  terminal, 1097
  veins, 967, 1095
  X-ray examination, 1097
Bronchioles, 1097
Bronchus, apical and cardiac, 1096
    eparterial and hyparterial, 1081, 1096
  left and right, 1081
Bucca. *See* Cheek
Buds, limb, 44, 290
  taste, 848, 1122
Bulb, Bulbs, or Bulbus—
  aortæ, 880
  articular, 857
  of brain. *See* **Medulla oblongata**
  cordis, 72, 1033
  end, of Krause, 856
  of eye. *See* **Eyeball**
  of hair, 854
  of internal jugular vein, inferior, 970
    superior, 151, 970
      relation to ear, 1358
  oculi. *See* **Eyeball**
  olfactory, **621**, 663
    arterial supply, 904
    connexions, 645

Bulb, Bulbs, or Bulbus—*continued*
  olfactory—*continued*
    development, 38, 620
    function, 625
    relation to skull, 157
  of posterior horn, 632
  urethræ, 487, 488, **1284**
    arteries, 943, 945
    homologue in female, 1309
    nerves, 770
    surgical anatomy, 1418
    veins, 992
  of vestibule, 489, 1293, **1309**
    arteries, 943, 945
    nerves, 770
    surgical anatomy, 1426
    veins, 992
Bulbo-spiral system, 875
Bulla, 171
  auditory, 200
  ethmoidalis, **171**, **173**, 207, **797**
    bulging into meatus, 133
    opening of sinuses on, 176
Bundle. *See also* **Fasciculus** and **Tract**
  atrio-ventricular, 875
  ciliary, of orbicularis oculi, 451, 817
  longitudinal, medial, 587
      connexion with posterior commissure, 613
        with vestibular nucleus, 603
      development, 559
      relation to facial nerve, 597
    in medulla oblongata, 561, 562, 564, 587
    in mid-brain, 586, 587
    in pons, 568, 570, 587
Bursa, infracardiac, 1240
  omental, 1155, 1223, **1227**
    development, 1240
    relation to suprarenal gland, 1328
    surgical anatomy, 1408, 1409, 1413
  ovarica, 1301
  pharyngea, 51, 1137
Bursæ mucosæ, 304, 368
    subcutaneous and subtendinous, 305
  of biceps brachii, 236, 383
  of coraco-clavicular ligament, 321
  of costo-clavicular ligament, 320
  of cruciate ligaments, 350
  of extensores carpi radiales, 399
  of flexor carpi radialis, 389
  of gastrocnemius, 347, 350, 429
    surgical anatomy, 1452
  of gluteus maximus, 264, 417
    surgical anatomy, 1452
  of gluteus medius, 264, 418
  of gluteus minimus, 264, 419
  of gracilis, 347, 413
  of hyoid bone, 183, 1066
  infrapatellar, 347
  of infraspinatus, 323, 325, 378
  of latissimus dorsi, 371
  of medial epicondyle of humerus, 381
  of obturator internus, 420
  of olecranon, 381
  of pectoralis minor, 374
  of peroneus longus, 428
  of popliteus, 348
  prepatellar, 1454
  of psoas major, 344, 412
    surgical anatomy, 1454
  of quadratus femoris, 420
  of rectus femoris, 408
Bursæ mucosæ—*continued*
  of sartorius, 347, 408, 413
  of semimembranosus, 350, 423
  of semitendinosus, 347, 422
  subacromial, 222, 378
    function, 325
  subdeltoid. *See* **B.**, subacromial
  subscapular, 222, 323, 325
    relation to coracoid process, 223
  suprapatellar, 265, 350, 410
  of tendo calcaneus, 278, 429
  of teres major, 371
  of trapezius, 223, 369
  of triceps brachii, 233, 384
Buttock, 247
  arteries, 942, 944, 946, 953, 954
  fasciæ, 404
  lymph vessels, 1022
  muscles, 416
  nerves, 718, 747, 751, 752, 757, 758, 759, 765, 767, 768
  surface and surgical anatomy, 1449
  veins, 992

Cæcum, 155
  cupulare, 842
Cæcum of intestine, 1203
      in carnivora, 1206
      in child, 1207, 1411
      in herbivora, 1207
    arteries, 935, 1202, 1207
    connexion with ileum and parietes, 1156
    development, 52, 1238
    fœtal and infantile, 1205
    lymph glands, 1028
    lymph vessels, 1031, 1207
    nerve supply, 791
    resection, 1412
    structure, 1205
    surgical anatomy, 1404, 1411, 1412
    variations, 1205
    veins, 1000
Calamus scriptorius, 551
Calcaneum, 277
Calcaneus, **277**, 278
  attachments, 278
  homology, 293
  ossification, 288
  surgical anatomy, 1457, 1458
  variations, 290
Calcar avis, 632, 657
  femorale, 265
Calculus, biliary, 1406
  renal, 1416, 1417
  salivary, 1110
    removal, 1374
  urethral, 1419
Calipers, 298
Calvaria, 125
Calyces of ureter, major and minor, 1255
Calyculi gustatorii. *See* Buds, taste
Camera. *See also* Chamber
  princeps of His, 1163
Canaliculi—
  of bone, 84
  carotico-tympanic, 151, 200, 828
  of cornea, 805
  dentales, 1111, 1112, 1234
  innominatus, **147**, 163, 204
  mastoid, **151**, 199
  tympanic, **151**, 200

Canals, 87. *See also* **Canaliculi**
- adductor, 406, 407, 413, **416**
  - surgical anatomy, 1453
- alimentary, 3, **1101**
  - primitive, 42, 44
    - relation to neurenteric canal, 28
      - to notochord, 29
- alveolar, superior, anterior, 212
  - middle, 212
  - posterior, 141, 211
    - relation to maxillary sinus, 175
- anal, 486, 487, 494, 1218
  - arteries, 944, 1221
  - at birth, 1239
  - development, 55, 1239
  - lymph vessels, 1222, 1423
  - nerves, 1222
  - structure, 1218
  - surgical anatomy, 1422
  - variations, 1223
  - veins, 992, 1222
- atrio-ventricular, 1033
  - division, 1034
- of auditory tube, 152, 828
- carotico-tympanic, 151, 200, 828
- carotid, **151**, 199
  - relation to auditory tube, 152
    - to foramen lacerum, 159, 161
    - to semilunar ganglion, 163
  - variations, 202
- carpal, 238
- **central**, of cochlea, 200, 839, 845
  - of medulla oblongata, 527, 543, 545, **564**
    - development, 41
  - of modiolus, 200, 839, 845
  - of spinal medulla, 523, 524, 527
- cervical, of uterus, 1299
- condyloid, **149**, 165, 194
- cranio-pharyngeal, 186, 187, 205, 1340
- ento-dermal, primitive, 29
- of epididymis. *See* **Duct**
- ethmoidal, anterior and posterior, 134, 136, **157**, 190, 207
  - relation to ethmoidal sinuses, 176
- facial, 150
  - at birth, 201
  - opening, 200
  - ossification, 200
  - relation to ear, 167
    - to epitympanic recess, 827
  - surgical anatomy, 1359
- femoral, **407**, 951
- gastric, 1166
- Haversian, 84
  - development, 89
- hyaloid, 814
  - development, 820
- hypoglossal, **149**, 164, 194
  - level, 151
  - variations, 196
- incisive, **169**, 174, 213
  - opening into mouth, 1107
- infra-orbital, 134, 135, 212
  - development, 213
  - lymph vessels transmitted, 1013
- inguinal, 478, 481, **484**, 1275
  - surface anatomy, 1398
- innominate. *See* **Canaliculi**
- mandibular, 181
  - at birth, 180
- metopic, 191

Canals—*continued*
- musculo-tubal, 152, 161, 199
- naso-lacrimal, **134**, **173**, 174, 208, 212
  - opening in orbit, 136
  - relation to maxillary sinus, 176
- neural, openings on surface, 36
- neurenteric, 28, 31, 77
  - relation to notochord, 29
- notochordal, 29
- of Nuck, 1302
- nutrient, of bones, 86, 91
- obturator, 340
- **palatine**, greater, **145**, 212, 214
    - opening on palate, 144
      - in pterygo-palatine fossa, 142
    - relation to nose, 173, 174
    - variation, 215
  - lesser, 215
- pharyngeal, 142, **146**, 169, 215
- pleuro-pericardial, 75
- portal, 1191
- pterygoid, 142, 148, 160, **162**, 205
- pterygo-palatine. *See* **C.**, palatine, greater
- pyloric, 1161, 1163
- radicis dentis, 1110
- re-uniens. *See* **Ductus**
- sacral, 103, **104**, **106**
  - variations, 112
- **semicircular**, 838
    - arteries, 895
  - *lateral*, 838
    - relation to antrum, 830
    - surgical anatomy, 1359, 1361
  - *posterior*, 838
    - relation to antrum, 1359
      - to aperture of aqueduct, 200
      - to sinus tympani, 828
    - surgical anatomy, 1361
  - *superior*, 160, 167, 200, **838**
    - ossification, 200
    - relation to antrum, 830
      - to subarcuate fossa, 200
- spheno-vomerine, 210
- spiral, of cochlea, 838
- for tensor tympani, 152, 199, 826, 828
  - relation to petrosal nerve, 200
- of tuba auditiva, 152, 828
- urogenital, 1311, 1313
- vertebral, 95, 106
  - veins of, 982

Canthi, 816

Capacity of bladder, 1264
- of heart, 876
- of skull, 295
- of stomach, 1156

Capillaries, blood, 861
  - structure and tissues, 865
- of heart, 876
- lymph, 861

Capitate bone, 241. *See also* **Os**

Capitulum of humerus, **227**, 234

Capsules—
- **articular**, 304
    - development, 89, 123, **306**
  - acromio-clavicular, 223, 225, **321**
  - of ankle joint, 271, 280, **354**
  - calcaneo-cuboid, 359
  - carpal, 332
  - carpo-metacarpal, 242, 244, **334**
  - costo-vertebral, 117, **316**
  - cuneo-navicular, 360
  - of elbow joint, 229, 233, **326**

- **Capsules**—*continued*
  - articular—*continued*
    - of hip joint, 259, 264, **342**
    - interchondral, 317
    - inter-metatarsal, 363
    - interphalangeal, 245, 287, **336**, **363**
    - of knee joint, 265, 270, **346**
    - of mandibular joint, 152, 180, **314**
    - metacarpo-phalangeal, 244, 335
    - metatarso-phalangeal, 286, 363
    - pisi-triquetral, 242, 333
    - radio-carpal, 236, 330
    - radio-ulnar, 233, 236, 329
    - sacro-iliac, 105, 260, **337**
    - of shoulder joint, 222, 229, **323**
    - sterno-clavicular, 115, 225, **320**
    - sterno-costal, 318
    - talo-calcanean, 278, 280, **356**
    - tarso-metatarsal, 361
    - tibio-fibular, 270, 274, **351**
    - of vertebral joints, 96, 109, 306, 311, 312
    - of wrist joint. *See* **C.**, radio-carpal
  - auditory, 187
  - **cerebral**, external, 636, **640**
    - *internal*, 639
      - arteries, 904, 905
      - relation to thalamus, 608
  - of kidney, 1245
      - adipose, 1247
    - of glomeruli, 1253
  - of lens, 814
  - of liver, fibrous, 1190
  - of lymph glands, 1003
  - nasal, 187
  - of prostate, 1288, 1420
  - of thyreoid gland, 1331, 1379
- Caput columnæ posterioris, 525
- Carbonic acid, 862
- Cardia of stomach, 1158
- Cardioptosis, 1394
- Carina urethralis, 1306
- **Carpal bones**, 85, 217, **238**
  - growth, 90
  - ossification, 246
  - variations, 247
- **Carpus**, 238
  - attachments, 242
  - at birth, 246, 289
  - compared with tarsus, 294
  - homologies, 293
  - joints, 331
  - movements, 336
  - ossification and structure, 246
  - surgical anatomy, 1445
- **Cartilage**, 83, **87**
    - bones, 88, 188
    - cells, 88
    - classification of, 87
    - formation and development of, 88
    - ossification in, 88
    - periblast of, 88
  - accessory, of mandible, 181
  - of acoustic meatus, 140, 152, **825**
  - alar, greater and lesser, 168, 794
  - articular, 83, 85, 88, 303
  - **arytenoid**, 1064
    - development, 1098, 1099
    - in laryngoscopic examination, 1076
    - ossification and structure, 1065
    - in pharyngeal wall, 1141
    - during swallowing, 1072
- **Cartilage**—*continued*
  - of auditory tube, 152, **831**
    - development, 57
  - of auricle of ear, 140, 152, **823**
  - of branchial arches, 181, 183, 314, 835, 1098
  - of bronchi, 88, 1081, **1097**
  - corniculate, 1064, **1065**, 1068
    - development, 1099
    - during swallowing, 1072
  - **costal**, 87, 113, 114, 116, **119**, 120
      - attachments, 122
      - characters, 87
      - ossification and variations, 123
    - first, 119
      - relation to clavicle, 224
    - second, 114, 119, 122
    - seventh, 119, 122
      - surface anatomy, 1389
    - ninth and tenth, 119
      - surface anatomy, 122, 1401
  - **cricoid**, 448, 465, **1063**
    - development and morphology, 1098
    - level, 96
    - ossification and structure, 1065
    - in pharyngeal wall, 1141
    - surface anatomy, 96, 1379
  - cuneiform, **1065**, 1068
    - development, 1099
  - ensiform. *See* **Process**, xiphoid
  - epiglottic, 1065
    - development, 1098
  - epiphyseal, 90
  - of external acoustic meatus, 140, 152, **825**
  - of foramen lacerum, 162
    - development, 188
  - hyaline, 87, 88, 301
  - of hyoid arch, 183
  - of Jacobson, 210
  - of larynx, 87, **1062**
    - development, 49, 1098
    - ossification, 1065
  - of mandibular arch, 181, 314, 835
  - of mandible, accessory, 181
  - of meatus acusticus externus, 140, 152, **825**
  - Meckel's. *See* **C.** of mandibular arch
  - of nose, 87, 168, **794**
    - alar, 169, **794**
    - lateral, 794
    - septal, 169, **794**
  - parachordal, 186
  - paranasal, 187
  - paraseptal, 187, 210
  - prechordal, 186
  - semilunar. *See* Menisci of knee
  - septal, 169, 794
  - sesamoid, 88
    - of larynx, 1065
  - **thyreoid**, 448, 460, 465, 466, **1062**
    - development, 1098
    - level, 96
    - ossification and structure, 1065
    - in pharyngeal wall, 1141
    - surgical anatomy, 1378
  - of trachea, 87, **1080**
  - triradiate, 254
  - triticea, 1066
    - development, 1098
  - vomero-nasal, 169, **795**
  - of xiphoid process, 115
- **Carunculæ**—
  - hymenales, 1306, 1308
  - lacrimalis, 816

Carunculæ—*continued*
lacrimalis—*continued*
development, 822
surgical anatomy, 1369
minor of duodenum, 1179
sublingual, 1104
Catheter, passage of Eustachian, 1376
passage of female, 1426
male, 1218, 1292, 1419, 1424
in child, 1424
false, 1419
Cauda equina, 521, **712**
"Caudal," definition, 5
Cavities. *See also* **Space**
of abdomen, 1148, 1149. *See also* **Abdomen**
amniotic, 44, 59, 66
articular, 302
buccal, primitive, 29
of cerebral vesicles, 41
cranial, 124, 153
floor, 155
relation to ethmoidal sinuses, 176
to frontal sinus, 176
roof, 154
entodermal, relation to notochord, 29
epidural, 665, 667
glenoid, of scapula, 219
attachments, 222
of temporal bone. *See* **Fossa**, mandibular
of joints, 302
of knee joint, upper limit, 265
of larynx, 1068
medullary, 84, 86
formation, 89
of mouth, 186, **1101**
proper, 1103
of nose, 146, **168, 795.** *See also* **Nose**
of pelvis, **257,** 1149, **1150**
measurements, 258, 298
surgical anatomy, 1419, 1425
in female, 258
bi-manual examination, 1427
pericardial, primitive, 75
separation, 77
peritoneal, 1148, **1223**
development, 75, 1240
surgical anatomy, 1402
surgical divisions, 1404
of pharynx, 1134
of pleura, 1082
development, 34, 75, 1099
of primitive brain, 41
pulp, of teeth, 182, 1109
segmentation, 26
of septum pellucidum, 630
development, 626
subarachnoid, 519, 669. *See also* **Space**
subdural, 668. *See also* **Space**
of thorax, 119, **1082**
of tooth, 182, 1109
tympanic, 124, 126, 140, 826
arteries, 836; *and see* **Aa.**, meningeal (middle), petrosal, of pterygoid canal, stylomastoid, and tympanic
contents, 832, 835
development, 48, 57
in fœtus, 836
lymph vessels, 836, 1012, 1018
medial wall, 199
mucous membrane, 836
muscles, 835
nerves, 697, 836

Cavities—*continued*
tympanic—*continued*
ossicles, 832. *See also* **Ossicles**
relation to auditory tube, 152
to brain, 161
to carotid artery, 151
to jugular vein, 151
to meatuses, 167
to petro-tympanic fissure, 152
seen through meatus, 140
surgical anatomy, 1358
veins, 836
of uterus, 1299
Cavum. *See also* **Cavity** and **Space**
conchæ, 822
Meckelii, 681
Cells—
adamant, 1283
air—
ethmoidal. *See* **Sinus**, air
of lung, 1097
mastoid, 126, **830**
border, 1360
arteries, 895
development, 201
nerves, 689, 698
relation to sigmoid sinus, 166
surgical anatomy, 1360
amacrine, of retina, 811
animal, 8
acquisition of different functions, 11
amitotic division of, 9
body of, 8, 11
conditions of functioning, 11
daughter, 9, 11, 12, 13
division of, 9
anaphase, **11,** 13, 18
metaphase, **10,** 13, 18
telophase, **11,** 13, 18
in malignant tumours, 10
in mammals, 12
life of, 12
life-history of, 9
membrane, 8
mitotic division of, 9
mother, 9
nucleus of, 8, 10
reproduction of, 9
resting stage of, 9
structure of, 7
basal, of nose, 799
basket, of cerebellum, 579
of Betz, 649
bipolar, 511, 602, 620, 621, 799, 811, 845, 847
blood. *See* **Corpuscles**
bone-forming, 89
cartilage, 88
central, of stomach, 1169
of cerebellum, 579
of cerebral cortex, 649
chromaffin, 1323
development, 27, 36, 1326
of Claudius, 845
of Deiter's. *See* **C.**, supporting
endothelial, of serous membranes, 1089, 1153
development, 34
ependymal, 512, 528
funicular, 506
of ganglia, bipolar, 511, 602, 620, 621, 799, 811, 845, 847

Cells—*continued*
  germ, 10, **12**, 22, 23, 25
    female, 12
    male, 12, 21
    non-maturing, 13
  germinal, of neural tube, 40, 503
    of retina, 821
  glial, 512
  gustatory, 849
  hair, of maculæ acusticæ, 841
    of semicircular ducts, 842
    of spiral organ, 844
  of Hensen, 844
  horizontal, of retina, 811
  indifferent, of neural tube, 40, 504
  inter-neuroglial, 1341
  interstitial, of ovary, 1322
  of membrana granulosa, 15
  of Merkel, 856
  mesenchyme, 69, 70
  mitral, of olfactory bulb, 621
  nerve, 507
      in fishes, 512
      primitive, 40
    basket, of cerebellum, 579
    of Betz, 649
    bipolar, 511
      cochlear, 602, 845
      olfactory, 620, 621, 799
      retinal, 811
      vestibular, 602, 847
    of brain, 507
    of cerebellum, 579
    of cerebral cortex, 649
    efferent, 499, 508
      of neural tube, 506
      somatic and splanchnic, 506
    funicular, 506
    of ganglia, 511, 596
    germinal, of neural tube, 40, 503
    glial, 512
    indifferent, of neural tube, 40, 504
    intercalated, 499, 500, 508
      importance of, 513
    inter-neuroglial, 1341
    mitral, 621
    motor, 499, 500
      of spinal medulla, 508, 530
    multipolar, 507
    neuroglial, 512
      development, 41
    non-germinal, 41
    of olfactory membrane, 511
    of olivary nucleus, 556
    of Purkinje, 579
    pyramidal, 508, 649
    sensory, 499
      in metazoa, 500
      migration, 500
    of sensory ganglia, 511
    of spinal medulla, 507, 529
      development, 40
      non-germinal, 41
    sympathetic, 777
      development, 36
    unipolar, 512
  neuro-epithelial, 512
  neuroglia, 512
    development, 41
  non-germinal, 41
  nurse, 21
    of spermatocytes, 20

Cells—*continued*
  olfactory, 511, 621, **799**
  oxyntic, 1169
  pineal, 1341
  of primitive sheaths, 27
  scleratogenous, 33
  somatic, 12
  sperm, 12, 1315
  splenic, 1344
  star, of liver, 1191
  supporting, of maculæ acusticæ, 841
    of nose, 798
    of semicircular ducts, 842
    of spiral organ, 845
    of taste buds, 849
Cell-tract, intermediate, 44
  derivatives, 34
  formation, 32
Centres—
  defæcation, 1223
  for hearing, higher, 653
    lower, 605
  medullary, of hemisphere, 640, 642
  motor, 649
    character of cortex, 661
    surface anatomy, 1349, 1350
  of ossification, appearance, 88
    primary, 88, 90
    secondary or epiphyseal, 88
      dates of appearance, 90
    subcoracoid, 223
  sensory, 648
    character of cortex, 661
  for sight, higher, 618, 656
      arterial supply, 909
    lower, 618
  for smell, 623, 625
  for taste, 623
Centrioles, 8
  of oöcyte, 16
Centrosome, 8, 17, 24
  daughter, 10, 11
  in mitosis, 10
  of oöcyte, 16
    mature, 19
  of spermatids, 20, 21
  of spermatocytes, 20
  of spermatozoon, 21, 22
      anterior, 21
Centrum tendineum, 473
"Cephalic" (definition), 5
Cerebellum, 148, 541, 542, **570**
  arteries, 907, 908
  connexions, 576
    with vestibular nerve, 603
  development, 38, 553, 555, 570, 578
  functions, 517
  gray and white matter, 576
  growth, explanation, 517
  histogenesis, 578
  primitive, 555
  structure, 576
    minute, 578
  surgical anatomy, 1353
  veins, 977, 978
  vermis, 164, 570
Cerebral vesicles, primitive, derivatives, 38
Cerebro-pontine fibres. *See* **Fibres**
Cerebrum, 154, 541, 542. *See also* **Brain** and **Hemisphere**
  arteries, 670, **904, 905,** 1355
    relation to membranes, 671

Cerebrum—*continued*
base, 541
cortex, 640, **641**, 642. *See also* **Cortex**
development, 38, 501, 513, 606, 618, 623, 625, 626
lobe, frontal, 134, 155, 541, **663**
occipital, 165, **656**
parietal, 660
temporal, 135, 158, 541, **653**
See also **Lobe**
lymph channels, 1011
relation to frontal sinus, 176
to middle ear, 161
surface and surgical anatomy, 155, 161, 165, 1349, 1350
veins, 671, 672, **976**, 977, 1047
Cerumen, 826
Cervix, 94
columnæ posterioris, 525
uteri, 491, **1299**
surgical anatomy, 1425
Chain, auditory, nervous, 605
Chamæcephaly, 296
Chamæprosope, 297
Chamber of eye, anterior and posterior, 809, **815**
of heart, 869
for stomach, 1163
Changes in pelvis, 258
Cheek bone. *See* Zygomatic
Cheeks, 1106
lymph vessels, 1013
Chemotaxis, 506
Chest. *See* **Thorax**
Chiasma, optic, 542, 616, **679**
arteries, 904
development, 39, 606, 607
relation to anterior cerebral artery, 904
to sphenoidal sinus, 177
Child, lifts head, sits upright, begins to walk, 107
Chin, 177
movements, 315
in old age, 186
Choanæ, **125**, 126, **145**, 168, 1136
primitive, 54
relation to infra-temporal fossa, 146
to palatine bone, 128
to pterygoid process, 127, 146
to vomer, 144
seen through nose, 132
slope, 169
surgical anatomy, 1376
Cholesteatoma, 1361
Chondrification of limb bones, 291
of nose, 187
of skull, 186
of vertebræ, 123
Chondriosomes, 8
of oöcyte, 16
Chorda dorsalis. *See* **Notochord**
obliqua, 233, 236, **329**
Chordæ tendineæ, 873, 874
Willisii, 978
Chorioid of eyeball, 805
arteries, 807, 903
development, 821
Chorion, 25, **58**
connexion with embryo, 43
frondosum, 65
læve, 59, 65
Chromaffin bodies, 1323
development, 27, 36, 1326
Chromaphiloblasts, 1326
Chromatin, **8**, 10
allelomorph properties, 22
forming chromomeres, 10
functions, 22
Chromidia, 9
Chromomeres, 10
different qualities, 12
Chromosomes, 10, 12, 24
number of, 12
in oöcyte I, 25
mature, 25
in spermatocyte I, 25
in spermatozoon, 25
in zygote, 25
reduction of, 23
object of, 22
syndesis of, 13
daughter, 10, 11
diploid, 12, 13, 17, 18
of germ cells, 22
haploid, 13, 17, 18, 19, 23, 24
homologous, 12, 13
sex, 24, 25
of spermatids, 20
of spermatocytes, 20
twin, 12
Chyle, 1002
Chyme, 1156
Cilia. *See* Eyelashes
Cingulum of cerebrum, 646
extremitatis. *See* Girdle
of teeth, 1113, 1114
Circulation of blood, 861
fœtal, 1050
sinusoidal, 1242
Circulus arteriosus (Willis), 670, **909**
major and minor of eyeball, 809
Circumduction, 305
Circumference of skull, 296
Cisterna chyli, 1004
abnormality, 1032
development, 1050
Cisterns, subarachnoid, 669
cerebello-medullary, 669
surgical anatomy, 1352
chiasmatic and interpeduncular, 670
pontine, 669
Classification of bones, 84
of skull, 125
of cartilage, 87
of cerebral nerves, 676
of joints, 301
of spinal nerves, 520
Claustrum, 637
Clava, 548, 560
Clavicle, 217, **223**
of amphibians, 292
of ape, horse, and tiger, 2
attachments, 225
development, 292
dislocation, 224, 1438, 1439
epiphysis, 90, 225
fracture, 1438
functions, 294
homology, 2, 292
joints, 319
movements, 321
nutrient artery, 912
ossification, 225, 292
structure and variations, 225
surface and surgical anatomy, 1438

Cleft, branchial, 47
    first, derivatives, 58
  natal, 247
    surgical anatomy, 1450
  olfactory, 798, 1369
  pharyngeal. *See* **C.**, branchial
  urogenital, 1293, **1306**
    development, 1310
"Clinoid," 158
Clitoris, 1293, 1308
  arteries, 945, 1309
  development, 1311, 1317
  lymph vessels, 1023
  nerves, 770, 1309
  veins, 992, 993
Clivus of skull, 164
Cloaca, 44, 53, 1310, 1313, 1316
  persistence, 1223
Club-foot, 1459
Co-aptation in joints, 305
Coat, subserous. *See* Tissue, extraperitoneal
Coccyx, 94, **95**, **104**, **106**, 108, 259, 260
  in female, 258
  ossification, 111
  at pelvic outlet, 257
  relation to pelvis, 248, 255
  variations, 112
Cochlea of ear, 167, 838
    blood supply, 847, 908
    development, 55, 847
    nerves, **602**, **696**, 837, 838, 840, 843, **845**
    ossification, 200
Cœlom, 44, **74**
    derivatives, 76
    formation, 32
    relation to pericardium, 32
      to lateral plates, 32
    subdivisions, 43
  extra-embryonic, 26, 27, 42, **74**
  intra-embryonic, 42, **75**
Cog-tooth of malleus, 833
Collar bone. *See* **Clavicle**
Collaterals of axons, 508
  of posterior nerve root fibres, 536
  of sensory nerve fibres, 536
Colles' fascia. *See* **Fascia**
Colliculi. *See* **Corpora quadrigemina**
Colliculus facialis, 597
  relation to abducent nucleus, 598
Collum. *See* **Neck**
Colon, 1209
    arteries, 935, 936, 1172, 1202
    development, 52, 1238
    in fœtus, 1210, 1211
    lymph glands, 1029
    lymph vessels, 1031, 1202
    nerves, 791, 1203
    structure, 1171, 1213
    veins, 1000, 1001
  ascending, 1209
    adherent to omentum, 1156
    in child, 1411, 1412
    connexion with parietes, 1156
    resection, 1412
    surface and surgical anatomy, 1412, 1430
  descending, 1210
    surface and surgical anatomy, 1405, 1413, 1430
  iliac, 1211
    connexion with parietes, 1156
    surgical anatomy, 1405, 1413
  pelvic, 1212
Colon—*continued*
  pelvic—*continued*
    at birth, 1213
    surgical anatomy, 1413
  transverse, 1209
    surgical anatomy, 1404, 1405, **1413**
Colostomy, 1401
Colour of eye, 808
Columns—
  of fornix, 609, 615
    arteries, 905
    connexion with corpus mamillare, 613
    development, 38, 625, 626
  rectal, 1219, **1220**
    surgical anatomy, 1422
    vessels in, 1221, 1222
  renal, 1252
  of rhombencephalon, 552
    somatic, 552
    splanchnic, 553
  rugarum, 1306
  of spinal medulla, 524, 530, 558
    anterior, 524
      development, 532
      traced into medulla oblongata, 558, 559
    antero-lateral, 531
    antero-median, 530
    central, 531
    intermedio-lateral, 532
    lateral, 525
    posterior, 525
      development, 522
      traced into medulla oblongata, 560
    postero-lateral, 531
    postero-median, 530
    retro-postero-lateral, 531
    vesicular, posterior, 530
  vertebral, 29, 91, **94**
      membranous, 33, 123
      as a whole, 106
    chondrification, 123
    curvatures, 100, **107**, 308
      variations, 299, 1436
    development, 29, 33, **123**, 496
    in different races, 299
    dislocations, 1435
    fracture-dislocations, 1435
    homologies, 2, 112
    joints, **307**, 309, 337
    koilorrhachic and kyrtorrhachic, 299
    movements, 106, 311
    orthorrhachic, 299
    ossification, **109**, 123
    relation to cranial fossa, 163
    surgical abnormalities, 1436
    surgical anatomy, 1435
    variations, 111, 1436
Commissures—
  of brain, 613, 625, 644, 645, 679
        (corpus callosum. *See* **Corpus**)
      development, 38, 39, 607, 626
    anterior, 614, **644**
      arteries, 904
      connexions, 626, 644
      development, 38, 39, 626
      relation to internal capsule, 639
    gray or middle. *See* Massa intermedia
    habenular, **613**, 1341
      development, 39
    hippocampal, 625, 645
      development, 626
    inferior (Gudden), 616, 679

- **Commissures**—*continued*
  - of brain—*continued*
    - posterior, 587, 588, **613**, 615, 1341
      - connexion with central nucleus, 610
      - development, 39, 607
  - of eye, lateral, 815
    - medial, 816
  - of lips, 1101
  - optic. *See* Chiasma
  - of spinal medulla, gray, 524, 540
      - anterior and posterior, 524
    - white, 524, 540
  - of vulva, anterior, 1306
    - posterior, 1307
- Compact bone, 84, 85
- Comparison of limbs and their girdles, 294
- Compartments of perineum, 1418
- Compas glissière, 298
- Components, nerve, 506
- **Concha**, 127
  - auriculæ, 822
  - nasal, 170, 172, 173, 797
      - chondrification, 187
      - development, 188
      - seen through choana, 145
      - seen from front, 132, 133
        - through speculum, 1369
      - variations, 208
    - *inferior*, 127, 170, **173**, **208**, 797
      - absence, 209
      - ossification, 209
      - relation to maxillary sinus, 175
        - to naso-lacrimal canal, 134, 173
      - seen from front, 133
    - *middle*, 127, 171, **172**, 206, 207, 797
      - relation to spheno-palatine foramen, 142
      - seen from front, 133
    - *superior*, 127, 133, 171, **172**, 206, 797
    - *suprema*, 797
  - sphenoidal, 169, 184, **205**
    - chondrification, 187
- **Condyles**, 87
  - of femur, 262, 266, 345
      - articular surfaces, 345
      - surgical anatomy, 1455
    - lateral, **262**, 264, 265, 266
    - medial, **263**, 266
  - of mandible. *See* **Mandible**, head
  - occipital, 126, 144, **148**, 194
      - level, 150, 151
    - third, 196
  - of tibia, 267, 270
      - articular surfaces, 346
      - surgical anatomy, 1455
    - lateral, 268
    - medial, **268**, 271
- Cone bipolars of retina, 811
  - granules of retina, 811
  - of light of tympanic membrane, 829, 1357
- Cones of retina, 812
    - development, 821
- Confluens sinuum, 978, 979
- **Conjunctiva**, 816, **817**
  - arteries, 818
  - development, 822
  - end-bulbs in, 856
  - lymph vessels, 818, **1012**
  - nerve supply, 681, 682, 683, 687, 818
  - surgical anatomy, 1368
  - tactile corpuscles in, 858
  - veins, 818
- Conjunctivitis, 1368
- Constrictions of œsophagus, 1144
  - pyloric, 1158
  - of ureter, 1256, 1416
- **Conus** arteriosus, 872
  - elasticus, 1066
    - level, 1433
  - medullaris, **519**, 526
    - level, 521, 1433
    - structure, 526
  - vasculosus, 1273
- Convolutions of brain. *See* **Gyri**
- Copula of tongue, 51
- Cor. *See* **Heart**
- "Coracoid," 221
    - of amphibians, 292
- **Cords**—
  - of brachial plexus, 729
  - genital, 1316
  - lymph, 1003
  - spermatic, 475, 476, 478, 481, 482, 484, 485, 1271, 1274, **1281**
    - coverings. *See* Coverings
    - surgical anatomy, 1398
  - spinal. *See* **Medulla spinalis**
  - sympathetic. *See* **Trunk**
  - umbilical, 27, 53, 60
  - vocal, false. *See* **Fold**, ventricular
    - true. *See* **Fold**, vocal
- Corium, 850
  - development, 496, 855
  - under nail, 852
- Cornea, 803
  - development, 821, 822
  - in fœtus, 805
- **Cornu**, 87
  - coccygeal, 104, 106
    - homology, 106, 112
  - of fossa ovalis, 405
  - of hyoid bone, 182
  - of lateral ventricle, 630, 631, 632
    - surgical anatomy, 1349, 1352
  - sacral, 104, 106
    - homology, 106, 112
  - of thyreoid cartilage, 1063
- Corona, 129
  - glandis, 1283
  - radiata of brain, 640
    - of ovum, 16, 18
- "Coronoid," 179, 231
- **Corpus, Corpora**. *See also* **Body**
  - adiposum buccæ, 446, 453, 456, **1106**
    - relation to parotid duct, 1131
  - albicans of ovary, 1296
  - amylacea, 1341
  - callosum, 542, **627**
    - absence, 647
    - arteries, 905
    - connexions, 644
      - with thalamic fibres, 611
    - development, 38, 39, 626
    - veins, 977
  - cavernosa, 1283, 1308
    - structure, 1284
    - *clitoridis*, 489, **1308**
      - arteries, 945, 1309
      - lymph vessels, 1023
      - nerves, 770, 1309
      - veins, 992
    - *penis*, 488, 489, **1283**
      - arteries, 945, 946, 1285
      - lymph vessels, 1023, 1285
      - nerves, 770, 791, 1285

- **Corpus, corpora**—*continued*
  - **cavernosa**—*continued*
    - *penis—continued*
      - veins, 992, 993, 1285
    - *urethræ*, 487, 488, **1283**
      - arteries, 945, 1285
      - homologue in female, 1309
      - lymph vessels, 1023, 1285
      - nerves, 770, 791, 1285
      - veins, 1285
  - luteum, 1296, 1322
  - **mamillare**, 542, 607, **613**
    - arteries, 908
    - development, 39, 606
    - relation to ventral stalk, 611
    - veins, 977
  - ponto-bulbare, 549, 550
    - origin, 553, 556
  - **quadrigemina**, 518, 543, **580**
    - arteries, 908
    - connexion with motor nuclei, 590
    - development, 38, 590
    - veins, 977
    - *inferior*, 580
      - connexion with cochlear nuclei, 604
        - with lateral lemniscus, 605
        - with opposite medial geniculate, 616
        - with optic tract, 616
      - function, 584
      - relation to cerebellum, 574
        - to lateral lemniscus, 583
      - structure, 584
    - *superior*, 580
      - connexion with medial lemniscus, 589
        - with occipital lobe, 618
        - with oculomotor nuclei, 602
        - with optic tract, 617
      - function, 584
      - structure, 585
  - striatum, 634. *See also* **Nucleus**, caudate and lentiform
    - arteries, 904, 905
    - connexions, 637
      - with red nucleus, 587
      - with thalamus, 610
    - development, 619
    - function, 637
    - veins, 977
  - trapezoideum, 567, **604**
    - connexion with facial nucleus, 598
      - with lemniscus, 589
- **Corpuscles**, blood, development, 69, 70, 83
  - bone, 84, 89
  - concentric, of thymus, 1336
  - genital, and of Grandry, 857
  - of Golgi, and of Herbst, 858
  - inter-renal, 1330
  - of kidney, 1253
    - development, 1313
  - lymph, 1001
  - of Mazzoni, and of Meissner, 858
  - of Pacini, 857
    - on ulnar nerve, 735
  - tactile, and of Wagner, 858
- **Cortex** cerebelli, 570, **576**
    - connexion with vestibular nerve, 603
    - structure, 579
  - cerebri, 640, **641**, 642
    - connexion with corpus striatum, 637
    - relation to hippocampus, 624
- Corti's ganglion, etc. *See* **Ganglion**, etc.
- Costæ. *See* **Ribs**
- Coverings of spermatic cord, 476, 479, 481, **1281**, 1282
  - arteries, 949
  - nerves, 751
- Coxa. *See* Hip
- "Cranial" (definition), 5
- Craniology and craniometry, 294
- Cranium, 124, **125**. *See also* **Skull**
  - cartilaginous and membranous, 186
    - derivatives, 188
- Crescents of Gianuzzi, 1134
- **Crest**, 87. *See also* **Crista**
  - conchal, of maxilla, 172, 212
    - of palatine, 173, 214
  - ethmoidal, of maxilla, 172, 212
    - of palatine, 173, 215
  - of fibula, 272, 274
  - frontal, 154, 155, **157**, 190
  - iliac, **249**, 259
    - level, 101
    - surgical anatomy, 1449
  - incisor, of maxilla, 133, 169, 213
  - infratemporal. *See* **Line**
  - interosseous, of fibula, 272, 274
    - of radius, 236
    - of tibia, **268**, 270, 271
    - of ulna, 233
  - lacrimal, anterior, 136, 212
    - posterior, 136, 209
  - of malleus, 833
  - of maxilla, conchal and ethmoidal, 172, 212
    - incisor, 133, 169, 213
    - lacrimal, 136, 212
    - nasal, 169, 213
  - nasal, of maxilla, 169, 213
    - of nasal bone, 169, 210
    - of palatine bone, 169, 214
  - neural, 37, 501, 502, 773
      - derivatives, 36, 707
      - development, 36
    - of mid-brain, 600
  - obturator, of pubis, 253
  - occipital, external, **149**, 150, 193
    - internal, 164, 194
  - of palatine, conchal and ethmoidal, 173, 214
    - nasal, 169, 214
    - palatine, 145
  - pubic, **253**, 259, 260
    - in pelvic brim, 257
    - surgical anatomy, 1453
  - of rib, 117
  - of sacrum, median, 103, **106**
  - of scapular spine, 220, 223
  - sphenoidal, 169, 202
  - supinator, 231, 233
  - supramastoid, **138**, 139, 140, **197**
    - in child, 1359
  - supraventricular, 873
  - of tibia, 268, 270, 271
  - transverse, of acoustic meatus, 200, 839
  - trochanteric, 262
- "Cribriform," 127
- **Crista**, 87. *See also* **Crest**
  - ampullaris and basilaris, 842
  - cutis, 850
  - galli, 127, 155, **157**, 206
  - quarta of semicircular duct, 842
  - semilunaris, 839
  - spinarum, 826
  - terminalis, 870
  - transversa of meatus, 200, 839
  - tympanica, 826

- **Crista**—*continued*
  - urethralis, female, 1270
    - male, 1288, **1289**
  - vestibuli, 837
- Crowns of teeth, 181, 1109
- **Crus**, **Crura**, 248
  - antihelicis, 822
  - **clitoridis**, 1308
    - artery, 945, 1309
    - attachments, 253, 260
    - lymph vessels, 1023
    - nerves, 770, 1309
    - veins, 992
  - commune, 838
  - of cruciate ligament, 313
  - of diaphragm, 472
    - development, 497
  - of fornix, development, 626
  - helicis, 822
  - of incus, 834
  - of inguinal ring, 478
  - **penis**, 489, **1284**
    - artery, 945, 1285
    - attachments, 253, 260
    - lymph vessels, 1023, 1285
    - nerves, 770, 791, 1285
    - veins, 992, 993, 1285
  - of stapes, 834
- Cryptorchism, 1280
- Cryptozygous skulls, 297
- Crypts of tonsil, 1139, **1141**
  - development, 1236
- Cubitus. *See* **Elbow**
- **Cuboid bone**, **280**, 283, 285
  - homology, 293
  - ossification, 288
  - variations, 290
- Culmen of cerebellum, 573
- Cumulus, ovarian, 15, 16, 20, 1297
- **Cuneiform bones**, 282
    - attachments, 284
    - homology, 293
    - ossification, 288
    - variations, 290
  - first, 282
  - second and third, 283
- Cuneus, 282
  - of cerebrum, 657, **659**
    - arteries, 909
- Cup, optic, of retina, 809
  - of optic vesicle, 820
- Cupula cochleæ, 838
  - pleuræ, 118, 120, 468, **1083**
    - surgical anatomy, 1385
  - terminalis, 842
- **Curvatures** of rectum, 1214
  - of stomach, 1158, **1160**
    - level, 1433
    - surgical anatomy, 1407, **1430**
  - of vertebral column, 100, **107**, 308
    - variations, 299
      - surgical bearing, 1436
- Cushions, endocardial, 1034, 1035
- Cusps of heart valves, 873, 874
  - of teeth. *See* **Tubercle**
- Cut-throat, 1378
- Cuticle, 851. *See also* Epidermis
  - of hair, 853
  - of teeth, 1111
- Cutis lamella of mesoderm, 34
- Cutis vera, 850
  - development, 496, 855
- Cutis vera—*continued*
  - under nail, 852
- Cuvier, duct of. *See* **Duct**
- Cylinder, axis. *See* Axon
- Cymba conchæ, 822
- Cyst, Meibomian, 1368
  - pancreatic, 1417
  - thyreo-glossal, 1332, 1372
- Cystotomy, 1400
- Cytolymph, 8
- Cytoplasm, 8, 10, 16
  - of oöcyte, 16
  - of spermatids, 22
- Cyto-reticulum, 8

- Dacryon, 136, 296
- Daughter cells, 9, 11, 12, 13
  - centrosomes, 10, 11
  - chromosomes, 10, 11
  - equatorial plates, 10, 11
  - nucleus, 11
- Death of organs and tissues, 9
- **Decidua**, 58
    - basal layer, 68
    - strata of, 62
  - basalis and capsularis, 62, 65
  - marginalis and uterina, 62
  - vera, 62, 66
- Declive cerebelli, 573
- **Decussation** of brachia conjunctiva, 586
  - fountain, 588, **589**
  - of lemnisci (sensory), 561
  - of pyramids (motor), 544, **546**, 556, **558**
- Defectus recti, 1223
- Definition of terms, 4, 87
- Degeneration of nerve fibres, 534
- Deglutition, 182, 467, 1062, 1072, 1138
- "Deltoid," 268
- Dendrites, 508, 511
  - of sensory cells, 512
- Dens epistrophii, 97, 98
  - connexion with epistropheus, 313
  - development, 123
  - homology and variations, 112
- Dens serotinus, 1115
- Dentes. *See* **Teeth**
- Dentine. *See* Ivory
- Dentition, 1235
  - delayed, 1371
  - diphyodont and polyphyodont, 1235
  - heterodont and homodont, 1235
- Dermatology, definition, 3
- Dermis, 850
  - development, 496, 855
  - under nail, 852
- Descent of ovary, 258, **1296**
  - of testis, 1279
- Descriptive terms, 4, 87
- Determination of sex, 24
- Deutoplasm, 17, 58
  - of oöcyte, 16
- **Development**, 1, **7**. *See also* **Morphology**
    - embryonic and fœtal, 7
    - intra-uterine and post-natal, 7
    - pre-embryonic and pre-natal, 7
  - of abducent nerve, 709
  - of accessory nerve, 711
  - of accessory thyreoid glands, 1332
  - of acoustic nerve, 708
  - of adamantine, 1232, 1233
  - of air sinuses, 183, 205, 213
  - of alar lamina, 41, 87

Development—*continued*
of alar ligament of dens, 123
of allantois, 43
of alveolar periosteum, 1233
of anal canal, 55, 1239
of aorta, 61, 71, 72, 73, 1035, 1037, 1038
of aortic bodies, 1326
of apertures of fourth ventricle, 41, 554
of appendices testis, 1310, **1316**
of appendices vesiculosæ, 1310
of aqueductus cerebri, 41, 590
of arachnoid, 41
of arches, branchial, 47, 49, 51, 53, 73, 181, 183, 314, 497, 710, 835, 1056, 1098
  of palm, 1056
  of vertebræ, 123
of arteria centralis retinæ, 820
    comitans nervi ischiadici, 946, 1041
of arteries, 68, 71, 1032, 1037, 1052
  of limbs, 1041, 1056, 1057
of articular capsules, 89, 123, **306**
of articular discs, 89, 306
of ary-epiglottic folds, 1098
of arytenoid cartilage, 1098, 1099
of ascending cervical artery, 1055
of atlas vertebra, 123
of atrium of heart, 72, 1033
of auditory organ, 55, 848
of auditory ossicles, 57, 835
of auditory tube, 48, 57
of auricle of ear, 48, 58, 79, 81
of axillary artery, 1039, 1041, 1056
of axillary vein, 1058
of azygos vein, 1042, 1047, 1049, 1058
of basal lamina, 41
of basal vein, 1047
of basilar artery, 1040
of basilic vein, 1041, 1058
of bile duct, 52, 1242
of bladder, 52, 53, 1310, 1313
of blood corpuscles, 69, 70, 83
of bone, 88
of brachial artery, 1041
of brachium conjunctivum, 38
of brain, 36, 37, 38, 501, 513, 550, 553, 570, 578, 590, 606, 618, 623, 625, 626
of branchial arches, 47, 49, 51, 53, 73, 181, 183, 314, 497, 710, 835, 1037, 1056, 1098
of bronchi, 46, 50, 1099
of bronchial artery, 73, 927, 1056
of bulbo-urethral gland, 1317
of cæcum, 52, 1238
of calcarine fissure, 657
of cardiac ganglion, 37
of carotid arteries, 1038
of carotid gland, 37, 1326
of cartilage, 88
  of auditory tube, 57
  of larynx, 49, 1098
of cartilago triticea, 1098
of caruncula lacrimalis, 822
of cavity of pleura, 75
  of septum pellucidum, 626
of cavernous sinus, 1041
of central canal of medulla, 41
of cephalic vein, 1041, 1058
of cerebellum, 38, 553, 555, 570, 571, 578
of cerebral peduncles, 38
of cerebral veins, 1047
of cerebrum, 38, 501, 513, 606, 618, 623, 625, 626
of check ligaments, 123

Development—*continued*
of choanæ, 54
of chorioid of eye, 821
of chorioid fissure, 619
of chorioid plexus, 553, 619
of chromaffin bodies, 27, 36, 1323, 1326
of chromaphil system, 1326
of ciliary body, 38
of ciliary ganglion, 692, 792
of ciliary glands, 822
of cisterna chyli, 1050
of clavicle, 292
of clitoris, 1311, 1317
of coccygeus, 497
of cochlea, 55, 847
of cochlear duct, 847
of cœliac artery, 73, 1040, 1056
of cœliac ganglion, 37
of colon, 52, 1238
of columna vertebralis, 29, 33, **123**, 496
of commissures of brain, 38, 39, 607, 626
of common carotid artery, 1038
of conchæ of nose, 188
of conjunctiva, 822
of connective tissue, 34
of constrictor muscles, 497
of corium, 496, 855
of cornea, 821, 822
of corniculate cartilage, 1099
of coronary ligament of liver, 77, 1242
of coronary sinus, 1037
of coronary valve, 1037
of coronary vein, 1058
of corpora mamillaria, 39, 606
of corpora quadrigemina, 38, 590
of corpus callosum, 38, 39, 626
of corpus striatum, 619
of corpuscles of blood, 69, 70, 83
of corpuscles of kidney, 1313
of cortical system, 1329
of costo-cervical trunk, 1054
of cranium, 186
of cricoid cartilage, 1098
of crura of diaphragm, 497
of crypts of tonsil, 1236
of cuneiform cartilage, 1099
of cutis vera, 496, 855
of cystic duct, 1242
of deep cervical artery, 1055
of dens epistrophei, 123
of dentate fascia, 623
of dentate nucleus, 579
of dermis, 496, 855
of diaphragma, 77, 497, 1042
of diaphragmatic hernia, 77
of digastricus, 497
of digestive system, 1231
of digital arteries, 1056
of digits, 45, 80, 81, 291
of discs, articular, 89, 306
of dorsal venous arch, 1058
of dorsalis pedis artery, 1041
of dorsum sellæ, 187
of ductuli aberrantes, 1310, 1316
of ductus deferens, 1310, 1312, 1316
    endolymphaticus, 55, 847
    re-uniens, 56, 848
    venosus, 1042, 1044
of duodenum, 52, 1238
of dura mater, 41
of ear, 48, 55, 58, 79, 81, 847
of efferent ducts of testis, 1310, 1315, 1316

Development—*continued*
of ejaculatory duct, 1310
of embryonic area, 7, 26, 27, 28, 31, 32, 77
of endothelial cells, 34
of ependyma, 40
of epidermis, 855
of epididymis, 1310, 1312, **1316**
of epigastric arteries, 1040, 1054
of epiglottis, 1098
of epiploic foramen, 1240
of epithalamus, 39, 606
of eponychium, 855
of ep-oöphoron, 1310, 1317
of ethmoid bone, 187
of external acoustic meatus, 48
of external carotid artery, 1038
of eye, 38, 820
of eyebrows, 82
of eyelashes, 82
of eyelids, 79, 81, 82, 821
of facial muscles, 497
of facial nerve, 710
of falciform ligament, 77, 1042, 1240, 1242
of falx cerebelli, 620
of fasciculus circum-olivaris, 556
    obliquus pontis, 556
of femoral artery, 1040, 1041, 1057
of femoral vein, 1059
of fibro-cartilages, 123
of flexures of rectum, 1240
of flocculus, 571
of foramen cæcum linguæ, 49, 1236
    lacerum, 188
    ovale of heart, 1034
of forebrain, 38, 606
of foregut, 42, 46, 1232
of fornix cerebri, 38, 625, 626
of frenulum veli, 590
of frontal bone, 188
of funiculi of spinal medulla, 522
of gall bladder, 52, 1242
of ganglia of nerves, 36, 37
of gastric arteries, 1056
of gastric veins, 1058
of gastro-splenic ligament, 1241
of geniculate bodies, 39, 606
of genital organs, 34, 35, 1310 *et seq.*
of glomus coccygeum, 1326
of glossopharyngeal nerve, 710
of gluteal artery, 939, 1040, 1041, 1057
of gluteal vein, 1058
of gray matter, 41
  of spinal medulla, 522, 532
of gums, 46, 55
of hair, 81, 855
of Haversian canals and systems, 89
of head, 42, 46, 53, 186, 497
of heart, 69, 72, 1033
of hemiazygos veins, 1042, 1049, 1058
of hepatic artery, 1056
of hepatic veins, 1044, 1058
of hind-brain, 38, 553
of hind-gut, 42, 52, 1232
of horizontal fissure of cerebellum, 574
of hyaloid artery, 820
of hymen, 1316
of hyoid arch, 47, 49, 51, 73, 183, 497, 710, 1037, 1038, 1056
of hypogastric artery, 939, 1040, 1056
of hypogastric vein, 1042, 1048, 1049, 1058
of hypoglossal nerve, 709
of hypophysis cerebri, 39, 53, 606, 614, 1339

Development—*continued*
of hypothalamus, 39, 606
of ileum, 52, 1238
of iliac arteries, 1040, 1041, 1056, 1057
of iliac veins, 1042, 1048, 1049, 1058
of incus, 57, 181, 835
of inferior epigastric artery, 1040, 1054
of inferior mesenteric artery, 73, 1040, 1056
of infrahyoid muscles, 497
of infraorbital canal, 213
of infundibular recess, 607
of infundibulum of hypophysis, 39, 606, 614
of innominate artery, 1038
of innominate veins, 1042, 1047, 1057
of insula, 652
of interarticular ligaments, 89, 306
of intercostal arteries, 1039, 1040, 1053, 1054
of intercostal muscles, 497
of internal carotid artery, 1038
of internal maxillary artery, 1039
of interosseous arteries, 1041, 1056
of intersegmental arteries, 72, 73, 1039, 1052, 1055
of interspinales, 496
of interventricular foramen, 41, 606, 618
of intestines, 52, 1238
of iris, 38, 821
of islets of Langerhans, 1243
of isthmus rhombencephali, 38
of ivory of teeth, 1233
of jejunum, 52, 1238
of joints, 89, 306
of jugular veins, 1042, 1046, 1047, 1057, 1058
of kidney, 1313
of labia pudendi, 1311, 1315, **1317**
of labyrinth of ear, 55, 847
of labyrinth of ethmoid, 187
of lacrimal bone, 188
of lacrimal caruncle and duct, 822
of lacrimal gland and sac, 822
of lamellæ of bone, 89
of lamina terminalis, 38, 606
of laryngeal muscles, 497
of larynx, 46, 49, 50, 1098
of lateral fissure, 652
of lateral umbilical ligament, 1041
of lens crystallina, 79, 821
of levator ani, 497
of lieno-renal ligament, 1241
of ligaments, 306
of ligamentum apicis dentis, 123
    arteriosum, 1038
    flava, 123
    teres hepatis, 1044
    teres uteri, 1280
    venosum, 1044
of limb arteries, 1041, 1056, 1057
    muscles, 498
    plexuses, 774
of limbs, 44, 290
of lingual muscles, 497, 498, 709
of lips, 1232
of liver, 52, 77, 1042, 1241
of lobules of epididymis, 1316
of longitudinal fissure, 620
of longus capitis and colli, 497
of lower limb, 44, 290
of lumbar arteries, 1039, 1053, 1054
of lumbodorsal fascia, 497
of lung, 46, 50, 76, 1090, 1099
of lymphatic system, 1050
of malleus, 57, 181, 835

Development—*continued*
of mammary artery, 1040, 1054
of mammary gland, 1320
of mandible, 181
of mandibular arch, 47, 49, 51, 53, 54, 72, 181, 314, 497, 710, 835, 1037, 1038, 1056
of mastoid cells, 201
of maxilla, 188
of medial longitudinal bundle, 559
of median artery, 1041, 1056
of mediastinum testis, 1315
  thoracis, 76
of medulla oblongata, 38, 553
of medullary cavity, 89
of medullary vela, 38, 571
of menisci, 89
of mesenteric arteries, 61, 73, 1040, 1056
of mesenteric veins, 1043, 1058
of mesentery, 1241
of metathalamus, 39, 606
of metencephalon, 38
of mid-brain, 38, 590
of mid-gut, 42, 52, 1232
of middle ear, 48, 57
of middle sacral artery, 73, 1039, 1055
of middle umbilical ligament, 52, 53, 1314
of mitral valve, 1034
of mouth, 53, 1232
of muscles, 495
  of back, 496
  of mastication, 497
of myelencephalon, 38
of mylohyoid groove, 181
of nails, 45, 81, 855
of naso-lacrimal duct, 822
of nerve sheaths, 27, 36, 37
  trunks, 37
of nervous system, 35, 501
of neural crest, 36
of neural folds, 35
of neural tube, 35, 43, 707
of neuroblasts, 46
of neuroglia, 41
of nose, 53, 54, 187
of notochord, 28, 31
of nuclei of cerebellum, 579
of oblique vein of left atrium, 1042, 1058
of obliqui abdominis, 497
of obliterated umbilical artery, 1040
of occipital bone, 186, 187, 188
of occipital lobe, 620
of oculomotor nerve, 709
of œsophageal arteries, 73, 1056
of œsophagus, 49, 1237
of olfactory bulb, 38, 620
of olfactory nerve, 708
of olfactory tract, 620
of omental bursa, 1240
of omentum majus, 1240
  minus, 77, 1042, 1240, 1242
of opercula insulæ, 652
of ophthalmic vein, 1046
of optic chiasma, 39, 606, 607
of optic nerve, 36, 38, 708, 821
of optic recess, 606
of orbital muscles, 497, 709
of orifices of heart, 1034
of ossicula auditiva, 57, 835
of otic ganglion, 692, 792
of otic vesicle, 502
of ovarian artery, 1040, 1055
of ovarian ligament, 1280

Development—*continued*
of ovarian vein, 1049, 1050
of ovary, 1315
of palatine bone, 188
of palatine muscles, 497
of palatine tonsil, 1236
of pancreas, 52, 1242, 1433, 1434
of papillæ of skin, 855
of paradidymis, 1310, 1316
of paraflocculus, 571
of paraganglia, 1326
of parathyreoid glands, 49, 1333
of para-urethral glands, 1317
of parietal bone, 188
of par-oöphoron, 1310, 1317
of parotid gland, 1232
of pars analis recti, 55
  membranacea septi, 1036
of peduncles of cerebrum, 38, 590
of pelvic mesocolon, 1241
of pelvis, 258
of penis, 1311, 1318
of pericardial area, 32, 42
of pericardium, 32, 34, 77, 1042
of perichondrium, 88
of perilymphatic space, 848
of perineum, 28
of periosteum, 89
  alveolar, 1233
of peritoneal cavity, 75
of peritoneum, 75, 1240
of peroneal artery, 1041, 1057
of petrosal sinuses, 1047
of pharynx, 46, 1232, 1236
of philtrum, 1232
of pia mater, 41
of pineal body, 39, 606, 1341
of pineal recess, 606
of plantar arteries, 1041
of platelets of blood, 70
of platysma, 497
of pleura, 34, 75, 1099
of plica triangularis, 1236
of pons, 38, 553
of popliteal artery, 1041, 1057
of popliteal vein, 1058
of portal vein, 1043, 1058
of primitive blood vessels, 71
of primitive sheaths, 36, 37
of prostate, 1317
of prostatic utricle, 1310, 1316
of pulmonary artery, 1035, 1038, 1056
of pulp of teeth, 1233
of pylorus, 1433
of pyramidalis abdominis, 497
of quadratus lumborum, 497
of radial artery, 1041, 1056
of rami communicantes, 532, 792
of Rathke's pouch, 53
of recesses of fourth ventricle, 553
of rectum, 52, 53, 1239, 1311
of rectus abdominis, 497
of red nucleus, 586
of renal artery, 1040, 1055
of renal vein, 1042, 1048, 1049, 1050
of respiratory system, 46, 1098
of rete testis, 1315, 1316
of retina, 36, 38, 502, 820, 821
of rhombencephalon, 38, 553, 555
of ribs, 124
of roof nuclei, 579
of roots of spinal nerves, 37, 773

Development—*continued*
of rotatores, 496
of saccule of ear, 56, 848
of saccus endolymphaticus, 55, 56, 847
of sagittal sinuses, 1047
of saphenous veins, 1058
of scalene muscles, 497
of scalp muscles, 497
of sclera, 821
of scrotum, 1311, 1317
of sebaceous glands, 855
of Seessel's pouch, 46
of semicircular ducts, 56, 847
of seminal vesicle, 1310, 1316
of seminiferous tubules, 1315, 1316
of sensory nerves, 502
of septum of heart, 1034, 1036
  pellucidum, 626
  of rhombencephalon, 555
  of spinal medulla, 523
of sheaths of nerves, 27, 36, 37
of sigmoid sinus, 1047
of skin, 855
of skull, 186
of spermatic artery, 1040, 1055
of spermatic veins, 1049, 1050
of sphenoid, 188
of spheno-mandibular ligament, 181
of spheno-palatine ganglion, 692, 792
of spinal arteries, 1040, 1053
of spinal ganglia, 36
of spinal medulla, 36, 37, 40, 522
of spinal nerves, 37, 773
of spines of vertebræ, 123
of spiral ganglion, 502
of spiral organ, 848
of spleen, 1345
of splenic artery, 1056
of stapedius, 497
of stapes, 57, 183, 835
of sternum, 124
of stomach, 52, 1237
of straight sinus, 1047
of striped muscle, 34
of stylo-hyoid ligament, 183
of stylo-hyoid and stylo-pharyngeus, 497
of subarachnoid space, 41
of subclavian artery, 1038, 1039, 1054
of subclavian vein, 1041, 1058
of subdural space, 41
of sublingual gland, 1236
of submaxillary ganglion, 692, 792
of submaxillary gland, 1236
of substantia ossea of teeth, 1233
of superior intercostal veins, 1042, 1047, 1048, 1057
of superior mesenteric artery, 61, 73, 1040, 1056
of superior thyreoid artery, 1056
of superior vesical artery, 1041
of suprapineal recess, 39
of suprarenal artery, 1055
of suprarenal gland, 37, 1329
of suprarenal vein, 1049
of supratonsillar fossa, 1236
of suspensory ligament of dens, 123
of sweat glands, 855
of sympathetic cells, 36
of sympathetic ganglia, 37, 792
of sympathetic system, 792
of tænia thalami, 606
of tarsal glands, 822

Development—*continued*
of teeth, 55, 1233
of tegmentum, 590
of telencephalon, 38, 618
of temporal bone, 188
of tensor tympani, 497
  veli palatini, 497
of testicular vein, 1049, 1050
of testis, **1315**, 1316
of thalamus, 39, 606
of thoracic duct, 1050
of thymus, 48, 49, 1336
of thyreo-cervical trunk, 1054
of thyreo-glossal duct, 49, 1331
of thyreoid cartilage, 1098
of thyreoid gland, 46, 49, 1331
of thyreoidea ima, 1056
of tibial arteries, 1041, 1057
of tongue, 50, **1236**
of tonsil (palatine), 1236
of trachea, 46, 50, **1099**
of transverse fibres of pons, 571
of transverse mesocolon, 1241, 1403
of transverse processes, 123
of transverse sinus, 1047
  of pericardium, 1033
of transverse temporal gyri, 653
of tranversus abdominis, 497
  thoracis, 497
of tricuspid valve, 1034
of trigeminal nerve, 710
of trigonum habenulæ, 606
of trochlear nerve, 709
of tuber cinereum, 39, 606
of tubercle of navicular, 294
of tunica albuginea testis, 1315
  vaginalis testis, 1280
of tympanic membrane, 57
of tympanum, 48, 57
of ulnar artery, 1041, 1056
of umbilical artery, 1040, 1041
of umbilicus, 42, 43
of upper limb, 44, 290
of ureter, 1310, **1313**
of urethra, 52, 53, 1310, 1311, **1314**, 1318
of urogenital organs, 34, 35, 1310
of uterine tube, 1310
of uterus, 1310, **1316**
of utricle of ear, 56, 848
  of prostate, 1310, 1316
of vagina, 1310, 1311, 1315, 1316
of vagus, 710
of valves of heart, 1034
of valve of vena cava, 1037
of vascular system, 68, 1032, 1052
of veins, 1041
of vena cava inferior, 1042, 1044, 1048, 1049, 1050, 1058
  superior, 1042, 1047, 1057, 1058
of venæ comites, 1059
of venous sinuses, 1041, **1047**
of ventricle of larynx, 1098
of ventricles of heart, 72, 1033
of ventriculus lateralis, 41, 618
  quartus, 41
  tertius, 41, 607
of vermiform process, 52, 1238
of vertebral artery, 1040, 1054, **1055**
of vertebral column, 29, 33, **123**, 496
of vesicula seminalis, 1310, 1316
of vesicular appendices, 1310
of vestibular gland, 1317

Development—*continued*
  of vestibule of mouth, 1232
    of vagina, 53
  of vitreous body, 820
  of vocal folds, 1098
  of volar arches, 1056
  of vomer, 188
  of white matter, 41
  of zonula ciliaris, 820
  of zygomatic bone, 188
Diameters of pelvis, 257
  of skull, bi-asterionic, 296
    bi-stephanic and bi-zygomatic, 296
Diaphragma, 115, 120, 122, **472**, 481
    arteries, 914, 929, 936
    development, 77, 497, 1042
    fascia, 475, 1150
    level, 115, 1433
      in expiration, 1149
    lymph vessels, 1021, 1032
      surgical anatomy, 1404
    morphology, 497
    nerves, 473, 727, 746, 789
    relation to œsophagus, 1145
    surgical anatomy, 1430
    veins, 967, 969, 990
  pelvis, 493, 1150
  sellæ, 158, 667
  urogenitale, 200, 256, 260, **489**
    relation to pelvis and perineum, 257
Diaphysis, 90
Diarthrosis, 303
Diencephalon, 38, 39, 542, 606
Differences between jejunum and ileum, 1200
Differentiation of embryonic area, 27
  of neural tube, 37
  of secondary mesoderm, 30
Digestion, 1101
Digestive System, 1101
Digits, 217, 248
    development, 45, 80, 81, 291
    homology, 293
  of foot, 248
    arteries, 958, 959, 962
    bones, 286
    joints, 248, **363**
    lymph vessels, 1022
    movements, 285, 287, **364**
    nerves, 760, 761, 762, 764, 765
    surgical anatomy, 1447
    veins, 996, 997
  of hand, 217
    arteries, 922, 923, 926
    bones, 245
    joints, 217, **336**
    lymph vessels, 1017
    movements, 243, 336
    nerves, 734, 737, 741
    surgical anatomy, 1447
    veins, 984
Digitus post minimus, 293
Diploë, **85**, 124, 191
  in old age, 186
  veins of, 132, 670, 973, **975**, **976**, 981, 982, 1347
Discs, articular, 88, 304
      development, 89, 306
    acromio-clavicular, 224, **321**
    mandibular, 153, 179, **314**, 456
    sterno-clavicular, 115, 122, 224, 225, **320**
    triangular, 217, 232, 233, 236, 241, **329**, 330
Discs—*continued*
  optic, 809
  tactile, 856
Dislocation of clavicle, 224, 1438, 1439
  of elbow, 234, 1444
  of hip, 1454
  of shoulder, 1439
  of vertebral column, 1435
Displacement of stomach, 1164
"Distal" (definition), 5
Diverticulum, allantoic, 43, 44, 53, 77
  of bladder, false, 1420
  of duodenum, 1180
  ilei (Meckel), 1200
    surgical anatomy, 1411
  of œsophagus, pulsion, 1384
  olfactory, 38
Division of cells, amitotic, 9
    hetero-typical, 12, 17
    homotype, 10, 25
    maturation, 12, 14
        first, 18
        second, 18, 19
      of spermatocytes, 20
    meiotic, 10, **12**, 13, 17
    mitotic, **9**, 25
  of germ cells, 12
  of spermatocytes, 20
Doctrine, neurone, 504
Dolicho-cephaly, 295
Dolicho-facies, 297
Dolicho-hieria, 299
Dolicho-kerkia and dolicho-knemia, 299
Dolicho-pellia and dolicho-urania, 298
"Dorsal," definition, 5
Dorsiflexion, 305
  of fingers, 243, 336
  of foot, 355
  of toes, 285, 287, 364
Dorsum of foot, 248
  ilii, 251, 259
  of nose, 793
  penis, 1282
  sellæ, **158**, 163, 164, 202
    at birth, 205
    chondrification, 187
    relation to notochord, 186
  of tongue, 1119
Douglas, pouch of. *See* **Pouch**, recto-uterine
Dropsy, 367
Drop-wrist, 1443
Drum of ear. *See* **Cavity**, tympanic
Ducts or **Ductus**—
  alveolar, of lung, 1097
  arteriosus, 1038, 1051, 1052
  bile, 1192, **1193**
    arteries, 933
    development, 52, 1242
    level, 1433
    structure, 1194
    surgical anatomy, 1404, **1406**, 1409
    termination, 1178, 1194
  biliferous, 1192
  branchial, 48
  choledochus. *See* **D.**, bile
  cochlearis, 57, 842
    development, 847
    in vestibule, 841
  of Cuvier, 74, 76, 878, 964, 1047
      morphology, 1057
    left, derivatives, 1042
      persistence, 966, 967

Ducts or **Ductus**—*continued*
  of Cuvier—*continued*
    right, derivatives, 1042
  cystic, 1192, **1193**
    development, 1242
    surgical anatomy, 1406
  deferens, 476, 491, 493, 1271, **1274**
    arteries, 942, 943, 1279, 1281
    development, 1310, 1312, **1316**
    lymph vessels, 1026
    nerves, 791, 1279
    relation to fovea femoralis, 1224
    structure, 1279
    surgical anatomy, 1421
    veins, 992, 993
  ejaculatory, 1271, 1274, **1277**
    development, 1310
    entering prostate, 1287
    opening in urethra, 1289
  endolymphaticus, 167, 837, **841**
    development, 55, 847
  of epididymis, 1272, **1274**
    development, 1310, 1312, **1316**
    homologue in female, 1298
  excretory, of liver, 1192
      structure, 1194
    primary. *See* **D.**, Wolffian
  fronto-nasal, 176, 798
  of glands, lobar, 1127
  hepatic, 1192
  interlobular, of liver, 1192
  intralobular, of liver, 1191
  lacrimal, 819
    development, 822
    surgical anatomy, 1369
  lactiferous, 1319
  lingual, 1332
  of liver, excretory, 1192
      structure, 1194
    interlobular, 1192
    intralobular, 1191
  lobar, of glands, 1127
  of lung, alveolar, 1097
  lymph. *See* Lymph-duct
  Müllerian, 1310, 1316
    homologue in male, 1272, 1289
  naso-lacrimal, 134, 820
    development, 822
    seen through speculum, 1369
    surgical anatomy, 1368
  pancreatic, 1194, **1197**
      surgical anatomy, 1406
      termination, 1178, 1194
    accessory, 1179, 1198
  para-urethral, female, **1270**, 1308
    male, 1292
  parotid, 456, **1130**
    arteries, 896
    in cheek, 1106
    in mouth, 1103
    surgical anatomy, 1367
  pharyngo-branchial, 49, 1336
  pre-cervical, 47
  primary excretory or pronephric. *See* **D.**, Wolffian
  prostatic, 1288
  re-uniens, 840, 842
    development, 56, 848
  semicircular, 841
    development, 56, 847
    nerves, **602**, **696**, 837, 838, 839, 840, **846**
  of seminal vesicle, 1277, 1278

Ducts or **Ductus**—*continued*
  of sublingual gland, 1104, **1133**
      major, 1133
  submaxillary, 462, 463, 1104, **1131**
    surgical anatomy, 1374
  sudoriferous, 854
  thoracic, 473, 1001, **1004**
    abnormalities, 1032
    development, 1050
    level in neck, 1433
    surgical anatomy, 1384, **1385**
  thyreo-glossal, 1331
    development, 49, 1331
    surgical anatomy, 1372
  utriculo-saccular, 841
  venosus, 999
      development, 1042, 1044
    obliterated. *See* **Ligamentum** venosum
  of vestibular gland, 1308
  vitello-intestinal, 42, 52, 60
    persistence, 1200
  Wolffian, 53, 1310, **1311**, 1316
    connexion with gubernaculum, 1280
    derivatives, 1310
DUCTLESS GLANDS, 1225, 1226, **1321**
Ductuli—
  aberrantes of epididymis, 1274
    development, 1310, **1316**
    homologue in female, 1298
  efferentes of testis, 1273
    development, 1310, 1315, 1316
    homologue in female, 1298
Duodenum, 1175
  adherent to gall bladder, 1155
  arteries, 933, 935, 1180
  development, 52, 1238
  diverticula, 1180
  interior, 1179
  level, 1433, 1434
  lymph glands, 1027, 1028
  lymph vessels, **1031**, 1180
  nerves, 789, 1180
  structure, 1171, 1179
  surgical anatomy, 1404, 1405, 1406, **1409**, 1413
  variations, 1180
  veins, 1180
Dura mater *encephali*, 665
    development, 41
    relation to skull bones, 153, 154, 155
  arteries, 157, 159, 161, 166, 894, 895, 897, 898, 903, 904, 907
  lymph vessels, 147, 148, 149, 151, 162, 167, **1101**
  nerves, 681, 685, 689, 700, 704, 726
  veins, 976
  spinalis, 519, 667
    in child, 1435
    level of lower end, 1434
    in sacral canal, 104, 106
  arteries, 907, 911, 928, 938, 941
  nerves, 713, 779
  veins, 982

Ear, 822
  external, 822. *See also* **Auricle** and **Meatus**
    cartilage, 88
    development, 48, 58, 79, 81
    muscles, extrinsic, 449
  internal, 124, 126, **837**
    arteries, 847, 895, 908
    development, 55, 847
    lymph vessels (absent), 1002, 1012

Ear—*continued*
  internal—*continued*
    nerves, **602**, **696**, 837, 838, 840, 843, **845**
    relation to carotid artery, 151
      to meatus, 167
    surgical anatomy, 1361
  middle, 124, 126, 140, **826**. *See also* **Cavity**, tympanic
Ear-hole. *See* **Meatus**, acoustic, external
Ectoderm, 31
  amniotic, 26, 31
  surface, origin of, 31
  trophoblastic, 25, 58
Ecto-mesoderm, 26, 30, 31
Ectopia cordis, 116
  vesicæ, 1414
Egg-tubes of ovary, 1296
Elbow, 217. *See also* **Joint**
  dislocation, 234, 1444
  lymph glands, 1015
  "pulled," 1444
  skiagrams, 1444
  surgical anatomy, 1443
Eleidin, 851
Elements of central nervous system, 499
Embolus of cerebellum, 576
Embryo, 43. *See also* **Fœtus**
  external features at different periods, 77
  formation, 42
  nutrition and protection, 25, 58
EMBRYOLOGY, 1, 7. *See also* **Development**
Eminence, arcuate, 160, 200
    relation to ear, 167
  canine, 133, 134
  collateral, 634
  cruciate, **165**, 193
  frontal, 130, **132**, 137, 138, 189
    at birth, 185
    surface and surgical anatomy, 1349
    in women, 186
  genital, 1311, 1317
  hypothenar, 394
  ilio-pectineal, 250, 253, 260
  intercondylar, of tibia, **268**, 270, 346
  parietal, **130**, 136, 137, 138, 191
    at birth, 185
    surface and surgical anatomy, 1349
    in women, 186
  thenar, 394
Eminentia conchæ, 823
  cruciata, **165**, 193
  medialis of fourth ventricle, 552
  pyramidalis of middle ear, 828
  scaphæ and triangularis, 823
Emissaria. *See* **Vein**, emissary
Empyema of maxillary sinus, 1370
Enamel of teeth. *See* Adamantine
Enarthrosis, 303
Encephalon. *See* **Brain**
End-arteries of kidney, 1254
End-bulbs of Krause, 856
End-organs of nerves, special, 856
    sensory, 27
End-ring of spermatozoon, 21
Endings of nerves, sensory, 856
Endocardium, 870, 874, **875**
Endocranium, 153
Endolymph, 840
Endoscope, 1419
Endosteum, 86
Endothelium of blood-vessels, 863, 864, 865
  origin, 69, 70
Enlargements of spinal medulla, **521**, 525, 526
  cells in, 531
  level, 1433
Enophthalmos, 1386
Enteron, primitive, 28
Entoderm, 26, 27, 28
Ependyma, 503, 512
  of spinal medulla, 528
    origin, 40
Epicardium, 874, **875**
Epicondyle, 87
  of femur, lateral, 262, 265
    medial, **263**, 265
      homology, 293
  of humerus, 227
      surgical anatomy, 1443
    lateral, **227**, 229, 230
      homology, 293
      in pronation and supination, 237
      relation to radius, 234
    medial, **227**, 229
Epicoracoid, 292
Epidermis, **851**
  development, 855
  nerve-endings in, 856
Epididymis, 1271, **1272**
  arteries, 931
  development, 1310, 1312, **1316**
  lymph vessels, 1026
  nerves, 1274
  structure, 1273
  surgical anatomy, 1421
Epigastrium, 1152, 1401
Epiglottis, 1065
  development, 1098
  epithelium, 1071
  in laryngoscopic examination, 1076
  level, 1061, 1433
  nerves, 698, 700
  in pharyngeal wall, 1141
  relation to hyoid bone, 183
  surgical anatomy, 1378
  in swallowing, 1072
Epihyal bone, 315
Epiphora, 1369
Epiphyseal cartilage and line, 90
Epiphyses of bones, 90
    relation to joint-unit, 306, 307
    separation of, 91
  of clavicle, 90, 225
  of femur, 90, 265
  of hip-bone, 91, 255
  of humerus, 90, 230
    surgical anatomy, 1439, 1443
  of ribs, 91, 123
  of scapula, 91, 223
  of tibia, 90, 271
  of vertebræ, 91, 110, 306
Epiphysis cerebri. *See* **Body**, pineal
Epipteric bones, 184, 202, 211
Epispadias in female, 1414
Episternal bones, 116
Epistropheus. *See* **Vertebra**, cervical, second
Epithalamus, 607, 1340
  development, 39, 606
Epithelium, auditory, 55
  of ciliary body, development, 38
  germinal, 1315
    of ovary, 1296
Epitrichium, 855
Eponychium, 852
  development, 855

- Ep-oöphoron, 1298
  - development, 1310, 1317
- Equator of eyeball, 801
  - of lens, 814
- Erect position, 4, 107, 258, 340, 349, 1165
- Eruption of teeth, 182, 185, **1116**
  - method, 1233, 1235
- Erythroblasts, 70
- Erythrocytes, origin, 70
- **Ethmoid bone**, 127, 153, **206**
    - in anterior cranial fossa, 155
    - position, 127
    - in child, 185
    - chondrification, 187
    - origin, 188
    - ossification and variations, 207
  - *bulla*, 171, 173, 207, 797
    - bulging into meatus, 133
    - openings of sinuses on, 176
  - *cribriform plate*, 127, 207
    - in anterior cranial fossa, 155, 157
    - in roof of nose, 168, 169
    - relation to frontal bone, 190
  - *labyrinth*, 127, 176, **206**
    - relation to anterior cranial fossa, 155, 157
      - to nose, 169, 171, 172
      - to orbit, 136, 172
  - *perpendicular lamina*, 127, 169, **206**
    - seen through apertura piriformis, 132, 133
- Ethmo-turbinals, 206
- Eutelolecithal oöcytes, 17
- Eversion of foot, 280, **364**
- **Examination**, bimanual, 1427
  - cystoscopic, 1419, 1427
  - endoscopic, 1419
  - laryngoscopic, 1076
  - otoscopic, 829, 1356
  - rhinoscopic, 1369, 1376
  - sigmoidoscopic, 1424
  - vaginal, 1427
- Excavatio. *See also* **Pouch**
- Excavatio papillæ N. optici, 809
- **Excision** of cæcum and ascending colon, 1412
  - of kidney, 1414, 1416
  - of prostate, 1420, 1421
  - of pylorus, 1409
  - of rectum, 1420, **1424**
  - of spleen, 1434
  - of stomach, 1408, 1413
  - of thyreoid gland, 1379
- Expansion, extensor, of fingers, 246, 400
  - of toes, 426
- Extension at joints, 305
- Exterior of skull, 129
- "External," definition, 5
- Extravasation of urine, 404, 475, 487, 1418
- Extremities. *See* **Limbs**
- **Eye**, 134, 800
    - parietal or pineal, 1342
  - "black," cause of swelling, 1368
  - colour, 808
  - development, 38, 820
  - distance between, 127
  - myopic and hypermetropic, ciliary muscle in, 808
    - diameters in, 801
- **Eyeball**, 124, **800**
  - arteries, 802, 803, 807, 809, 812, **903**
    - in inflammation, 1368
  - axis, 135, 801
  - at birth and at puberty, 801
  - extirpation, effect, 584
- **Eyeball**—*continued*
  - fascia, 453, 454, 802
  - lymph vessels (absent), 803, 1002, 1012
  - muscles, extrinsic, 453
    - intrinsic, 807, 809
  - nerves, 683, 803, 805, 809
  - veins, 803, 807, 809, 812, 974
- Eyebrows, 130, 132, **815**
  - first appearance, 82
- Eyelashes, 816, **817**
  - first appearance, 82
- **Eyelids**, 79, 446, **815**
    - closure in fœtus, 81
    - development, 821
    - re-opening in fœtus, 82
  - arteries, 818, 898, 903, 904
  - epidermis, 851
  - fascia, 446
  - in fracture of skull, 1369
  - lymph vessels, 818, 1012
  - muscles, 450, 816
  - nerves, 681, 682, 683, 687, 695, 818
  - papillæ of skin of, 850
  - surgical anatomy, 1368
  - veins, 818
- Eye-teeth, 1114

- **Face**, 91
  - arteries, 892, 896, 898, 903
  - bones, 130, 177
  - fascia, 446
  - landmarks, 1366
  - lymph glands, 1007
  - lymph vessels, 1011, 1012, 1013
  - measurements, 296
  - muscles, 450
  - nerves, 681, 682 ; 686, 687 ; 690, 691 ; 692 ; 695 ; 723
  - surgical anatomy, 1366
  - veins, 971
- **Facet**, 87
  - fibular, of tibia, **268**, 270
  - for ilio-femoral ligament, 265, 344
  - for peroneal sesamoid, 281
  - "pressure," on tibia, 271
  - for ribs, 100, 108
    - variations, 112
  - tibial, of fibula, 271
- **Falx** cerebelli, 164, 667
  - cerebri, 157, 164, **665**
    - development, 620
    - function, 154
  - inguinalis aponeurotica, 260, 480, **482**, 484, 486
    - surgical anatomy, 1399
- **Fascia**—
  - deep, 367
    - of abdominal walls, 369, 372, 437, **475**
    - of arm, upper, 381
    - of axilla, 369, 373
      - surgical anatomy, 1441
    - of back, 368, 437
    - of buttock, 404
    - cervical, 369, **446**
      - surgical anatomy, 1376
    - of chest, 372
    - of face, 446
    - of foot, 423
    - of forearm, 384, 385
    - of hand, 385
    - of infraspinatus, 376, 377
    - lata, 259, 265, 270, **404**, 409, 416, 417, 418, 475, 478

Fascia—*continued*
- **deep**—*continued*
  - of leg, 271, 274, 408, 421, 422, **423**
  - lumbo-dorsal, 106, 109, 122, 369, 437, **438**, 439, 440, 480, 481, 486
    - anterior lamella, 338
    - development, 497
  - of neck, 369, **446**
    - surgical anatomy, 1376
  - of parotid, 150, 152
  - parotideo-masseteric, 446, 452, **1130**
  - pectinea, 405
  - pectoral, 372
  - of perineum, 487
  - popliteal, 407, 423
  - of scalp, 446
  - of shoulder, 376
  - temporal, 139, **446**, 456
  - of teres minor, 376
  - of thigh, 404. *See also* **F.** lata
- **superficial**, 367
  - of abdomen, 475
  - of arm, upper, 381
  - of back, 368
  - of buttock, 404
  - of chest, 372
  - of Colles, 260, 340, **486**
    - surgical anatomy, 1418
  - of face, 446
  - of foot, 423
  - of forearm and hand, 385
  - of groin, 404
  - of head and neck, 446
  - over ischial tuberosity, 486
  - of leg and foot, 423
  - pectoral, 372
  - of penis, **486**, 487
  - of perineum, 260, **486**
    - surgical anatomy, 1418
  - of scalp, 446
  - of scrotum, 486, 487, 1282
  - of sole, 423
  - of thigh, 404
- of abdomen, 369, 372, 437, 475, 1150
  - surgical anatomy, 1399
- axillary, 369, 373
  - surgical anatomy, 1441
- bucco-pharyngeal, 1142, **1143**
- bulbi, **453**, 454, **802**
- cervical, 369, **446**, 447, 448, 468
  - surgical anatomy, 1376
- of Colles, 260, 340, **486**
  - surgical anatomy, 1418
- cremasteric, 478, 481, 485, **1281**
  - in scrotum, 1282
- cribrosa of thigh, 405
- dentata, 627
  - development and function, 623
- diaphragmatic, 475, 1150
- endopelvic, 491, 1150
- of eyeball, 453, 454, 802
- iliaca, 259, 407, 474, 475, 478, 1150
- infraspinata, 376, 377
- infundibuliform. *See* **F.** spermatica interna
- intercolumnar. *See* **F.** spermatica externa
- lacrimal, 820
- lata, 259, 265, 270, **404**, 409, 416, 417, 418, 475, 478
- lumbo-dorsal, 106, 109, 122, 369, 437, **438**, 439, 440, 480, 481, 486
  - development, 497
  - anterior lamina, 338

Fascia—*continued*
- of muscles, 365
- of obturator internus, 491, 494
- of orbit, 453, 454, 802
- of palm, 385, 386
- parotid, 150, 152
- parotideo-masseteric, 446, 452, **1130**
- pectinea, 405
- pectoral, 372
- of pelvis, 491, 1150
- penis, 486, 487, 1284
- perineal, 257, 260, **340**, **486**, 487, 489, 492
  - surgical anatomy, 1418
- perinephric. *See* **F.**, renal
- pharyngo-basilar, 1142
- phrenico-pleural, 1088
- popliteal, 407, 423
- of popliteus, 423, 431
- pretracheal, 448
- prevertebral, 148, 149, **447**, 468
- profunda. *See* **F.**, **deep**
- propria of hernia, 1399
- rectal, 1218
- recto-vesical, 493, 1287
- renal, 1247
  - surgical anatomy, 1414
- salpingo-pharyngea, 832
- of scalp, 446
- of scrotum, 486, 487, 1282
- Sibson's, 109, 119, 122, **1084**
- spermatic, 1281
  - surgical anatomy, 1399, 1421
  - in scrotum, 1282
  - external, 479, 481, 485, **1281**
  - internal, 476, 484, **1281**
- temporal, 139, **446**, 456
- of tibialis posterior, 271, 274, **423**
- transversalis, 259, 260, 407, **475**, 478, 482, 484, 486, 1150
  - surgical anatomy, 1399
- of urogenital diaphragm, inferior, 257, 260, **340**, 486, 487, 488, **489**
  - superior, 260, 487, **490**, 492

Fasciculi. *See also* **Bundle** and **Tract**
- of brachial plexus. See **Cords**
- interfusal, of tendons, 859
- of muscles, 365
- spiral, of cochlear nerve, 846
- transverse, of palmar aponeurosis, 387
  - of plantar aponeurosis, 424
- **of central nervous system**—
  - methods of distinguishing, 534
  - antero-lateral superficial. *See* **F.**, spino-cerebellar, anterior
  - bulbo-spinal, 539
  - bulbo-thalamicus, 589, 648
  - cerebello-olivaris. *See* **F.**, olivo-cerebellar
  - cerebello-spinal. *See* **F.**, spino-cerebellar, posterior
  - cerebro-nucleares, 649
  - cerebro-pontine. *See* **Fibres**
  - cerebro-rubricus, 639
  - *cerebro-spinal*, 539, 540
    - connexion with cerebral nuclei, 593, 594, 598
    - origin, 649
    - in basis pedunculi, 590
    - in internal capsule, 639
    - in medulla oblongata, 546
    - in pons, 549
    - anterior, 540
    - lateral, 539

- **Fasciculi**—*continued*
  - of central nervous system—*continued*
    - cerebro-spinal, lateral—*continued*
      - decussation, 544, **546**, 556, **558**
    - circum-olivaris pyramidis, **549**, 558
      - development, 556
    - cuneatus, 524, 526
        - origin, 535
      - in medulla oblongata, 548, **559**
    - fronto-pontine. *See* **Fibres**
    - gracilis, 524, 526
        - origin, 535
      - in medulla oblongata, 548, **559**
    - interfascicularis, 535
    - longitudinalis inferior, 646
      - medialis. *See* **Bundle**
      - of pons, 565, 566
      - superior, 646
    - mamillo-thalamicus, 610, 613
    - obliquus pontis, 550
      - development, 556
    - occipito-frontalis inferior, 646
      - superior, 647
    - olivo-cerebellar, 557
      - in cerebellum, 577
      - relation to spinal tract, 599
    - olivo-spinalis, 539
    - postero-lateralis, 536
    - proprius anterior, **537**, 540
        - in medulla oblongata, 547, 558
      - lateralis, 537, 539
        - in medulla oblongata, 547
      - posterior, 537
    - retroflexus, 589, **612**
    - rubro-spinal, 539, 650
        - function, 518
      - in mid-brain, 587
      - in medulla oblongata, 564
    - septo-marginalis, 537
    - *spino-cerebellar*, 533
        - function, 539
      - anterior, 538
        - in medulla oblongata, 547, 564, 578
        - in pons and cerebellum, 578
      - posterior, 538
        - in cerebellum, 577
        - in medulla oblongata, 547, 563
        - in restiform body, 549
    - spino-tectal, 538
    - *spino-thalamic*, 536, 538, 562, 648
          - crossing, 536, 562, 648
          - function, 539
          - origin and termination, 536, 648
        - in lemniscus, 589
        - in medulla oblongata, 564, 648
        - in mid-brain, 589, 648
        - in spinal medulla, 536, 538, 562, 648
      - anterior, 539
      - posterior, 538
    - strio-nigricus, 637
    - strio-rubricus, 637
    - strio-thalamicus, 637
    - tecto-bulbaris et spinalis, 590
    - tecto-spinal, 539
        - function, 518
      - in medulla oblongata, 561, 564
      - in pons, 568
    - temporo-pontine. *See* **Fibres**
    - temporo-thalamicus, 640
    - thalamo-mamillaris, 610, 613
    - thalamo-olivaris, 557
      - in medulla oblongata, 564
- **Fasciculi**—*continued*
  - of central nervous system—*continued*
    - thalamo-olivaris—*continued*
      - in pons, 568
    - uncinatus, 646
    - vestibulo-mesencephalicus, 604
    - vestibulo-spinalis, 539
      - origin, 604
- Fasciola cinerea, 627
- Fat, extraperitoneal, 476, 1151. *See also* **Tissue**
  - paranephric, 1247
  - perinephric, 1247, 1416
  - subcutaneous, 367
- **Femur**, 84, 89, 248, **260**
    - of horse, 266
  - attachments, 264
  - compared with humerus, 300
    - with tibia, 299
  - epiphyses, 90, 265
  - fracture, 1449
  - homology, 293
  - nerve supply, 754
  - nutrient artery, 955
  - obliquity, 266
  - ossification, 265
  - platymeric, 266, 300
  - structure and variations, 265
  - surgical anatomy, 1449, 1450, 1451, 1454, 1455
- **Fenestra**, 140
  - cochleæ, 827, 1358
    - seen through tympanic membrane, 1357
  - vestibuli, 827
    - seen through meatus, 140
- Fertilisation of ovum, 23
- **Fibrae**; **Fibres**—
    - dendritic, of tympanic membrane, 829
    - intercrural, 478
    - interfusal, of tendons, 859
    - lentis, 815
    - muscle, 365
      - development, 34
    - perforating, of Sharpey, 85
      - of teeth, 182
    - of Purkinje (heart), 875
    - supporting, of spiral organ, 845
    - sustentacular, of retina, 810, **812**
  - **nerve**, 509
        - last medullated, 655
        - when medullated, 510
        - of spinal medulla, 533
      - afferent, 507, 510
        - splanchnic, 778, 779, 784, 785
          - of vagus, 594, 596
        - visceral, 777
      - association, of cerebral hemisphere, 645
          - intracortical and subcortical, 646
          - long and short, 646
        - of spinal medulla, lateral, 539
          - posterior, 537
      - cardiomotor, 780, 781
      - cellulifugal, 512
      - cellulipetal, 512
      - commissural, of cerebral hemispheres, 644
      - efferent, 506, 510
        - somatic, 784
          - of vagus, 596
        - splanchnic, 778, 779, 784, 785
          - of ciliary ganglion, 602
          - of facial nerve, 597
          - of spinal medulla, 532
        - visceral, 777
          - in cerebral nerves, 775

Fibrae; Fibres—*continued*
  nerve—*continued*
    inhibitory, 511
    intracortical, of brain, 646
    medullated or myelinated, 509
    motor, 510
    non-medullated, 509
    para-sympathetic, 775, 777
    pilomotor, 779, 780, 781, 784
    post-ganglionic, 775, 777
    pre-ganglionic, 775, 777
    projection, of brain, 647
    secretory, 510, 780, 781, 784
    sensory, 510
      of abdominal viscera, 784
    somatic efferent, 784
      of facial nerve, 597
      of vagus in medulla, 596
    splanchnic, afferent, 777, 778, 779, 784, 785
        of vagus, 594, 596
      efferent, 778, 779, 784, 785
        of facial nerve, 597
    subcortical, of brain, 646
    sympathetic, 777
    taste, in medulla oblongata, 594, 596
    vasomotor, 779, 780, 781, 784, 785
    viscero-inhibitory, 784
    viscero-motor, 784, 785
  arcuate, external, 545, **549**, 556
        in cerebellum, 577
      anterior, 563
      posterior, 563
    internal, **561**, 564
      from olive, 557
    of pons, 567
  cerebello-olivary. *See* **Fasciculus**, olivo-cerebellar
  cerebro-spinal. *See* **Fasciculus**
  cerebro-pontine, 649, 650
    in basis pedunculi, 590
    in internal capsule, 639
    in pons, 566
  cortico-striate, 650
  cortico-thalamic, 610
  fronto-pontine, 649
    in basis pedunculi, 590
    in internal capsule, 639
  olivo-cerebellar. *See* **Fasciculus**
  pontis (transverse), 565, **566**
    development, 571
  pyramidal. *See* **Fasciculus**, cerebro-spinal
  temporo-pontine, 650
    in basis pedunculi, 590
    in internal capsule, 639
  thalamo-cortical, 610, **611**
Fibre-tracts, acoustic, 653
  visual, 656
Fibrils, achromatic, 10
  central, of spindle, 10
  dental, of Tomes, 1111, 1234
  mantle, 10, 11, 13
  spiral, of spermatozoon, 21
Fibro-cartilage, 83
  white and yellow, 88
  of clavicle, 320
  intervertebral, 308
    development, 123
    proportion of backbone, 106
    relation to notochord, 29, 30, 124, 313
  cervical, 96, 107

Fibro-cartilage—*continued*
  intervertebral—*continued*
    lumbar, 102, 107, 412
    sacral, 104
    sacro-coccygeal, 105
    thoracic, 100, 117, 120
  of symphysis pubis, 260, **339**
Fibula, 248, **271**
  attachments, 274
  homology, 293
  nerve supply, 763
  nutrient artery, 958
  ossification, 274
  structure and variation, 275
  surgical anatomy, 1455, 1456
Figure, achromatic, 10, 11
Fila of abducent nerve, 598
  of accessory nerve, 593
  of glossopharyngeal nerve, 596
  of hypoglossal nerve, 593
    relation to arteries, 907
    within medulla, 564
  of oculomotor nerve, 583, 586
  of vagus, 596
    within medulla, 564
Filament, axial, of spermatozoon, 21
Fillet. *See* Lemniscus
Filum terminale, 104, 106, 519, **528**
      arteries, 941
      origin, 40
    externum, 528, 667
    internum, 528
Fimbria of brain, formation, 625
Fimbriæ of uterine tube, 1297
  ovarian, 1295, 1297
Fingers, 217
  arteries, 922, 923, 926
  bones, 245
  development, 45, 80, 81, 291
  homology, 293
  joints, 217, **336**
  lymph vessels, 1017
  movements, 243, 336
  nerves, 734, 737, 741
  surgical anatomy, 1447
  veins, 984
Fissures—
    of anus, 1421
    antitrago-helicine, 823
    chorioid, of eyeball, 820
    of liver. *See* **Fossæ**
    of lung, 1094
      surface anatomy, 1391
    palpebral, 815
    urogenital. *See* **Cleft**
    vestbuli of ear, 839
  of cerebellum—
    horizontal, 574
    postlunaris, 574
    postnodularis, 572
    post-tonsillaris, 574
    prima, 572
    secunda, 573
      in adult, 574
    suprapyramidalis, 573
    tertia, 573
  of cerebrum. *See also* **Sulcus**
    calcarine, 657
      relation to calcar avis, 632
    chorioid, **633**, 672
      development, 619
    collateral, 658, **659**

Fissures—*continued*
of cerebrum—*continued*
hippocampi, 624
lateral (Sylvius), 139, 541, 542, 643, **650**
stem, 643, **651**
rami, 651
development, 652
surface anatomy, 161, 1349, 1350
longitudinal, 541, 542, 618, **643**
development, 620
parieto-occipital, 643, **659**
in child, 1348
surface anatomy, 136, 1348, 1350
rhinalis, 622
transverse, 672
of medulla oblongata, anterior median, 544
posterior median, 545, 549
of medulla spinalis, antero-median, **523**, 524
development, 523
of skull—
nasal. *See* Slit
orbital, inferior, 134, **135**
relation to pterygo-palatine fossa, 142
seen in infratemporal fossa, 141, 144, 147
in orbit, 134, 135
superior, 134, **135**, 203
seen in orbit, 134, 135
inside skull, 157, 159, 163
variation, 206
petro-basilar, 200
petro-squamous, 200
petro-tympanic, **152**, 198
level, 828
pterygoid, 205
pterygo-maxillary, 141, 142
tympano-mastoid, 140, 151, 198
Fistula in ano, 1422
Fistulæ thyreo-glossæ, 1372
Fixation of bladder, 1268
of kidney, 1248
of liver, 1188
of muscles, 367
Flat bones, 85
Flexion at joints, 305
Flexure of brain, cephalic, 78, 515
cervical, 78, 515
pontine, 516
results of, 553
of colon, 1209, 1210
level, 1433
surgical anatomy, 1404, 1405, **1413**, **1430**
left, 1210
right, 1209
sigmoid, 1211, 1213
duodeno-jejunal, 1180
adherent to mesocolon, 1156
surgical anatomy, 1405, 1410
of rectum, lateral, 1214, 1216, **1217**
perineal and sacral, 1214
development, 1240
Flocculus of cerebellum, 575
development, 571
relation to cochlear nuclei, 602
Floor of cranial cavity, 155
of mouth, 1103, 1104
of nose, 133, 145, **169**, 798
of orbit, 135
of temporal fossa, 138, 139, 153
of fourth ventricle, 545, 551
Floor-plate of spinal medulla, 40
Fluid, amniotic, 59, 68
cerebro-spinal, 519, 669, **1011**
lacrimal, 134
subarachnoid, 519, 669, **1011**
subdural, 668
Fœtus, 81. *See also* **Embryo**
appendages, 58
circulation, 1050
development, 7
estimation of age, 82
length and weight, 81, 82
membranes, 58
nutrition, 25, 58
Folds. *See also* **Plicæ**
alar, of knee, 350
ary-epiglottic, 1065, **1068**, 1069
development, 1098
in laryngoscopic examination, 1076
in pharyngeal wall, 1141
when swallowing, 1072
"bloodless." *See* **F.**, ileo-cæcal
cæcal, 1208
cephalic or head, 42
gastro-pancreatic, 1164, 1177, 1228
glosso-epiglottic, **1067**, 1121
in laryngoscopic examination, 1076
nerve supply, 698
gluteal, 247, 417
surgical anatomy, 1449
ileo-cæcal, and ileo-colic, 1208
labio-scrotal, 1311, 1317
lateral, of embryo, formation, 42
malleolar, of ear, **829**, 834
surgical anatomy, 1356
mesenterico-mesocolic, 1179
of nates. See **F.**, gluteal
neural, 27, 28, 78
formation of, 35
relation to embryonic area, 28
patellar, synovial, 265, **350**
pharyngo-epiglottic, **1067**, 1121
recto-uterine, 1226, 1300
recto-vaginal, 1300
sacrogenital, 1268, 1277, 1300
salpingo-palatine, 832, **1138**
salpingo-pharyngeal, 832, **1138**
semilunar, of Douglas. *See* **Linea** semicircularis
synovial patellar, 265, **350**
tail, 42
transverse, of rectum, 1215, 1219
surgical anatomy, 1423
utero-vesical, 1300
ventricular, 1068, **1069**
in laryngoscopic examination, 1076
vestigial, of pericardium, 868, **878**
vocal, 1068, 1069, **1070**, 1074, 1075
absence of glands, 1072
development, 1098
epithelium of, 1071
level, 1433
in laryngeal paralysis, 1073
in laryngoscopic examination, 1076
muscles acting on, 1072
in thyreotomy, 1379
Folia of cerebellum, 579
linguæ, 1122
Follicle, hair, 853
nerve endings in, 856
lingual, 1120
of lymph glands, 1003

Follicle—*continued*
- ovarian, primary (Graafian), 15, 1315
  - vesicular, **15**, 16, 1296
    - rupture of, 18
- tooth, 1233

Fontanelle, antero-median or frontal, 130, 183, 1348
- antero-lateral or sphenoidal, 184
- metopic, 191
- postero-lateral or mastoid, 184, 296
- postero-median or occipital, 184
- sagittal, 130, 184, 192

Fonticulus. *See* **Fontanelle**

Foot, 248
- arches, **287**, 359, **364**, 437
- arteries, 958, 961
- bones, 248, **275**
- compared with hand, 294
- eversion and inversion, 280, 364
- fascia, 423
- incisions, 1459
- joints, 356
- lymph vessels, 1022
- mechanism and movements, 280, 364
- muscles, 427, 432, 433
- nerves, 754, 760, 761, 762, 763, 764
- resting on ground, 277, 287
- surgical anatomy, 1457
- veins, 996, 997, 998

Foramina, 87
- apicis dentis, 1109
- cæcum of medulla oblongata, 545
  - of skull, 155, 157, 190, 206
  - of tongue, 1119, 1332, 1372
    - development, 49, 1236
- carotico-clinoid, 158, 206
- carotid. *See* **F.**, lacerum
- centrale (of internal meatus), 838
- of cribriform plate, 157, 174
- epiploic, 1155, 1223, **1227**
  - development, 1240
- ethmoidal, 136, 157
- of Huschke, 826
- incisive, 144, **145**, 213
- infra-orbital, **133**, 134, 136, 211
  - surgical anatomy, 1366
- interventricular, 543, 544, 609, **615**, 630
  - development, 41, 606, 618
- intervertebral, 95, 108
- jugular, 150, 166
  - level, 151
  - relation to aqueduct, 168
  - seen from below, 149, **150**
    - inside skull, 163, 164, 165, **166**
- lacerum, 148, 159, **161**
  - origin of cartilage in, 188
  - seen from below, 148, 150, 151
    - inside skull, 158, 159, **161**, 163
- of Magendie. *See* **Apertures** of fourth ventricle
- magnum, 30, 125, **148**, 195
  - in child, 185
  - level, 141, 150, 151
  - relation to mastoid process, 141
  - seen from below, 142, 148
    - inside skull, 163, 164
- mandibular, 129, 147, **179**, **180**
- mastoid, **136**, 137, 165, 199
  - diploic vein in, 976
- mental, 178, 179
  - at birth, 180, 184
  - surgical anatomy, 1366

Foramina—*continued*
- nervosa of cochlea, 843
- nutrient, 86, 91
- obturator, 248, 251, **254**, 259
  - from behind, 254
  - in female, 258
- occipitale magnum. *See* **F. magnum**
- oculo-motor, 680
- optic, 134, **136**, **158**, 203
  - relation to sinuses, 176
  - seen in cranial cavity, 155, 157, **158**
    - in orbit, 134, **136**
  - variations, 206
- ovale of heart, 870, 871
    - primary and secondary, 1034
    - closure, 1034
    - development, 1034
    - patent, 876, 1035
  - *of skull*, 141, **147**, **159**, 204
    - in needling mandibular nerve, 1367
    - relation to auditory tube, 152
    - seen from below, 146, **147**, 151, 152
      - inside skull, 159, 163
    - variations, 206
- palatine, greater, 144, **145**, 213, 214, 215
    - surgical anatomy, 1376
  - lesser, **145**, 146, 215
- papillaria of kidney, 1252
- parietal, **130**, 136, 154, 184, 191
  - variations, 192
- pterygo-spinous, 206
- rotundum, 142, **159**, 163, 204
  - relation to cartilaginous cranium, 187
  - variations, 206
- sacral, anterior, 102, **105**, 106
  - posterior, 103, **106**
- of Scarpa, 145, 169
- sciatic, greater, 256, 259, 339
  - lesser, 256, 259, 339
- singulare, 200, 840
- spheno-palatine, 141, **142**, 145, 174
  - relation to sphenoidal concha, 205
  - seen in nose, 145, 169, 173, 174
    - in pterygo-palatine fossa, 141, 142
  - variations, 215
- spinosum, 141, **147**, 159, 204
  - relation to auditory tube, 152
  - seen from below, 146, 147, 151, 152
    - inside skull, 159
  - variations, 206
- of Stensen, 145, 169, 213
- stylo-mastoid, **150**, 167, 199
  - absence, 202
- supra-orbital, **132**, 135, 189
  - surface anatomy, 1348
- thyreoid, 1098
- transversarium, 96, 97
  - homology, 112
  - variations, 111, 112
  - vein transmitted in seventh, 969
- venæ cavæ of diaphragm, 473
- venarum minimarum, 870, 871
- of ventriculus quartus. *See* **Apertures**
- vertebral, 94, 95
- of Vesalius, **147**, 161, 204
- zygomatic, 135, 216
- zygomatico-facial, 134, 216
- zygomatico-temporal, 139, 216

Forceps of corpus callosum, 629

Forearm, 217
- arteries, 920, 923
- bones, 217, 230

Forearm—*continued*
  fascia, 384, 385
  incisions, 1448
  joints, 328
  lymph glands, 1015
  lymph vessels, 1017
  movements, 237, 294, 327, 330
  muscles, 388
  nerves, 733, 734, 737, 738, 740, 741, 742
  in supination and pronation, **237,** 330
  surgical anatomy, 1445
  veins, 985
Fore-brain, 515, 606
    development, 38, 606
  primitive, 38
  secondary, 38
    derivatives, 38
Fore-gut, 46
  derivatives, 46, 1232
  formation, 42
Forehead, 130, 132, 138
  at birth, 185
  in women, 186
Form of muscles, 366
Formatio hippocampalis, 622
    function, 625
  reticularis alba et grisea, 564
    of medulla oblongata, 560, 564
    of pons, 567
    of spinal medulla, 525
Formation of chromaffin, 37
  of embryo, 42
  of nerve ganglia, 37
  of notochord, 28
  of primitive nerve sheaths, 37
  of secondary mesoderm, 28
Fornix cerebri, 625
      arterial supply, 904, 905, 908
      development, 38, 625, 626
      in fœtus, 626
      function, 623
    conjunctival, 817, 819
    of vagina, 1305
      surgical anatomy, 1426
Fossæ, 87. *See also* **Pouch**
  acetabular, 254, 259
  cæcal, 1208
  canine, 133, 211
  cerebellar, 165
  cerebral, posterior, 165
    asymmetry, 196
  cerebri lateralis, 621
  cloacal, ectodermal, 1311
  condyloid, 149, 194
  coronoid, of humerus, **227**, 229, 231
  cranial, 125
    anterior, 125, 134, **155**
      relation to ethmoid sinuses, 176
        to nose, 168
    middle, 125, 134, 135, 148, **157**
      relation to nose, 168
    posterior, 125, 136, **163**
      relation to vertebral column, 163
  cubital, 384
  digastric, of mandible, 178, 180
  digital, of fibula, 272, 274
  of ductus venosus, 1184
  duodenal, 1178, 1410
  epigastric, 113, 114, 115, 1389
  floccular, 201
  of gall bladder, 1184
  hyaloid, of eye, 813
Fossæ—*continued*
  hypophyseal, 158, 202
    in skiagrams, 1364, 1365
    surgical anatomy, 1364
  hypotrochanteric, 266
  ileo-cæcal, 1208
  incisive, of mandible, 178, 179
    of maxilla, 133, 134, 211
  iliac, **251**, 259
    in female, 258
    structure of floor, 255
  incudis, 828
  infraspinous, 219, 222
  infra-temporal, 134, **141**, 146
    relation to maxillary sinus, 174, 175
  inguinal. *See* Fovea
  intercondyloid, of tibia, 268, 270
  interpeduncular, 542
  intersigmoid, 1213
    surgical anatomy, 1414
  ischio-rectal, 486, 1218
    surgical anatomy, 1422
  jugular, of temporal bone, 151, 199
    at birth, 201
    relation to ear, 826, 1358
    variations, 202
  for lacrimal gland, 134, 135, 190
      at birth, 185
      variations, 191
  for lacrimal sac, 133, **134**, 135, **136**, 212
    at birth, 185
    relation to nose, 173
  of ligamentum teres. *See* **F.** of umbilical
    vein
  of liver, 1183, 1184, 1186
  mandibular, 150, **152**, 179, 197
    at birth, 184, 201
    level, 148
    relation to spine of sphenoid, 146, 147
      to articular tubercle, 138, 144
      to post-glenoid tubercle, 139
  mastoid, 1359
  navicularis urethræ, 1292
    of vulva, 1308
  olecranon, 227, 229, 231
    variation, 230
  ovalis of heart, 870
    of thigh, 405
      relation to lumbo-inguinal nerve, 751
      surgical anatomy, 1453
  ovarii, 1296, 1301
  paraduodenal, 1178
  pararectal, 1216, 1217, 1227
  paravesical, 1227, 1267
  parieto-occipital, 659
  parotid, 1128
  pharyngeal, 196
  popliteal, 248, 264, 420, 421, 429, 430
    surgical anatomy, 1452
  pterygoid, 127, **146**, 204
    relation to nose, 124
  pterygo-palatine, 128, **141**, 205
    relation to foramen rotundum, 159
      to nose, 171, 173, 174
      to palatine bone, 128
      to palatine canal, 145
      to pharyngeal canal, 146
      to pterygoid canal, 148, 163
  radial, of humerus, 227, 229, 234
  rectovesical. *See* **Pouch**
  retro-cæcal, 1208
    surgical anatomy, 1412

Fossæ—*continued*
  retro-ureteric, 1265
  rhomboidea, 545, 551
  sagittal, of liver, 1183, 1184
  scaphoid, **146**, 147, 204
  subarcuate, 167, 200
    at birth, 201
  sublingual, 178, 180
  submaxillary, 178, 180
  subscapular, 219
  supinator, 231, 233
  supraspinous, 219, 222
  supra-tonsillar, 1138, 1139
    development, 48, 1236
  temporal, 135, **138**, 139
    relation to frontal sinus, 176
      to infra-temporal fossa, 141
      to middle cranial fossa, 158
    thickness of floor, 153
  triangularis of auricle, 823
  trochanteric, 261, 264
  of umbilical vein, 1183
  for vena cava in liver, 1184, 1186
  vermian or vermiform, 164, 196
Fossulæ of internal meatus, 839
  of tonsil, 1139, 1141
Fovea, 87
  bursæ, 196
  centralis of retina, 809
    structure, 812
  femoralis, 1224
  inguinal, lateral, 1224
    medial, 1224, 1227
    supravesical, 1224
  trochlearis, 135, 190
  of ventriculus quartus, inferior, 551
    superior, 552
Foveolæ gastricæ, 1169
  granulares, 154, 190, 192
Fracture of clavicle, 1438
  of femur, 1449
  of humerus, 1443
  of patella, 1455
  of radius, 236, 237
  of scapula, 1439
  of skull, 159, 1349
  of sternum, 1389
  of tibia, 1456
Fracture-dislocation of vertebral column, 1435
Frenulum of clitoris, 1307, 1308
  of colic valve, 1204
  labii, 1103
    superioris, at birth, 1108
  labiorum pudendi, 1307
  linguæ, 1104, 1123
    artery of, 892
    surgical anatomy, 1374
  of prepuce, 1283
  veli, 581
    development, 590
Front of skull, 130
Frontal bone, 124, **125**, 153, 161, **189**
      nasal part, 133
      orbital part, 125, 135, 155
        relation to ethmoid, 176
    seen in cranial cavity, 154, 155
      in front of skull, 130, 132, 133
      in nose, 168
      in temporal fossa, 138
      in top of skull, 129
  at birth, 184, 185, 191
  origin, 188

Frontal bone—*continued*
  ossification, 191
  structure and variations, 191
Frontal plane, 5
  region of skull, 130
    age changes, 185
Functions of cells, acquisition of, and conditions necessary, 11
Fundus of bladder, 1259
  of cæcum, 1203
  of gall-bladder, 1192
  of internal meatus, 839
  of stomach, 1161
    level, 1433
    surgical anatomy, 1407
  of uterus, 1299
Funiculus cuneatus, 548
  gracilis, 548
  separans, 552
  spermatic. *See* **Cord**
  of spinal medulla, 535, 537, 540
      development, 522
    anterior, 524, 526, 537, 540
    antero-lateral, 524, 537
    lateral, 524, 526, 537
    posterior, 524, 526, 535
Furcula, 49, 1098
Furrow. *See also* **Groove** and **Sulcus**
  bicipital, lateral, and medial, 1442
  nuchal, 1387
  sternal, 1389
Fusion of epiphyses, 90

Galea aponeurotica, 136, 139, 150, **446**, 449
Gall-bladder, 1192
  adherent to duodenum, 1155
  artery, 933, 1193
  development, 52, 1242
  lymph vessels, 1031
  nerve supply, 727, 789, 1193
  structure, 1193
  surface and surgical anatomy, 1398, 1404, 1406
  variations, 1193
  veins, 998, 1000, 1193
Gall-stone, 1406
Gametes, **13**, 22, 23
  female, 13, 21
  male, 13, 21
Ganglia—
      of wrist (surgical), 1446
    basal, of brain, 634
    habenulæ, 612
    interpeduncular, 589, 612
    olfactory, 620
  nerve, 500
      in embryo, 44
      formation, 37
      origin, 36
    autonomic, 506
    of cerebral nerves, 3, 681, 683, 687, 691, 693, 696, 697, 700
      origin, 37
    peripheral, 506
    of sensory nerves, 507, 511
      formation, 500
    spinal, 3, **711**
      aberrant, 712
    sympathetic, 3, 506, 507
        connexion with intermedio-lateral column, 532
        development, 37, 792

- **Ganglia**—*continued*
  - nerve—*continued*
    - *sympathetic*—*continued*
          - structure, 777
        - central, 777
        - collateral, 777
        - terminal, 777
      - cephalic, 692
      - cervical, 780, 781, 782, 783
      - lumbar, 785
      - pelvic, 786
      - thoracic, 784
  - acoustic. *See* **G.**, spiral
  - aortico-renal, 785, **789**, 790
  - basal, of brain, 634
  - cardiac, of Wrisberg, 787
    - origin, 37
  - *cervical*, inferior, 97, 148, **780**, **783**
      - level, 1433
      - surgical anatomy, 1390
    - middle, 780, 782
      - surgical anatomy, 1384
    - superior, 151, **780**, 781
  - cervical, of uterus, 1304
  - *ciliary*, 683
    - connexion with sympathetic, 692, 782
    - development, 692, 792
    - origin of efferent splanchnic fibres, 602
    - root, long, 683
      - motor, or short, 680
    - structure, 692
  - coccygeal. *See* **G.** impar
  - cœliac, 785, **789**, 790
    - origin, 37
  - diaphragmatic, 727, 789
  - geniculi, 596, **693**
    - connexion with sympathetic, 782
  - of glosso-pharyngeal, inferior or petrous, 697
      - connexion with sympathetic, 782
    - superior, 697
  - habenulæ, 612
  - impar, 775, **786**
  - interpeduncular, **589**, 612
  - jugular, 698, **700**
    - connexion with sympathetic, 782
  - lumbar, 785
  - mesenteric, superior, 790
  - nodosum, 698, **700**
  - olfactory, 620
  - *otic*, 691
    - connexion with spheno-palatine ganglion, 688
      - with sympathetic, 692, 782
    - development, 692, 792
    - origin of efferent fibres, 597
    - structure, 692
  - pelvic, 786
  - petrous, 697
    - connexion with sympathetic, 782
  - phrenic, 727, 789
  - Scarpa's. *See* **G.**, vestibular
  - *semilunar*, 160, **681**
    - blood supply, 897, 898, 902
    - relation to carotid canal, 163
    - surgical anatomy, 1355
  - *spheno-palatine*, 141, 142, **687**
    - connexion with sympathetic, 692, 782
    - development, 692, 792
    - origin of efferent fibres, 597
    - structure, 692
  - spiral, 602, **696**, 838, 845
    - development, 502

- **Ganglia**—*continued*
  - splanchnic, 785
  - stellate. *See* **G.**, cervical, inferior
  - *submaxillary*, 463, **691**
    - connexion with sympathetic, 692, 782
    - development, 692, 792
    - origin of efferent fibres, 597
    - structure, 692
  - thoracic, 784
  - of uterus, cervical, 1304
  - vestibular, 602, **696**, 847
- Gastro-enterostomy, 1409
- Gastroptosis, 1408
- Genealogical tree, 2
- Geneion, 178
- Gennari, stria of, 642
- Genu of corpus callosum, 627, **628**, 631
- Germs, adamant, 1233
  - tooth, 1233
    - permanent, 1235
    - reserve, 1234
- Germ cells, 10, **12**, 22, 23, 25
  - female, 12
  - male, 12, 21
  - non-maturing, 13
- Germinal spot, 17
- Giacomini's banderella, 627
- Gianuzzi's crescents, 1134
- Gill-pouches, 1
- Gills of fish, 2, 862
- Gingivæ. *See* Gums
- Ginglymus, 303
  - lateral, 328
- Girdle-pain, 1401
- **Girdles**, limb, 217, 248
    - compared, 294
    - homologies, 291
  - pelvic, 248
  - primitive, 292
  - shoulder, 217
    - of amphibians, 292
    - of Permian reptiles, 292
- Glabella, **130**, 132, 190, 295, 1348
  - in women, 186
- **Glands**, or **Glandulæ**, 1125
      - structure, 1126
    - acinous, 1126
      - compound, 1126
    - alveolar, 1126
    - clausæ. See **G.**, ductless
    - compound, 1126
    - cytogenic, 1125
    - digestive, 3
    - ductless, 1125, 1126, **1321**
    - epithelial, 1126
    - evehentes, 1126
    - hæmal, **1003**, 1050
    - racemose, 1126
    - salivary, 1127
      - structure, 1133
    - sebaceous, 854
      - development, 855
    - sexual, 12, 13, 1315
    - simple, 1126
    - sudoriferous, or sweat, 851, 854
      - development, 855
      - nerve endings in, 856
    - vasculares, 1126
  - areolar, 1318
  - of Bartholin. *See* **G.**, vestibular
  - biliary (mucous), 1194
  - bronchial, 1097

Glands, or **Glandulæ**—*continued*
  buccal, 1106
  bulbo-urethral, 1271, **1288**
    artery, 945
    development, 1317
    surgical anatomy, 1418
  cardiac, 1169
  carotid, 782, **1325**
    development, 37, 1326
  ceruminous, 826
    in fœtus, 855
  ciliary, 817, 855
    development, 822
  circum-anal, 1220
  Cowper's. See **G.**, bulbo-urethral
  ductless, 1125, 1126, **1321**
  duodenal, 1172, 1175, **1180**
  of fundus, 1169
  gastric, 1169
  genital, or sex, 12, 13, 1315
  hæmal, **1003**, 1050
  Haversian, 343
  intestinal, 1172
  labial, 1105
    surgical anatomy, 1370
  lacrimal, 134, **818**
      accessory and inferior, 819
      superior, 818
    arteries, 819, 898, 903
    development, 822
    nerve supply, 681, 819
    relation to membrane, 802
    surgical anatomy, 1368
    veins, 819
  lingual, 1124
    anterior, 1124
      surgical anatomy, 1373
  lymph. *See* **Lymph glands**
  mammary, 376, **1318**
      arteries, 912, 914, 918, 928, 1320
      development, 1320
      lymph vessels, **1018**, 1320
      nerves, 1320
        Pacinian corpuscles of, 857
      surgical anatomy, 1440
      variations, 1319
      veins, 1320
    male, at birth and puberty, 1320
  molar, 1106
  of Moll. *See* **G.**, ciliary
  œsophageal, 1148
  olfactory, 798
  palatine, 145, 1107, 1108
  parathymic. *See* **G.**, parathyreoid
  parathyreoid, 1332
      internal, 1333
    arteries, 1333
    development, 49, 1333
    structure, 1333
    surgical anatomy, 1380
  para-urethral, female, 1270
      development and homology, 1317
    male, 1289, **1292**
  parotid, 150, 152, 446, 456, 459, **1127**
      accessory, 1128
    arteries, 895, 896, 897, 1131
    fascia, 150, 152, 446, 452, **1130**
    development, 1232
    lymph vessels, **1014**, 1131
    nerves, 690, 1131
    relation to mandible and ear, 180
      to spheno-mandibular ligament, 315

Glands, or **Glandulæ**—*continued*
  parotid—*continued*
    sheath, 446
    surgical anatomy, 1367
    surgical relation to ear, 1356
    veins, 1131
  pineal. *See* **Body**
  prostate. *See* **Prostate**
  of prostate, 1288
  pyloric, 1169
  salivary, 1127
    structure, 1133
  sexual, 12, 13, 1315
  sublingual, 180, 462, 463, 1104, **1132**
    arteries, 892, 893, 1133
    development, 1236
    lymph vessels, 1014
    nerve, 691, 1133
    surgical anatomy, 1374
  submaxillary, 180, 446, 462, 463, **1131**
    arteries, 893, 1132
    development, 1236
    lymph vessels, 1014, 1132
    nerves, 691, 1132
    sheath, 446
    surgical anatomy, 1381
    veins, 1132
  suprarenal, 27, 476, **1327**
        in frogs and elasmobranchs, 1330
        in selachia, 1324
      accessory, 1327
    arteries, 929, 930, 937, 1055, 1328, 1329
    development, 37, 1329
    level, 1433
    lymph vessels, 1032, 1328
    nerves, 727, 789, 1328, 1329
    structure, 1329
    surgical anatomy, 1404, 1430
    veins, 990, 1328, 1329
  tarsal, 816, **817**
    development, 822
  thymus. *See* **Thymus**
  thyreoid, 1330
      accessory, 1331
        development, 1332
    arteries, 886, 887, 891, 911, 1331
    development, 46, 49, **1331**
    lymph vessels, 1014, 1331
    nerve supply, 783, 1331
    sheath, 448
    structure, 1331
    surgical anatomy, 1379
    veins, 970, 971, 1331
  urethral, 1289, **1292**
    female, 1270
      development and homology, 1317
  of uterus, 1303
  vestibular, greater, 1293, **1309**
      lesser, 1308
    development, 1317
    surgical anatomy, 1426
Glans of clitoris, 1308
    end-bulbs in, 857
  penis, 1283
    arteries, 945, 946
    end-bulbs in, 857
    structure, 1284
    veins, 993
"Glenoid," 88, 219
Glisson's capsule, 1190
Globus pallidus, 636

Glomeruli of kidney, 1253, **1254**
  olfactory, 621
Glomus caroticum. *See* **Glands**
  coccygeum, 1325
    artery, 938
    development, 1326
Glottis, 1074
"Gluteal," 247
Gnathic index, 297
Gonion, 296
Goose-skin, 854
Granulations, arachnoid, 154, **670**, 978
Granules, cone, of retina, 811
  rod, of retina, 812
  yolk, 16
Granulocytes, 70
Grinders. *See* **Teeth**, molar
Gristle. *See* **Cartilage**
Groin, 248, 1152
  fascia, 404
  surgical anatomy, 1453
Groove. *See also* **Sulcus**
  for abducent nerve, 158
  arterial, on skull, 154, **159**, 161, 165, 166, 190, 192, 197, 204
  for auditory tube, 200
    on sphenoid, 204
  carotid, 158, 202
    relation to foramen lacerum, 161
  carpal, 238
  costal, 117
  ethmoidal, of nasal bone, 210
  for external maxillary artery, 179
  for flexor hallucis longus on calcaneus, 277
    on talus, 279
    on tibia, 268
  for greater superficial petrosal nerve, 163, 200
  infra-orbital, 134, 135
    relation to maxillary sinus, 176
  inter-atrial, 867
  intertubercular, **226**, 229
    surface anatomy, 1440
  labial, 1232
  lacrimal, 209, 211, 212
  for lacrimal sac. *See* **Fossa**
  for lesser superficial petrosal nerve, 163, 200
  for maxillary artery, external, 179
  for meningeal vessels, 154, **159**, 161, 165, 166, 190, 192
    on sphenoid, 204
    on squamous temporal, 197
  for middle temporal artery, 191, 197
  mylo-hyoid, 129, 179, 180
    origin, 181
  naso-lacrimal, of maxilla, 208
  naso-pharyngeal, 1136, **1138**
  neural, 32, 43, 77
    formation of, 27, 35
    relation to notochord, 29
  for obturator externus on femur, 265
    on hip bone, 259
  for occipital artery, 150, 199
  for olfactory nerves, 169, 172
  optic, 155, **157**, 158, 202
    in skiagram, 1365
  for peroneus longus, 281
  for petrosal nerves, 163, 200
  for petrosal sinus, inferior, 164, 195, 199
    superior, 166, 199
  pharyngeal, 205
  for popliteus on femur, **263**, 265
    on tibia, 271
Groove—*continued*
  primitive, 28, 77
  pterygo-palatine, 205
  for radial nerve, 229
  sagittal, **154**, 165, 190, 192, 194
  for semimembranosus, 268, 271
  sigmoid, 136, 149, 163, **165**, **166**, 194, 199
  subclavian, of clavicle, 225
    of lung, 1092, 1093
  for tibialis anterior, 268
  transverse, of skull, 163, **165**, **166**, 192, 194
  vertebral, 109
Growing end of bone, 90
Growth of bones, 89
  of brain, 513
  of larynx, 1076
  of organs and tissues, 9
  of pelvis, 258
  of skull, 185
Gubernaculum dentis, 1235
  ovarii, 1296
  testis, 1280
Gullet. *See* **Œsophagus**
Gums, 145, 1103, **1109**
  development, 46, 55
  lymph vessels, 1013
Gyri—
  angular, 662
    surgical anatomy, 1350
  breves of insula, 652
  centralis anterior, 661, **663**, 664
      arterial supply, 905
      surgical anatomy, 1349, 1350
    posterior, 660, 661
      arterial supply, 905
  cinguli, 663
    veins, 977
  cunei, 659
  cuneo-lingualis, anterior, 657
  frontal, 663
      arterial supply, 905
    middle, surface anatomy, 132, 1349
  Heschl's. *See* **G.**, temporal, transverse
  lingualis, 657, 659
    arterial supply, 909
  longi of insula, 652
  pararrhinal, 655
  rectus, 663
    arterial supply, 904
    relation to skull, 157
  supra-marginal, 662
    surface anatomy, 130, 1349
  temporal, 654, 655
      arterial supply, 905
    transverse, 653
      connexion with medial geniculate body, 605
      development, 653
  transitional, 661

Habenula. *See* **Ganglion** habenulæ
Hæmal glands, **1003**, 1050
Hæmatocele, pudendal, 1426
Hæmatoma of scrotum, 1421
Hæmocytoblasts, 70
Hæmohistoblasts, 69, 70
Hæmorrhage, cerebral, 1355
  in cleft palate, 1376
  meningeal, 1354
  of scalp, 1347
Hæmorrhoids, 1422
  starting points, 1222

- Hair, 3, 853
    - appearance, 81
    - development, 855
  - gustatory, 849
  - olfactory, 799
- Hallux, 248
- Ham, 248
- Hamate bone, 241. *See also* **Os**
- **Hamulus**, 87, 146
  - lacrimalis, 209
    - variations, 209
  - laminæ spiralis, 839
  - pterygoid, **146**, **147**, 204
    - ossification, 205
    - surgical anatomy, 1376
- **Hand**, 217
    - compared with foot, 294
    - incisions, 1449
    - in pronation and supination, 238
    - surgical anatomy, 1445
  - arteries, 921, 922, 923, 925
  - bones, 217, **238**
  - fasciæ, 385
  - joints, 331, 334
  - lymph vessels, 1017
  - movements, 238, 331, 336
  - muscles, 385, 394
  - nerves, 733, 734, 737, 741
  - veins, 984
- Hand proper, 217
- Handle of malleus, 833
  - seen through tympanic membrane, 1358
- Hare-lip, 1370
- Haustra of colon, 1202
- **Head**, 91
    - arteries, 891 *et seq.*
    - bones, 124
    - development, 42, 46, 53, 186, 497
    - fascia, 446
    - joints, 83, 312, 314
    - lymph glands, 1006
    - lymph vessels, 1011
    - movements, 313
    - muscles, 448
    - myotomes, 188, **497**
    - nerves. *See* **Nerves**, cerebral, and **N.**, cervical
    - surgical anatomy, 1347
    - veins, 970
  - of femur, **260**, 265, 341, 344
    - in female, 258
    - surgical anatomy, 1453
  - of fibula, **271**, 274
    - surgical anatomy, 1455
  - of humerus, 226
    - surgical anatomy, 1439
  - of malleus, 833
  - of mandible, 129, 138, 150, 152, **179**, **180**
    - at birth, 180
    - surgical anatomy, 1366
  - of metacarpal bones, 243
  - of metatarsal bones, 285
  - of phalanges of fingers, 245
    - of toes, 287
  - of radius, 234
  - of rib, 117
  - of scapula, 218, **219**
  - of stapes, 834
  - of talus, 279
  - of ulna, **231**, 233, 236
- Head-fold, 78
- Head-process of notochord, 28
- **Heart**, 3, 115, 119, 861, **866**
        - primitive, 69, 72
      - of birds and mammals, 3
        - homoplasy of, 3
      - in fishes, 862
    - apex, 868
      - bifid, 1036
    - base, 867
    - chambers, 869
    - margins, 869
    - septum, 866, 869, 872, 874
      - in birds and mammals, 3
    - surfaces, 868
  - abnormalities, 876, 1034, 1035, 1036, 1037
  - age changes and capacity, 876
  - development, 69, 72, 1033
  - evolution with lungs, 862
  - level, 1433
  - lymph vessels, 876, **1021**
  - nerves, 701, 782, 784, 876
  - size, 876
  - sounds, 1396
  - structure, 874
  - surgical anatomy, 1394
  - tissues of, 863
  - vascular supply, 876, 884, 885, 964
  - weight, 876
- Helicotrema, 839, 840, 842
- Helix auriculæ, 79, **822**
- Helmholtz's ligaments, 834, 835
- Hemi-anæsthesia, 562
- **Hemispheres**, cerebellar, 541, **574**
    - connexion with vestibular nerve, 603
    - development, 571
    - surgical anatomy, 1353
  - cerebral, 541, 542, **618**. *See also* **Brain** and **Cerebrum**
        - in lowest vertebrates, 625
      - development, 38, 606, 618
      - external configuration, 643
      - formation, 518
      - functions, 518
      - growth, 620
      - structure, 640
    - borders, 643
      - surface anatomy, 155, 161, 165, 1349
    - fissures, 650
    - frontal region, 663
    - medullary centre, 640, 642
    - parietal region, 660
    - poles, 644
    - sulci, 650
    - surfaces, 643
      - arteries, 904, 905, 909
        - relation to membranes, 671
      - veins, 977, 978
- Hepar. *See* **Liver**
- Heredity, 22
- **Hernia**, diaphragmatic, origin, 77
  - femoral, 405, 407, 944, 949, 1151, 1398, 1453
  - inguinal, 478, 485, 1151, 1398
    - varieties, 1399
  - internal, 1410, 1414
  - lumbar, 1428
  - ventral, 1400
- **Hiatus**, 87
  - aorticus of diaphragm, 473
  - of facial canal, **160**, 163, 200
    - at birth, 201
  - interosseus of forearm, 329
  - œsophageus of diaphragm, 473
  - sacralis, 106

Hiatus—*continued*
  semilunaris, 171, **173**, 176, 207, 797
    relation to maxillary sinus, 174
Hilum of dentate nucleus, 576
  of kidney, 1245
    level, 1433
    surgical anatomy, 1414
  of lung, 1093
  of lymph gland, 1002
  of olivary nucleus, 556, 557
  of ovary, 1294
  of spleen, 1343
  of suprarenal gland, 1328
Hind-brain, 163, 515, 516
  development, 38, 553
Hind-gut, derivatives, 52, 1232
  formation, 42
Hip, 247
Hip bone, 94, 247, **249**
    in apes, 298
    in female, 258
  attachments, 259
  epiphyses, 91, 255
  homology, 292
  measurements, 298
  nutrient arteries, 941, 942, 944
  ossification, 254
  proper position, 253
  structure and variations, 255
Hippocampus, 633
    connexion with indusium, 627
      with stria medullaris, 613
    functions, 623
    relation to dentate fascia and cortex, 624
  inversus, 627
  supracallosal, 627
Hirschsprung's disease, 1413, 1423
Histology, definition, 4
Homodynamy, 292, 293
Homologous chromosomes, 12, 13
Homology, 2
    serial, 2, 3
  of accessory processes, 113
  of arches of vertebræ, 112
  of articular processes, 112
  of articular tubercles of sacrum, 106
  of atlas vertebra, 112
  of bulb of urethra, 1309
  of calcaneus, 293
  of capitate bone, 293
  of carpus, 293
  of cerebral nerves, 2
  of clavicle, 2, 292
  of columna vertebralis, 112
  of coracoid process, 292
  of cornua of coccyx and sacrum, 106, 112
  of corpus cavernosum urethræ, 1309
  of costo-transverse lamellæ, 112
  of cuboid bone, 293
  of cuneiform bones, 293
  of cutaneus colli nerve, 727
  of dens epistrophei, 112
  of duct of epididymis, 1298
  of ductuli aberrantes, 1298
  of efferent ducts of testis, 1298
  of epicondyles, 293
  of femur, 293
  of fibula, 293
  of fingers, 293
  of foramina transversaria, 112
  of girdles of limbs, 291
  of great auricular nerve, 727

Homology—*continued*
  of hamate bone, 293
  of hip bone, 292
  of humerus, 293
  of ilium, 292
  of intercostal muscles, 2
  of interosseous arteries, 1057
  of ischium, 292
  of laminæ of vertebræ, 112
  of lateral mass of atlas, 112
  of lateral mass of sacrum, 113
  of lesser occipital nerve, 727
  of ligamentum teres femoris, 324
  of limb girdles, 291
  of lower limb, 3, 292
  of lunate bone, 293
  of mamillary processes, 112
  of median artery, 1057
  of median nerve, 759, 763, 1057
  of metacarpal bones, 293
  of metatarsal bones, 293
  of Müllerian duct, 1272, 1289
  of multangulum majus and minus, 293
  of navicular bone, 293
  of nervus cutaneus colli, 727
  of odontoid process, 112
  of paradidymis, 1298
  of penis, 1308
  of peroneal artery, 1057
  of peroneal nerve, 759
  of phalanges, 293
  of pisiform bone, 293
  of processus vaginalis testis, 1302
  of prostate, 1270, 1317
  of pubis, 292
  of radial artery, 1057
  of radial nerve, 759
  of radius, 293
  of rectus femoris, 293
  of ribs, 2
  of sacrum, 112, 113
  of scapula, 292
  of scrotum, 1306
  of spinal nerves, 2
  of spines of vertebræ, 112
  of superior gleno-humeral ligament, 307
  of supraclavicular nerves, 727
  of talus, 293
  of tarsal bones, 293
  of thumb, 293
  of tibia, 293
  of tibial arteries, 1057
  of tibial nerve, 759, 1057
  of toes, 293
  of transverse processes, 112
  of transverse tubercles of sacrum, 113
  of triceps brachii (long head), 293
  of triquetre bone, 293
  of trochanter minor, 293
  of tubercle of navicular, 294
  of tubercles of humerus, 293
  of tubercles of sacrum, 112, 113
  of ulna, 293
  of ulnar artery, 1057
  of ulnar nerve, 759, 764, 1057
  of upper limb, 2, 291
  of uterine tube, 1272
  of vertebræ, 2, 112
Homoplasy, 3
Hook of os hamatum, 242
  surface anatomy, 238
Horizontal plane, 5

Horn. *See* **Cornu**
Horse-shoe kidney, 1254
Hough, 248
Hour-glass stomach, 1164
Housemaid's knee, 1454
Humerus, 84, 217, **225**
  attachments, 229
  compared with femur, 300
    with radius, 299
  epiphyses, 90, 230
  fracture, 1443
  homologies, 293
  nerve supply, 733
  nutrient artery, 918, 920
  ossification, 230
  in pronation and supination, 226, 237
  structure and variation, 230
  surgical anatomy, 1439, 1443
Humor, aqueous, 815
  vitreous, 814
Hyaloplasm, 8
Hydra, nervous system, 499
Hydrocele, 1400
Hydronephrosis, secondary, 1416
Hymen, 1306, **1308**
  development, 1316
Hyoid bone, 91, 124, **182**
  movements, 182, 461, 463, 467
  origin, 49
  surgical anatomy, 1378, 1381
Hyper-extension of toes, 285
Hypertrophy of bladder, 1420
  of prostate, 1419, 1420
Hypochondrium, 1152, 1401
Hypogastrium, 1152, 1402
Hypophysis cerebri, 607, **613**, 1337
      arteries, 902, 1338
      development, 39, 53, 606, 614, 1339
      lymph vessels, 1339
      nerves, 782, 1339
      structure, 1339
      veins, 1338
    relation to skull, 158
      to sphenoidal sinus, 177
    surgical anatomy, 1364
  pharyngeal, 1137
Hypothalamus, 586, 607, **611**
  connexion with corpus striatum, 637
  development, 39, 606
  function, 518
Hypothenar, 394
Hypsicephaly, 296
Hysterectomy, 1414

Ileo-sigmoidostomy, 1414
Ileum, 1198
  arteries, 934, 935, 1172
  connexion with cæcum, 1156
  development, 52, 1238
  kinking, 1411
  lymph glands, 1028
  lymph vessels, 1031, 1172
  nerves, 791, 1172
  structure, 1171, 1201
  surgical anatomy, 1410
  usual position, 1200
  veins, 1000, 1172
Ileus, 1404
Ilium, **249**, 259
  effect of erect position, 259
  in female, 258
  homology, 292
Ilium—*continued*
  nutrient arteries, 941, 942, 944
  ossification, 254
Impressions—
  of brain, petrous, 644
  of liver, cardiac, 1182
    colic, 1186
    duodenal, 1186
    gastric, 1184
    œsophageal, 1183, 1186
    renal, 1186
    suprarenal, 1186
  of skull, digital, 154, 155, 190, 197
      on sphenoid, 204
    trigeminal, **160**, 163, 200
Incisions, abdominal, 1400, 1406, 1429
  of arm, 1443
  of foot, 1459
  of forearm, 1448
  gridiron, 1401
  of hand, 1449
  of kidney, 1416
  of leg, 1457
  of thigh, 1451, 1454
  of tongue, 1373
Incisura, 87. *See also* **Notch**
  intertragica, 823
  tentorii, 666
  terminalis auris, 823
Inclination of great toe, 287
  of pelvis, 255
Incus, 826, 828, **834**
  development, 57, 181, 835
  movements, 836
  ossification, 835
  seen through tympanic membrane, 1357
  surgical anatomy, 1358
Index (Forefinger), 217
Index-calculator, 298
Indices used in anthropology, 295
  alveolar, 297
  brim, 298
  cephalic, 295
  dental, 298, 1236
  facial, superior, 296
    total, 296
  gnathic, 297
  humero-femoral, 300
  innominate, 298
  intermembral and lumbar, 299
  nasal, orbital, and palato-maxillary, 297
  pelvic, 298
  platyknemic and platymeric, 300
  radio-humeral and sacral, 299
  scapular, 298
  thoracic and tibio-femoral, 299
  vertical, 296
Indusium griseum, 627
"Inferior," definition, 5
Infundibulum of frontal sinus, 173, **176**, 797
    relation to lacrimal bone, 209
      to nose, 174
  of hypophysis, 542, 607, **613**, 614
    development, 39, 606, 614
  of right ventricle, 872
  of uterine tube, 1297
"Inguinal," 248
Inion, 136 295. *See also* **Protuberance**, occipital, external
Inlet of pelvis, 257
Inscriptions, tendinous, **483**, 1398
Insertion of muscles, 365

- Inspiration, 474
- **Insula**, 651
  - connexion with thalamus, 611
  - development, 652
  - relation to claustrum, 638
    - to lentiform nucleus, 635
  - veins, 977
- Integument, common, 849
- Interbrain, 542
- Interfrontal bones, 191
- Intermediate cell tract, derivatives, 34
- "Internal," definition, 5
- Interparietal bone, 184, 196
  - ossification, 195
- Intersections, tendinous, **483**, 1398
- **Intestine**; **Intestinum**, 1170, 1201
  - cæcum. *See* **Cæcum** of intestine
  - crassum. *See* **I.**, large
  - rectum. *See* **Rectum**
  - tenue. *See* **I.**, small
  - arteries, 934, 935, 1172, 1202, 1207
  - development, 52, 1238
  - lymph glands, 1028, 1029, 1199
  - lymph vessels, 1031, 1172
  - nerves, 791, 1172, 1203
  - rotation, 1238
  - structure, 1171, 1201, 1202
  - surgical anatomy, 1404, 1405, 1410, 1411, 1412, 1413, 1430
  - veins, 1000, 1172
  - large, 1201. *See also* **Colon**
    - in child, 1411
  - small, 1170. *See also* **Ileum**, **Jejunum**
    - at birth, 1170
    - usual position, 1200
- Introduction, 1
- Intumescentiæ. *See* Enlargements
- Intussusception, 1411, 1412
- Inversion of foot, 280, 364
- Iris, 808
  - arteries, 809, 903
  - development, 38, 821
- Iritis, 1368
- Irregular bones, 85
- "Ischiadic," 251
- Ischium, 249, **251**, 259
  - homology, 292
  - ossification, 254
- Islands, blood, 69
- Islets of Langerhans, 1198, 1322
  - development, 1243
- **Isthmus** of auditory tube, 831
  - cartilaginis auris, 823
  - of external acoustic meatus, 825
  - faucium, **1109**, 1138
    - level, 1433
  - pharyngo-nasal, 1135
    - closure in swallowing, 1138
    - surgical anatomy, 1374
  - rhombencephali, 515, 516
    - development, 38, 515
  - of thyreoid gland, 1330
    - surgical anatomy, 1379
  - of uterine tube, 1297
- Iter chordæ anterius, 828
- Ivory of teeth, 182, 1110, **1111**
  - development, 1233
  - formation, 1234

- Jaws, 128, 129
  - bones of. *See* **Mandible** and **Maxilla**
- Jejunostomy, 1410
- **Jejunum**, 1198
  - accessory pancreas in, 1198
  - arteries, 934, 935, 1172
  - development, 52, 1238
  - lymph glands, 1028
  - lymph vessels, 1031, 1172
  - nerves, 791, 1172
  - structure, 1171, 1201
  - surgical anatomy, 1410
  - usual position, 1200
  - veins, 1000, 1172
- **Joints**, 83, **301**. *See also* **Articulation** and **Symphysis**
  - classification, 301
  - construction, 303
  - development, 89, 306
  - movements, 305
  - arthrodial, 303
  - bi-axial or condyloid, 303
  - diarthrodial, 303
    - development, 89, 306
  - ellipsoid, 303
  - enarthrodial or ball and socket, 303
  - ginglymus or hinge, 303
  - immovable, and movable, 301
  - multi-axial, and uni-axial, 303
  - trochoid, 303
  - of auditory ossicles, 834
  - of clavicle, 319
  - of coccyx, 311
  - of fingers, 217, **336**
    - end bulbs in, 857
    - surgical anatomy, 1447
  - of foot, 356
  - of girdle, pelvic, 337
    - shoulder, 319, 320
  - of hand, 331, 334
  - of head, 83, 312, 314
  - of incus, 834, 835
  - of larynx, 1065
  - of lower limb, 341
  - of malleus, 834
  - of ossicles, auditory, 834
  - of pelvis, 259, 337
  - of pisiform bone, 333
  - of ribs, 315, 316
  - of skull, 83, 302, 312, 314
  - of stapes, 834
  - of sternum, 319
  - of thorax, 307, 315
  - of toes, 248, **363**
  - of upper limb, 319
  - of vertebral column, **307**, 309, 337
  - acromio-clavicular, 217, 221, 320
    - arteries, 912
    - dislocation, 224
    - movements, 321
    - surgical anatomy, 224, 1439
  - ankle, 248, 279, **353**
    - arteries, 958, 961
    - compared with wrist, 294
    - nerves, 760, 762, 763
    - surgical anatomy, 1457, 1458
  - aryteno-corniculate, 1066
  - atlanto-epistropheal, 311
  - atlanto-occipital, 312
    - level, 150
  - calcaneo-cuboid, 359
    - surgical anatomy, 1458
  - carpal, 331
    - arteries, 925
    - nerves, 742

Joints—*continued*
  carpal—*continued*
      in pronation and supination, 238
    transverse, 332
  carpo-metacarpal, 217, 238, **334**
    of thumb, 242, 244, **334**
  costo-chondral, 317
    surface anatomy, 122, 1389
  costo-transverse, 316
  costo-vertebral, 315
  crico-arytenoid, 1066
  crico-thyreoid, 1065
  cubo-navicular and cuneiform, 360
  cuneo-cuboid and cuneo-navicular, 360
  cuneo-metatarsal, first, surgical anatomy, 1458
  elbow, 217, **325**
    arteries, 920, 921, 924
    compared with knee, 294
    dislocation, 234, 1444
    felt on back of limb, 227
    nerves, 734, 737
    surgical anatomy, 1443, 1444
  hip, 248, 260, **341**, 405, 406, 409, 416, 420
    arteries, 944, 953
    compared with shoulder, 294
    dislocation, 1454
    level, 261
    nerves, 753, 754, 756, 758
    relation to obturator membrane, 340
    surgical anatomy, 1454
    veins, 992
  humero-radial, 325
  humero-ulnar, 325
  intercarpal, 217, **331**
    arteries, 925
    nerves, 742
    in pronation and supination, 238
  interchondral, 119, **317**
  intercoccygeal, 311
  intercuneiform, 360
  intermetacarpal, 217, **334**
  intermetatarsal, 248, 285, **363**
  interphalangeal of fingers, 217, **336**
      end bulbs in, 857
      surgical anatomy, 1447
    of toes, 248, 363
  intertarsal, 248, **356**
    arteries, 959, 961, 962
    nerves, 760, 762, 764, 765
  intervertebral, 83, 307, 309, 337
  knee, 248, **344**, 410
    arteries, 955, 956, 961
    arthrectomy, 1456
    compared with elbow, 294
    effusion into, 1456
    level, 267
    movements, 263, 294, **350**
    nerves, 753, 754, 759, 760, 762
    surgical anatomy, 1454, 1455
    upper limit of cavity, 265
  lumbo-sacral, 337
    transverse, 1438
    variations, surgical bearing, 1436
  mandibular, 129, 158, **314**, 456
    arteries, 896, 897
    level, 148
    nerves, 689, 690
    relation to auditory tube, 152
    surgical relation to ear, 1356
  metacarpo-phalangeal, 217, 243, 244, **335**
      surgical anatomy, 1446
    first, 403

Joints—*continued*
  metatarso-phalangeal, 248, 285, **363**
      nerves, 760
      surgical anatomy, 1459
    fifth, surface anatomy, 287
      surgical anatomy, 1458
  movements, **237**, 294, 330
  phalangeal, of fingers, 217, 336
      end bulbs in, 857
      surgical anatomy, 1447
    of toes, 248, 363
  piso-triquetral, 333
  radio-carpal. *See* **J., wrist**
  radio-ulnar, 217, **328**
      distal, 329
      proximal, 328
  sacro-coccygeal, 310
  sacro-iliac, 103, 249, 251, **337**
    level, 249
    surgical anatomy, 1449
  shoulder, 217, **322**
    arteries, 912, 918
    compared with hip, 294
    connexion with pectoralis major, 373
    dislocation, 1439
    movements, 294, 325
      in pronation and supination, 237, 238
    nerves, 731, 739
    relation to acromion, 220
      to acromial angle, 221
      to coracoid, 222
    surgical anatomy, 1440
  sterno-clavicular, 116, 217, 224, **319**
    arteries, 912, 917
    movements, 321
    surgical anatomy, 1438
  sterno-costal, 317
  talo-calcanean, 356
    surgical anatomy, 1458
  talo-calcaneo-navicular, 357
  talo-crural. *See* **J., ankle**
  talo-navicular, 359
    surgical anatomy, 1459
  tarsal, 356
      arteries, 959, 961, 962
      nerves, 760, 762, 764, 765
    transverse, 280, **359**
  tarso-metatarsal, 248, 285, **361**
      nerves, 760, 764, 765
      surgical anatomy, 285, 1458, 1459
    intermediate and medial, 361
    lateral, 362
  temporo-maxillary. *See* **J., mandibular**
  tibio-fibular, 248
    distal, 353
      nerves, 762
    proximal, 350, 351
      arteries, 961
      nerves, 760, 762
  transverse, of carpus, 332
    of tarsus, 280, **359**
  vertebral, 83, 307, 309, 337
  wrist, 217, 238, **330**, 332
    arteries, 925
    compared with ankle, 294
    movements, 294, 331
      in pronation and supination, 238
    nerves, 734
    surface and surgical anatomy, 234, 1445
  xiphisternal, 115, 120, 319
    level, 115, 121, 1389, 1402, 1433
Juga alveolaria, 21

Jugal point, 139, 142
Jugum sphenoidale, 205
Junction of epiphyses, 90
  sclero-corneal, 804
Junctura ossium, 301

Karyoplasm, 8
Karyo-plasmosomes, 8
Karyosomes, 8
  disappearance, 10
Keratin, and kerato-hyalin, 851
Kerkring's ossicle, 196
Kidney, 473, 476, **1245**
          floating, 1252
          horse-shoe, 1254
          movable, 1416
        artery, 930, 1254
        lymph vessels, 1032, 1254
        nerves, 789, 1254
        veins, 990, 1254
      excision, 1414, 1416
      exposed from behind, 1429
      relation to pleura, 1249
        to suprarenal gland, 1328
    at birth, 1313
    in child, 1252
    development, 1313
    fixation, 1248
    level, 1433, 1434
    movements, 1246
    structure, 1252
    surgical anatomy, 1404, 1405, **1414**, **1428**
    variations, 1252, 1254
  left, 1245, 1248, 1251, 1252
  right, 1245, 1248, 1250, 1252
Kinks of intestine, 1411, 1413, 1414
Knee. *See* **Joint**
Knee cap or pan. *See* **Patella**
Kneeling, 267
Knock-knee, 1455
Knuckles, 217
  surgical anatomy, 1446
Koilorrhachia and kyrtorrhachia, 299
Krause's end-bulbs, 856

Labia or **Labium**, 87. *See also* **Lip**
  oris, 1104
  pudendi, 1306, 1307
      development, 1311, 1315, **1317**
    majus, 486, 1293, **1306**
      arteries, 945, 952, 953, 1307
      lymph vessels, 1023
      nerves, 751, 767, 769, 1307
      veins, 997
    minus, 1293, **1307**
      lymph vessels, 1026
  tympanicum, 843
  vestibulare, 843
  vocale, 1074
Labrum glenoidale, 88
  of hip, 259, **342**
  of shoulder, 222, **322**
Labyrinth of ear, 837, 840
      surgical anatomy, 1361
    membranous, 837, **840**
      development, 55, 847
    osseous, 837
  of ethmoid, 127, 176, **206**. *See also* **Ethmoid Bone**
  of kidney, 1252
Lacertus fibrosus, **383**, 385
  relation to vessels, 919
  surgical anatomy, 1444
Lacrima, 134
Lacrimal bone, 124, 127, **209**
    development, 188
    ossification and variations, 209
  in naso-lacrimal canal, 173
  in nose, 171, 172
  in orbit, 134, 136
  relation to ethmoid, 176
    to maxillary sinus, 175
Lacteals. *See* **Lymph vessels** of intestines
Lacunæ of bone, 84
    of cornea, 805
    of female urethra, 1270
    of male urethra, 1292
  laterales of sagittal sinus, 670, 978
Lacus lacrimalis, 816, 819
Lagena, 842
Lambda, **130**, **136**, 295
  surface anatomy, 1348
Lamellæ, 87
  of bone, 84
      development, 89
    circumferential, 89
    Haversian, 84
    interstitial, 89
  costo-transverse, 97
    homology, 112
  cutis, of mesoderm, 34
Lamina, 87
  alar, of neural tube, 507
    cell columns of, 707
    derivatives—
      in diencephalon, 606
      in mesencephalon, 590
      in rhombencephalon, 507, 553
      in spinal medulla, 507, 553
      in telencephalon, 606
    development and function, 41
  basal, of chorioid, 807
    of neural tube, 507
      cell columns of, 707
      derivatives—
        in diencephalon, 606
        in mesencephalon, 590
        in rhombencephalon, 507, 552
        in spinal medulla, 507, 552
        in telencephalon, 606
      development and function, 41
  choriocapillaris, 806
  chorioidea, 619, 622, **631**
    epitheliales of fourth ventricle, 543
  cribriform. *See* Plate
  cribrosa of ear, 167, 200
    of ethmoid. *See* Plate, cribriform
    scleræ, 803
  dental, 1233
  elastic, of arteries, 864
    of cornea, anterior, 805
      posterior, **805**, 808
  fibrocartilaginea interpubica, 339
  fusca of eyeball, 803
  medullary, of lentiform nucleus, 636
    of thalamus, external, 608, 609
      internal, 609
  of neural tube, 507
    cell columns of, 707
    derivatives, 507, 552, 553, 590, 593, 606
    development and functions, 41
  papyracea of ethmoid, 206
  perpendicular, of ethmoid, 169, **206**. *See also* **Ethmoid bone**

- **Lamina**—*continued*
  - pterygoid, 127, 146, 147, 204
    - lateral, 127, 144, **146**, **147**, 204
      - in infratemporal fossa, 141, 146, 147
    - medial, 127, 144, **146**, **147**, 171, 204
      - in nose, 128, 145, 146, 147, 171
  - quadrigemina, 543, 583
  - reticularis of spiral organ, 845
  - spiralis ossea, 838
    - secundaria, 839
  - suprachorioidea, 806
  - terminalis, 606, 607, **614**
    - arteries, 904
    - connexion with corpus callosum, 628
    - development, 38, 606
    - relation to anterior cerebral artery, 904
      - to fornix, 625
  - vasculosa of chorioid, 806
  - of vertebræ, 94, 95, 109
    - homologies, 112
- Laminectomy, 1434
- Langerhans' islets, 1198, 1322
- Lanugo, 855
- Laparotomy, 1400
- Laryngotomy, 1379
- **Larynx**, 3, **1061**
  - at birth, 1076
  - development, 46, 49, 50, 1098
  - growth, 1076
  - in laryngoscopic examination, 1076
  - position at birth, 1062
  - sexual differences, 1071, 1076
  - in swallowing, 182, 467, 1062, 1072
  - aperture. *See* **Aditus**
  - arteries, 465, **891**, **911**, 1378
  - cartilages, 87, 1062. *See also* **Cartilage**
  - cavity, 1068
  - joints, ligaments, and membranes, 1065
  - lymph vessels, 1014
  - mucous membrane, 1071
  - muscles, extrinsic, 460, 465, 466
    - intrinsic, 1072
  - nerves, 700, 701, 1072
- "Lateral," definition, 5
- **Layer** of Henle, 854
  - of Huxley, 854
  - Langerhans', 64
  - mantle and marginal, of neural tube, 41, 503, 707
  - plasmodial or syncytial, of trophoblast, 58, 62, 63
- Leaping, 437
- Ledge, dental, 1233
- **Leg**, 248
  - arteries, 955, 957, 960
  - bones, 248, **267**
  - fascia, 271, 274, 408, 421, 422, **423**
  - incisions, 1457
  - lymph vessels, 1022
  - muscles, 425
  - nerves, 754, 759, 760, 761, 765
  - surgical anatomy, 1456
  - veins, 994, 995, 996, 997
- **Lemnisci**—
  - in superior corpus quadrigeminum, 585
  - **lateral**—
    - formation, 605
    - termination, 605
    - in corpus quadrigeminum inferius, 584
    - in mid-brain, 583, 589
    - in pons, 570, 589
  - **medial**, 556, 648
- **Lemnisci**—*continued*
  - medial—*continued*
    - connexion with superior corpus quadrigeminum, 589
    - decussation, 561
    - formation, 561
    - termination, 589
    - in hypothalamus, 611
    - in medulla oblongata, 564
    - in mid-brain, 586, 589
    - in pons, 568, 570
- Lens crystallina, **814**
  - age changes, 815
  - development, 79, 821
- Leptoprosope, 297
- Leptorrhine, 297
- Leucocytes, 8
- Lien. *See* **Spleen**
- Life, physical basis of, 8
- Life of cells, 12
- Life-history of cells, 9
- **Ligaments**, 83
  - development, 306
  - morphology, 307
  - of acetabulum, 254, 259, 342
  - of ankle joint, 271, 274, 280, **354**
  - of atlas, transverse, 98, 312, 313
  - of auditory ossicles, 834
  - of auricle, 824
  - of bladder, peritoneal, 1266, 1268
    - posterior, 493
  - of carpus, 242, 332
  - of coccyx, 105, 106, 311
  - of cranium. *See* **L.** of skull
  - of elbow, 229, 231, 233, **326**, 401
  - of epididymis, 1272
  - of eyeball, 135, 802
  - of eyelids, 135, 450, **816**
  - of fibula, 270, 271, 274, 351, 352
  - of foot, 278, 280, 281, 282, 284, 286, 287, **356**
  - of girdle, pelvic, 259, 337
    - shoulder, 115, 223, 225, 320, 322
  - of hand, 242, 244, 245, **334**
  - of head of fibula, 270, 274, **352**
  - of hip joint, 259, 264, 342
  - of knee joint, 265, 267, 270, 347, 348, 431
  - of larynx, 1065
  - of lateral malleolus, 271, 274, 353
  - of lens, 813
  - of liver, **1188**, 1224
  - of malleus, 834
  - of metacarpus, 245, 334
  - of metatarsus, 286, 363
  - of ovary, 1294, **1295**, **1301**
    - morphology, 1280
  - of pelvis, 259, 337
  - of pubis, 260, 483
  - of radio-ulnar joints, 233, 236, **328**
  - of ribs, 100, 109, 117, 122, **316**
  - of scapula, 219, 220, 223, 320, 322
  - of shoulder girdle, 115, 223, 225, 320, 223
  - of shoulder joint, 222, 229, 322
  - of skull, 83, 97, 98, 147, 148, 150, 152, 153, 154, 301, 311
  - of sutures, 83, 153, 154, 301
  - of tarsus, 278, 280, 281, 282, 284, 354, 356
  - of tibio-fibular joints, 270, 274, 351
  - of uterus, anterior, 1300
    - *broad*, 491, 1227, **1301**
      - nerve supply, 791
      - surgical anatomy, 1425

Ligaments—*continued*
of uterus—*continued*
cervical and lateral, 1301
posterior, 1300
round, 476, 478, 484, **1301**, 1307
arteries, 931, 943, **948**
morphology, 1280
surgical anatomy, 1425
of vertebral column, 95, 96, 97, 98, 102, 105, 109, **307**
of wrist, 233, 236, 242
of wrist-joint, 330
accessory, atlanto-epistropheal, 311
plantar, 286, 287, **363**
volar, 244, 245, 335
relation to sesamoids, 247
acromio-clavicular, 223, 225, **321**
alar, of dens, 98, 148, 149, **313**
development, 123
annular, of radius, 233, 234, 236, 326, **328**, 401
of stapes, 827, 835
apicis dentis, 98, 148, **313**
development, 123
arcuate, middle, 473
of pubis, 256, **340**
arteriosum, 880, 882
development, 1038
axis, of malleus, 835
bifurcatum, 278
calcaneo-navicular part, 359
of Bigelow. *See* **L.**, ilio-femoral
broad, of uterus, 491, 1227, **1301**
nerve supply, 791
surgical anatomy, 1425
calcaneo-cuboid, 278, **359**
calcaneo-fibular, 274, 278, **354**
calcaneo-metatarsal, 425, 434
calcaneo-navicular, plantar, 278, 282, **358**, 431, 432, 433
relation to talus, 279
surgical anatomy, 1459
calcaneo-tibial, 355
carpal, *dorsal*, 233, 236, 242, 385, **386**, 399
morphology, 307
radiate, 332
transverse, 238, 242, **385**, 388, 395, 396, 397
morphology, 307
volar, 242, 386
carpo-metacarpal, 242, 244, **334**
cervical, of uterus, 1301
check, of dens, 98, 148, 149, **313**
development, 123
of eyeball, 135, 802
collateral, carpal, 242, **333**
carpo-metacarpal, ulnar, 244
of elbow, radial, 229, **327**, 399, 401
ulnar, 229, 233, **326**, 391
intercarpal, 242, 333
of knee, fibular, 265, 274, 346, **347**, 349
morphology, 307
surgical anatomy, 1455
short, 348
tibial, 265, 271, 346, **347**, 349, 408, 415, 423
morphology, 307
metacarpo-phalangeal, 245, **335**
metatarso-phalangeal, 286, **363**
of patella, 346, 404, 406, 410, **423**
of phalanges of fingers, 245, 336
of toes, 287, 364

Ligaments—*continued*
collateral—*continued*
of wrist, radial, 236, 242, 330, 333, 403
relation to radial artery, 922
ulnar, 233, 242, 330, 333
colli costae, 100, 109, 117, 122, **317**
conjugate, of ribs, 316
conoid, 224, 225, **321**
coraco-acromial, 222, 223, **322**, 374, 377, 378
coraco-clavicular, 222, 223, 224, 225, **321**
coraco-glenoid, 324
coraco-humeral, 223, 229, **324**, 374
morphology, 307, 374
corniculo-pharyngeal, 1066
coronary, of knee, 350
of liver, 1188, 1189, 1225
development, 77, 1242
costo-clavicular, 119, 122, 225, **320**, 375
function, 321
costo-coracoid, 373
costo-transverse, anterior, 100, 109, 117, 122, **316**
posterior, 317
costo-xiphoid, 318
crico-thyreoid, **1067**, 1073
surgical anatomy, 1379
crico-tracheal, 1064
cruciate, of atlas, 148, 164, **313**
of knee, 262, 348
arteries, 957
anterior, 265, 270, **348**
posterior, 265, 270, **349**
of leg, 271, 278, **424**
cubo-navicular, 360
cuneo-cuboid, dorsal and plantar, 360
interosseous, 361
cuneo-metatarsal, 361
cuneo-navicular, 360
deltoid, 268, 271, 278, 280, 282, **354**
denticulatum, **519**, 670, **673**
falciform, of liver, **1188**, 1224
artery in, 914
development, 77, 1042, 1240, 1242
surgical anatomy, 1405
fibular, 270, 271, 274, 351, 352
flava, 95, 105, 109, 309
development, 123
gastro-colic, **1155**, **1230**, 1409
gastro-lienal. *See* **L.**, gastro-splenic
gastro-phrenic, 1163, 1225
gastro-splenic, **1155**, 1225, 1230, **1231**, 1343
development, 1241
gleno-humeral, inferior and middle, 324
superior, 324
homology, 307
of head of fibula, 270, 274, **352**
of Helmholtz, anterior, 834
posterior, 835
hepato-colic, 1155
hepato-duodenal, **1155**, 1177
hepato-gastric, 1155
hepato-renal, 1225
hyo-epiglottic, 183, 1068
hyo-thyreoid. *See* **L.**, thyreo-hyoid
ilio-femoral, 259, 266, **342**, 412
ilio-lumbar, 102, 109, 260, **338**, 412
inferior, 338
ilio-trochanteric, 342
inguinal, 259, 260, 404, 407, 412, 416, 475, **478**, 480, 481, 484, 485
surface and surgical anatomy, 253, 1453
reflex, 260, **479**, 484

Ligaments—*continued*
- interarticular, 304
    - development, 89, 306
  - of head of rib, 117, 122, 316
  - sacro-coccygeal, 311
  - sterno-costal, 115, **318**
- intercarpal, 242, **332**
- interchondral, 317
- interclavicular, 115, 225, **320**, 447
- intercoccygeal, 311
- intercuneiform, 284, 360
- interosseous, cubo-navicular, 281, **360**
  - cuneo-cuboid, 281, 284, **361**
  - cuneo-metatarsal, 361
  - of carpus, 242, **332**
  - of cuneiform bones, 284, **360**
  - of metacarpus, 244, **334**
  - of metatarsus, 286, **363**
  - sacro-iliac, 105, 260, 337
  - talo-calcanean, 277, 278, 280, **357**
  - tibio-fibular, 268, 271, 272, 274, **353**
- interspinous, 96, 106, 109, **310**
- intertransverse, 96, 109, **310**
- ischio-capsular, 259, **343**
- laciniatum, 271, 278, **423**, 429, 433
  - morphology, 307
- lacunar, 259, 407, 478, 484
- of lateral malleolus, 271, 274, **353**
- latum uteri, 491, 1227, **1301**
  - nerve supply, 791
  - surgical anatomy, 1425
- lieno-renal, **1225**, 1251, 1343
  - development, 1241
- Lisfranc's, 1459
- longitudinal (of vertebræ), anterior, 95, 97, 105, 109, **309**, 312, 316, 447
  - posterior, 95, 105, 109, **309**, 313
- lumbo-costal, 109, 122, **317**
- lumbo-sacral, lateral, 105, 109, 337, 412
- of Meckel, 834
- metacarpal, dorsal, interosseous, and volar, 244, 334
  - transverse, 335
      - relation to interossei, 398
    - superficial, 385
- metacarpo-phalangeal, 244, 245, 335
- metatarsal, dorsal, interosseous, and plantar, 286, **363**
  - transverse, 363
    - connexion with adductor hallucis, 435
    - connexion with plantar aponeurosis, 424
    - relation to interossei, 436
      - to lumbricales, 432
    - surgical anatomy, 1459
- metatarso-phalangeal, 286, 287, 363
- of neck of rib, 100, 109, 117, 122, **317**
- nuchæ, 96, 109, 150, **310**, 439, 442
- oblique popliteal. *See* **L.**, popliteal
- obturatorium atlanto-epistrophicum anterius, 311
  - posterius, 312
- ovarian, 1294, **1295**, **1301**
  - morphology, 1280
- palpebral, lateral. *See* **Raphe**
  - medial, 135, 450, **816**
    - surgical anatomy, 1368
- patellæ, 263, 267, 271, **347**, 410, 423
    - surgical anatomy, 1454
  - collateral, 346, 404, 406, 410, **423**
- pectinatum iridis, 805, 808
- perineal, transverse. *See* **L.**, transverse, of pelvis

Ligaments—*continued*
- petro-sphenoidal, 692
- phrenico-colic, **1210**, 1231, 1343
  - surgical anatomy, 1413
- piso-hamate, 242, **333**, 389
- piso-metacarpal, 242, 245, 333, 389
- plantar, long, 278, 281, 286, **359**, 432
- popliteal, arcuate, 347
  - oblique, **347**, 423, 429
    - morphology, 307
- pterygo-mandibular. *See* **Raphe**
- pterygo-spinous, 147, 204, **315**
- pubic, anterior, 339
  - posterior and superior, **340**
- pubo-capsular, 259, **343**
- pubo-prostatic, 260, 492, 1268, **1287**
- pulmonary, 1085
- pyloric, 1167
- quadratum of elbow, 233, 236
- radiate, of carpus, 332
  - of head of rib, 109, 117, 122, **316**
  - sterno-costal, 318
- radio-carpal, dorsal, 236, 242, **331**
  - lateral and volar, 236, 242, **330**
- radio-ulnar, 233, 236, **329**
- round, *of femur*, 259, 261, 264, 343
    - arteries, 944, 953
    - homology, 324
    - morphology, 307, 344
  - *of liver*, **999**, 1184, 1188, **1189**
    - in abdominal incisions, 1400
    - development, 1044
    - surgical anatomy, 1405
  - *of uterus*, 476, 478, 484, **1301**, 1307
    - arteries, 931, 943, **948**
    - morphology, 1280
    - surgical anatomy, 1425
- sacro-coccygeal, 105, **310**
  - interarticular, 311
- sacro-iliac, anterior, 105, 337, 412
  - interosseous, 105, 337
  - posterior, 440, 444
    - long and short, 106, 337
- sacro-spinous, 105, 106, 255, 256, 259, 260, **338**
  - effect on sacrum, 259
  - functions, 341
  - morphology, 260, 339
- sacro-tuberous, 105, 106, 255, 256, 260, **338**, 489
    - artery piercing, 946
    - nerves piercing, 718, 767, 768
  - connexions, 259
    - with biceps femoris, 421
    - with gluteus maximus, 259, 417
    - with piriformis, 259, 260, 419
  - effect on sacrum, 259
  - functions, 341
  - morphology, 338
  - in pelvic outlet, 257
- spheno-mandibular, 141, 147, 180, **314**, 458
  - development, 181
  - felt in mouth, 1103
  - morphology, 307
- spirale cochleæ, 842
- spring. *See* **L.**, calcaneo-navicular, plantar
- sterno-clavicular, 115, 225, **320**
  - anterior, 320
  - posterior, **320**, 460
- sterno-costal, 115, 122, **318**
- sterno-pericardial, 115, 877

Ligaments—*continued*
  stylo-hyoid, 150, 183, **315**, 464
    development, 183
    morphology, 307
  stylo-mandibular, 150, 180, **315**, 447, 1130
    morphology, 307
  subflavum, 391
  subpubic, 340
  supraspinous, 96, 106, 109, **310**
  suspensory, of clitoris, 1308
    of dens, 98, 148, **313**
      development, 123
    of eyeball, 135, **802**
    of lens, 813
    of mamma, 1440
    of ovary, 1295, 1301
      surgical anatomy, 1426
    of penis, 1284
    of thyreoid gland, 1330
  sutural, 83, 153, 154, 301
  talo-calcanean, 278, 280, **356**, **357**
  talo-fibular, anterior, 274, 280, **354**
    posterior, 274, 280, **354**
  talo-navicular, dorsal, 280, 359
  talo-tibial, 271, 280, **354**, **355**
  tarsal, of eye, lateral, 816
  tarso-metatarsal, 281, 284, **361**, **362**
  temporo-mandibular, 139, 153, 180, **314**
  teres. *See* **L.**, round
  thyreo-epiglottic, 1065, **1068**, 1074
  thyreo-hyoid, 183, **1066**
  tibio-fibular, 270, 274, 351
  tibio-navicular, 355
  transverse, of acetabulum, 254, 259, **342**
    of ankle joint, 271, 274, 353
    of atlas, 98, **312**
    of humerus, 229, **323**
    of knee, 350
    of leg, 271, 274, **424**
      morphology, 307
    metacarpal, 335
        relation to interossei, 398
      superficial, 385
    metatarsal, 363, 1459
      connexion with adductor hallucis, 435
        with plantar aponeurosis, 424
      relation to interossei, 436
        to lumbricales, 432
    of pelvis (or perineal), 340, 489
    of scapula, inferior, 220, 223, **322**
      superior, 219, 223, **322**
  trapezoid, 224, 225, **321**
  triangular, of liver, left, 1189, 1225
    right, 1189
  of tubercle of rib, 100, 109, 117, 122, **317**
  ulno-carpal, medial, 233, 242, **330**
  umbilical, lateral, 940, 942, 1224
      development, 1041
      relation to distended bladder, 1264
      relation to ductus deferens, 1276, 1277
    middle, 1223, 1259
      arteries, 942
      development, 52, 53, 1314
  utero-sacral, 1300
  utero-vesical, 1268, 1300
  vaginal, 1280
    of fingers, 387
    of toes, 425
  venæ cavæ sinistræ, 868, 878
  venosum, 999, 1184, **1190**
    development, 1044
  ventricular, 1064, **1067**, 1070

Ligaments—*continued*
  vocal, 1065, **1067**, 1070, 1074
  Y-shaped, 259, 266, **342**, 412
Ligula, 87
Limb buds, 44, 290
Limb girdles, 217, 248
    compared, 294
    homologies, 291
  pelvic, 248
  primitive, 292
  shoulder, 217
    in amphibians and Permian reptiles, 292
Limbs, 217, 247
    comparison, general, 294
      of length, 299
    development and morphology, 44, 290
    at different periods of development, 78 *et seq.*
    plan of innervation of muscles, 772
      of skin, 771
    serial homology, 3, 291
  lower, 247
      at birth, 258
      brachyknemic and dolichoknemic, 299
      development, 44, 290
      homology and morphology, 290
      movements, 437. *See also* **Movements**
    arteries, 942, 943, 946, 947, 1041, 1057
    bones, 247
    fascia, 404, 423
    joints, 341
    lymph glands, 1021
    lymph vessels, 1022
    muscles, 407
    nerves, 749, 757
    surgical anatomy, 1449
    veins, **993**, 1041, 1058
  upper, 217
        right compared with left, 4
      brachykerkic, dolichokerkic, and mesatikerkic, 299
      development, 44, 290
      homologies, 2, 291
      morphology, 290
      movements, 404. *See also* **Movements**
    arteries, 909, 1041, 1056
    bones, 217
    fascia, 368, 372, 376, 381, 385
    joints, 319
    lymph glands, 1015
    lymph vessels, 1017
    muscles, 368
    nerves, 723, 727, 744
    surgical anatomy, 1438
    veins, **983**, 1041, 1058
Limbus fossæ ovalis, 870
  laminæ spiralis, 843
    development, 848
Limen insulæ, 621, 652
  nasi, 796
Line or **Linea**, 87
  alba, 115, **477**, 480, 481, 482, 484
    surgical anatomy, 1398, 1401
  ano-cutaneous, 1220
  arcuata = iliac part of **L.** ilio-pectinea
  aspera, 264
    variations, 266
  axial, of limbs, 771
    dorsal, 719
    ventral, 770
  axillary, anterior, 1387
    middle and posterior, 1387

- **Line or Linea**—*continued*
  - base, of skull, 1350
  - epicondylic, of femur, **264**, 265
    - of humerus, **227**, 229
  - epiphyseal, 90
    - of femur, 265
      - surgical anatomy, 1455
    - of radius, surface anatomy, 234
    - of tibia, 271
  - gluteal, anterior, inferior, posterior, 251, 259
  - ilio-pectineal, 253, 260
    - change with erect attitude, 259
    - in pelvic brim, 257
  - incremental, of teeth, 1111
  - infra-temporal, **138**, 139, 141, 144, 147, 204
  - intercondylar, of femur, 265
  - intermediate, of iliac crest, 249
  - intertrochanteric, **262**, 264, 266
  - intertubercular, 1151
  - lateral, of abdomen, 1151
    - of skull, 1350
    - sternal, 1387
  - mammary, or mid-clavicular, 1087, 1387
  - median, 5
    - of back, surgical anatomy, 1427
    - of neck, surgical anatomy, 1378, 1387
  - mid-sternal, 1387
  - mylo-hyoid, 129, 147, 178, **180**
  - Nelaton's, 1449
  - nuchal, highest, 136, 193
    - inferior, **149**, 150, 193
    - superior, **136**, 137, 141, 149, **150**, 193
  - oblique, of mandible, **178**, 179
    - of skull, 1350
    - of thyreoid cartilage, 1063
  - para-sternal, 1387
  - pectineal, **253**, 259, 260
  - of pleural reflexion, 1086, 1087
      - surface anatomy, 1392
    - diaphragmatic, 1085, **1087**
    - sternal and vertebral, 1084, 1085, **1086**
  - popliteal, of tibia, **270**, 271
  - post-central, 1350
  - pre-central, 1350
  - scapular, 1389
  - of Schreger, 1111
  - semicircularis, 484
    - surgical anatomy, 1401
  - semilunaris, 483, 484
  - spiral, of femur, 262, **264**
  - splendens, 673
  - subcostal, 1151
  - of tarso-metatarsal joints, 285
  - temporal, 132, **138**, **139**, 190, 191
    - relation to brain, 1349
  - terminalis. *See* Brim of pelvis
  - transverse, of sacrum, 104
    - of sternum, 114
  - trapezoid, 224, 225
  - vertical, of tibia, 270, 271
  - white, of anus, 1220
- Lingua. *See* **Tongue**
- **Lingula**, 87
  - of cerebellum, 550
  - of mandible, 179, 180
  - of sphenoid, 159, 161, 163, 204
    - chondrification, 187
- Linin, 8
  - reticulum, 10, 11
    - of oöcyte, 16
      - mature, 19
- **Lips** of iliac crest, **249**, 259
  - of linea aspera, 264
  - of mouth, 1104
      - at birth, 1232
      - in child, 1105
      - development, 1232
      - surgical anatomy, 1370
    - arteries, **893**, 1105
    - end-bulbs in, 857
    - lymph vessels, **1013**, 1105
    - nerves, 687, 690, 691, 695, 1105
    - tactile corpuscles of, 858
    - veins, 973
  - rhombic, 571
- Liquor folliculi, 15, 1296
  - escape of, 18
- Lisfranc's ligament, 1459
- **Liver**, 3, 4, 70, 114, **1180**
      - bare area, **1186**, 1188, **1190**, 1225
    - development, 52, 77, 1042, 1241
    - fixation, 1188
    - structure, 1190
    - surgical anatomy, 1186, 1404, **1405**, **1430**
    - variations and weight, 1187
  - arteries, 914, 932, **933**, 935, 937, 1191
  - ligaments, **1188**, 1224
  - lymph glands, 1028
  - lymph vessels, 1031, 1192
  - nerves, 727, 789, 1192
  - peritoneum, 1188, 1225
  - sinusoidal tissue, 1042
  - veins, 989, 998, 1190, 1191
- **Lobes**—
  - azygos, of lung, 1094
  - cardiac, of lung, 1096
  - caudate, of liver, 1184, **1185**
    - peritoneum, 1228
  - of cerebellum, anterior, 573
    - axial, 574
  - of cerebrum—
    - *frontal*, 155, 541, **663**
      - connexion with thalamus, 610, 611
      - relation to orbit, 134
        - to parietal bone, 192
        - to sphenoidal sinus, 176
    - *occipital*, 165, 656
      - connexion with lower visual centres, 618
        - with oculo-motor nucleus, 602
        - with thalamus, 610
      - development, 620
      - relation to parietal bone, 192
      - surface anatomy, 1350
    - *parietal*, 660
      - connexion with thalamus, 610
      - relation to parietal bone, 192
    - *temporal*, 158, 541, 653
      - connexion with anterior commissure, 645
        - with thalamus, 611
      - relation to orbit, 135
        - to parietal bone, 192
      - surface anatomy, 1350
  - of glands, 1127
  - glenoid of parotid gland, 1129
  - of hypophysis, 614, 1337
  - of kidney, 1252
  - of liver, caudate, 1184, **1185**
      - peritoneum, 1228
    - left, 1184
    - quadrate, 1184, **1185**
    - Reidel's, 1187
    - right, **1184**, 1186

- **Lobes**—*continued*
  - of lung, 1094
      - correspondence, 1096
    - azygos, 1094
    - cardiac, 1096
    - inferior, 1094
      - level, 1433
    - middle and superior, 1094
  - of mammary gland, 1319
  - olfactory. *See* **Bulb** and **Tract**
    - arterial supply, 904
  - of prostate, 1287
  - quadrate, of liver, 1184, **1185**
  - Reidel's, of liver, 1187
  - of thyreoid gland, 1330
- **Lobules**—
  - of auricle of ear, 129, 822, **823**
  - of cerebellum, 573
    - ansiformis and biventral, 573
    - centralis and lunatus, 573
    - paramedian, 573
  - of cerebrum, paracentral, 661, 663
    - parietal, inferior, 662
        - arterial supply, 905
      - superior, 662
        - arterial supply, 905
  - of ear, 129, 822, **823**
  - of epididymis, 1273
    - development, 1316
  - of glands, 1127
  - of liver, 1190
  - of lung, 1096
  - of mammary gland, 1319
  - of spleen, 1344
  - of testis, 1273
- Locomotion, 437
- Locus cœruleus, 552
- Loins, 94
  - surgical anatomy, 1428
- Long bones, 84
  - growth, 90
- Loop of Henle, 1253
- Lower limb. *See* **Limbs**
- Lower surface of skull, 142
    - posterior region, 147
- Lumbar puncture, 102, 1435
- "Lumbus," 94
- Lunate bone, 240. *See also* **Os**
- **Lungs**, 3, 115, 119, 1061, **1089**
      - apex, 120, 1091
        - level, 118, 1433
        - surgical anatomy, 1390
      - lower border, level, 1433
      - root, 1094
        - level, 1433
        - surface anatomy, 1394
    - in child, 1090
    - development, 46, 50, **1099**
    - evolution, 862
    - in fœtus, 1090
    - growth, 76
    - variations, 1094
  - arteries, 878, 927, 1095, 1097
  - lymph vessels, 1021, 1095
  - structure, 1096
  - surface anatomy, 1390
  - veins, 963, 967, 1095, 1097
  - X-ray examination, 1097
- Lung-unit, 1096
- Lunulæ of nails, 852
  - of semilunar valves, 873
- Lymph, 861, 1001
- Lymph capillaries, 861
- Lymph channels of cerebrum, 1011
- Lymph cords, 1003
- Lymph corpuscles, 1001
- Lymph duct, left, 1032
  - right, 1001, **1006**
    - abnormalities, 1032
- Lymph follicles, 1003
- **Lymph glands**, 3, 1001, **1002**
        - deep and superficial, 1002
        - hæmal, 1003
      - blood-vessels, 1003
      - development, 1050
      - function, 1001
      - structure, 1003
    - of abdomen, anterior wall, 1023, 1029
      - interior, 1027
    - of arm, 1015
    - of axilla, 1016
      - surgical anatomy, 1441
    - of bladder, urinary, 1023
    - of cæcum, 1028
    - of colon, 1029
    - of duodenum, 1027, 1028
    - of elbow, 1015
    - of face, 1007
    - of forearm, 1015
    - of head, 1006
    - of intestines, 1028, 1029, 1199
        - during digestion, 1002
    - of liver, 1028
    - of lower limb, 1021
    - of neck, 1008
    - of pancreas, 1028
    - of parotid gland, 1006
    - of pelvis, 1023
    - of stomach, 1027
    - of thorax, 1018
    - of tracheal bifurcation, 1020
    - of upper limb, 1015
    - of vermiform process, 1028
  - ano-rectal, 1023
  - appendicular, 1028
  - auricular, anterior, 1006
      - surgical anatomy, 1367
    - inferior, 1008
    - posterior, 1006
  - axillary, 1016
      - surgical anatomy, 1441
    - anterior, 1016
    - central, 1017
    - lateral and posterior, 1016
  - biliary, 1028
  - brachial, 1015
  - bronchial, 1020
    - arterial supply, 927
    - X-ray examination, 1098
  - broncho-pulmonary, 1020
  - buccinator, 1007
  - cervical, 1008
      - surgical anatomy, 1376, 1377, 1382, 1385
    - anterior, 1009
    - deep, 1010
      - inferior, 1011
    - superficial, 1008
    - superior, 1010
  - circumflex iliac, 1023
  - cœliac, 1029
  - coronary. *See* **L. g.**, gastric, left
  - cubital, 1015
    - surgical anatomy, 1442
  - cystic, 1028

- **Lymph glands**—*continued*
  - delto-pectoral, 1017
  - epicolic, 1029
  - epigastric, inferior and superior, 1023
  - facial, deep, 1007
    - superficial, 1006
  - gastric, 1027
    - left (anterior and posterior), 1027
    - right and superior, 1027
  - gastro-epiploic, right, 1028
  - gluteal, 1025
  - hæmal, 1003
  - hæmorrhoidal, middle, 1025
    - superior, 1024
  - hepatic, 1028
  - hypogastric, 1025
  - ileal, 1028
  - ileo-colic, anterior and posterior, 1028
  - iliac, circumflex, 1023
    - common and external, 1025
  - infra-clavicular, 1017
  - infra-hyoid, 1009
  - infra-orbital, 1007
  - inguinal, 404, **1021**
  - intercostal, 1018
  - inter-iliac, 1025
  - inter-pectoral, 1017
  - inter-tracheo-bronchial, 1020
  - lingual, **1008**, 1014
  - lumbar, 1029
    - arterial supply, 930, 931
  - mediastinal, anterior, 1019
    - posterior, 1020
  - mesenteric, **1028**, 1199
      - arterial supply, 935
      - during digestion, 1002
    - inferior, 1029
  - meso-colic, 1029
  - obturator, 1025
  - occipital, 1006
  - pancreatico-lienal, 1028
  - para-aortic, 1029
  - paracardial, 1027
  - paracolic, 1029
  - paramammary, 1016
  - paramandibular, 1008
  - paratracheal, 1009
  - para-uterine, 1024
  - parotid, 1006
  - pectoral, 1016
  - popliteal, 1022
    - surgical anatomy, 1453
  - pre-aortic, 1029
  - prelaryngeal, 1009
  - pretracheal, 1009
    - surgical anatomy, 1379
  - pubic, 1023
  - pubo-gluteal, 1025
  - pulmonary, 1020
  - pyloric. *See* **L. g.**, gastric, right
  - retro-pharyngeal, 447, 1008
  - sacral, 1024
  - sternal, 1018
  - subaortic, 1024
  - subinguinal, 404, **1021**
      - arterial supply, 952
      - surgical anatomy, 1453
    - deep, 1022
    - superficial, 1021
  - submaxillary, **1008**, 1105
    - surgical anatomy, 1381
  - submental, 1008, 1106

- **Lymph glands**—*continued*
  - submental—*continued*
    - surgical anatomy, 1378
  - subpectoral, 1017
  - subpyloric, 1028
  - subscapular, 1016
  - supra-clavicular, **1011**, 1385
    - surgical anatomy, 1382
  - supra-femoral, 1025
  - supra-mandibular, 1007
  - supra-pancreatic, left and right, 1028
    - middle, 1029
  - supra-umbilical, 1023
  - tonsillar, 1383
  - tracheo-bronchial, 1020
  - umbilical, 1023
  - vesical, 1023
- **Lymph nodules**, 1174
  - aggregated and solitary, 1174
    - in child, 1175
  - of spleen, 1344
  - of stomach, 1169
  - of vagina, 1306
- Lymph plexuses, 1002, 1030
- Lymph sinuses, 1003
- **Lymph trunks**—
  - broncho-mediastinal, **1006**, 1019, 1020
  - collecting, of liver, 1031
  - descending, 1005, 1009
  - intestinal, 1005, 1172
  - jugular, 1006
  - lumbar, 1005
  - subclavian, 1006
- **Lymph vessels**, 3, 861, **1002**
      - abnormalities, 1032
      - development, 1050
      - structure, 1002
    - afferent, 1001
    - deep, 1002
    - efferent, 1001
    - perivascular, 1002
    - superficial, 1002
    - terminal, 1004
  - of abdomen, anterior wall, 1023
    - interior, 1030
    - posterior wall, 1032
  - of acoustic meatus, external, 826, 1012
  - of air sinuses, 1013
  - of anal canal and anus, 1222, 1423
  - of arm, 1018
  - of auditory tube, 1018
  - of auricle of ear, 824, 1012
  - of bladder, urinary, **1026**, 1269
  - of blood-vessels, 866
  - of buttock, 1022
  - of cæcum, 1031, 1207
  - of cheeks, 1013
  - of clitoris, 1023
  - of colon, 1031, 1202
  - of conjunctiva, 818, **1012**
  - of corpora cavernosa, 1023, 1285
  - of diaphragm, 1021, 1032
    - surgical anatomy, 1404
  - digital, of foot, 1022
    - of hand, 1017
  - of ductus deferens, 1026
  - of duodenum, **1031**, 1180
  - of ear, 824, 1002, 1012, 1018
  - of epididymis, 1026
  - of external acoustic meatus, 826, 1012
  - of external genital organs, 1023
  - of eyeball (absent), 803, 1002, 1012

Lymph vessels—*continued*
  of eyelids, 818, **1012**
  of face, 1011, 1012, 1013
  of fingers, 1017
  of foot, 1022
  of forearm, 1017
  of gall-bladder, 1031
  of genital organs, external, 1023
  of gluteal region, 1022
  of gums, 1013
  of hand, 1017
  of head, 1011
  of heart, 876, **1021**
  of hypophysis of brain, 1339
  intercostal, 1021
  of internal ear (absence), 1002, 1012
  of intestines, 1031, 1172
  intracranial, 1011
  of kidney, 1032, 1254
  of labium majus, 1023
  of labium minus, 1026
  of larynx, 1014
  of leg, 1022
  of lips, **1013**, 1105
  of liver, 1031, 1192
  of lower limb, 1022
  of lungs, 1021, 1095
  of mamma, 1018
    in mamma, 1320
  of meatus acusticus externus, 826, 1012
  meningeal, 147, 148, 149, 151, 162, 167, **1011**
  of middle ear, 836, 1012, 1018
  of neck, 1012, 1014
  of nose, 800, **1012**, 1013
    connexion with subarachnoid space, 671
  of œsophagus, **1014**, **1021**, 1148, 1398
  of orbit, 1012
  of ovary, **1026**, 1297
  of palate, 1109
  of palm, 1017
  of pancreas, **1031**, 1198
  of parotid gland, **1014**, 1131
  of pelvis, 1025
  of penis, **1023**, 1285
  of pericardium, 1021
  of perineum, 1022, 1025, 1026
  of pharynx, **1014**, 1143
  of pleura, 1021
  of prostate, 1026
  of rectum, **1026**, 1222
  of salivary glands, 1014
  of scalp, **1011**, 1347
  of scrotum, 1023
  of seminal vesicle, 1026
  of sinuses, 1013
  of skin, 852
  of sole of foot, 1022
  of spleen, **1032**, 1343
  of stomach, **1030**, 1169
  of sublingual gland, 1014
  of submaxillary gland, **1014**, 1132
  of suprarenal gland, 1032, 1328
  of teeth, 1013
  of testis, **1026**, 1274
  of thigh, 1022
  of thorax, 1021
  of thymus, **1021**, 1336
  of thyreoid gland, **1014**, 1331
  of toes, 1022
  of tongue, **1013**, 1124
    surgical anatomy, 1373

Lymph vessels—*continued*
  of tonsil (palatine), **1014**, 1140
  of trachea, 1014
  of tympanic cavity, 836, 1012, 1018
  of tympanic membrane, 830
  of umbilicus, 1023
  of upper limb, 1017
  of ureter, **1026**, 1032
  of urethra, female, 1026
    male, 1023, 1025
  of uterine tube, **1026**, 1298
  of uterus, **1026**, 1304
  of vagina, **1026**, 1306, 1426
  of vermiform process, **1031**, 1207
  vesical, **1026**, 1269
  of vesicula seminalis, 1026
Lymphoblasts, 70
Lymphocytes, 1001
  origin, 70

Maceration of bones, 86
Macrodont. *See* Megadont
Maculæ acusticæ, 841
    sacculi et utriculi, 840
  cribrosa of vestibule, inferior, 838
    media and superior, 837
  lutea, 809
    structure, 812
Male gametes, 13
  germ cells, 12
Malleoli, 268, 272
    relation to talus, 279
    surgical anatomy, 1457
  lateral, **272**, 274
  medial, 267, **268**, 271
    prominence, 364
    relation to posterior tibial artery, 957
Malleus, 152, 826, **832**
    anterior process, 152
  development, 57, 181, 835
  movements, 836
  ossification, 835
  seen through tympanic membrane, 1356
  surgical anatomy, 1358
Mamma, 1318. *See also* **Gland**, mammary
Mammals, cell division in, 12
Mandible, 91, 124, 129, 139, 150, **177**
    coronoid process, 129, 141, **179**, **180**
      felt in mouth, 1103
    head, 129, 138, 150, 152, **179**, **180**
    neck, 129, 147, 152, **179**, **180**
    ramus, 129, 141, **178**, **180**
  age changes, 180
  at birth, 180, 184
  in child, 185
  development and ossification, 181
  movements, 129, 179, 315
  in old age, 186
  relation to mucous membrane, 179
  structure, 180
  surgical anatomy, 1366
Manubrium of malleus, 833. *See also* Handle
  sterni, **113**, **115**, 120, 121
Manus. *See* **Hand**
Margin, alveolar of, mandible, 177, **179**
    of maxilla, 128, 144, 145
  of cerebrum, surface anatomy, 155, 161, 165
  supra-orbital, 132, 135, 189
    in women, 186
Marrow of bones, 70, 83
    origin, 89
  red and yellow, 84, 86

Mass, inner, of morula, 25, 26
inner, of zygote, 30
lateral, of atlas, 97, **98**, 149
development, 123
homology, 112
lateral, of sacrum, 102, **105**, 106
homology, 113
mulberry, 25
Massa intermedia, **609**, 615
"Masseter," 141
Mastoid temporal, 126, 140, 198. *See also* **Temporal bone**
Matrix of cartilage. *See* Periblast
Matrix of nail, 852
Matter, gray, 513
development, 41
of aqueduct, 583
central, of medulla oblongata, 564
of medulla spinalis, 524, **529**
of cerebellum, 576
of cerebral cortex, 641
white, 513
development, 41
of cerebellum, 576
of cerebral hemisphere, 644
of spinal medulla, **526**, 533
Maturation, 22
division, 12, 14
first, 18
second, 18
of spermatocytes, 20
of germ cells, 10
of oöcyte, 17
Mature oöcyte, 14
Maxilla, 124, 128, 135, 137, 141, **211**
in child, 185
development, 188
in old age, 186
ossification, 213
variations, 214
body, 128, 134, **211**
in front of skull, 132, 134
in nose, 171
relation to ethmoid, 176
alveolar process, 128, **144**, 145, 212
relation to incisor crest, 169
to maxillary sinus, 175
frontal process, 128, 212
in front of skull, 132, 133
in nose, 171, 172
in orbit, 134, 135, 136
relation to ethmoid, 176
palatine process, 128, 213
in floor of nose, 133, 169
in hard palate, 144
zygomatic process, 128, 211, 212
relation to maxillary sinus, 174
tuberosity, 128, **141**, **144**, 147, 211, 212
relation to palatine bone, 129
Maxillary region of skull, 133
Meal, bismuth or opaque, 1165, 1407
Measurements of limb bones, 299
of skeleton, 298
used in anthropology, 294
Meatus, 87
acoustic, *external*, 125, 126, **139**, **140**, 150, 198, **824**
arteries, 826, 895, 896, 897
at birth, 184, 826
in child, 140
connexion with temporal neuralgia, 1349

Meatus—*continued*
acoustic, *external*—*continued*
development, 48
lymph vessels, 826, 1012
nerves, 690, 700, 826
parts opposite, 151
relation to jugular foramen, 166
to mandible, 180
to roots of zygoma, 138
to tympanic plate, 144, 152
surgical anatomy, 1355
veins, 826
internal, 167, 200, 839
absence of, 202
ossification, 200
nasal, 171
seen through speculum, 1369
common, 171
inferior, 132, 133, 134, 171, 173, **798**
relation to maxillary sinus, 175
middle, 132, 133, 171, **173**, 176, 207, 797
relation to ethmoid sinuses, 176
to maxillary sinus, 174, 175
superior, 132, 133, 142, **171**, **172**, 176, 206, 797
relation to ethmoid sinuses, 176
nasopharyngeal, 171
relation to sphenoidal sinus, 176
urinarius. *See* **Orifice**, urethral
Mechanism of foot, 364
of pelvis, 340
Media, refracting, of eye, 813
uniting, of joints, 301, 303
"Medial," definition, 5
Mediastinum testis, 1273
development, 1315
thoracis, 1088
arteries, 914, 927
anterior, 1089
development, 76
dorsal. *See* **M.**, posterior
middle and posterior, 1089
superior, 1088
level, 1433
ventral. *See* **M.**, anterior
Medulla, 84
of kidney, 1252
oblongata, 148, 164, 517, 541, 542, **544**
areas of Flechsig, 564
closed and open parts, 545
arteries, 907
development, 38, 553
structure, 552
veins, 149, 978
spinalis, 3, 5, 28, 94, 98, 148, **518**
floor and roof plates, 40
gray matter, 524
regions, 520
different characters, 528
segments, 520
distribution, 1435
white matter, 526
development, 41
arteries, 907, 911, 928, 1040, 1053
relation to pia mater, 673
at birth, 519
development, 36, 37, 40, 522
in fœtus, 519
lesions, 1435
level, 150, 519
in child, 1434
structure, 524

Medulla—*continued*
spinalis—*continued*
surgical anatomy, 1434
veins, 983
relation to pia mater, 673
Megacaryocytes, 70
Megacephaly, 295
Megadont, 298, 1236
Megalocolon, 1413, 1423
Megaseme, 297
Meiosis, 10, **12**
Melanin of skin, 851
Membranæ, Membranes—
ossification in, 89
anal, 46
atlanto-occipital, anterior, 97, 148, **312**
posterior, 98, 148, **312**
basilaris of cochlea, 839, 842, **843**
-bones, 88, 188
of brain. *See* **Meninges**
of branchial clefts, 48
bucco-pharyngeal, 29, 32, 44, 53, 72
disappearance, 46
inversion of, 42
plane of, in adult, 1232
cell-, 8
cloacal, 44, 77
costo-coracoid, 122, **373**, 374, 375, 916
attachment to clavicle, 225
to coracoid process, 223
crico-thyreoid. *See* Conus elasticus
fœtal, 58
granulosa, 15, 16, 1297
hyaloid, of retina, 813
hyoglossal, 1123
hyothyreoid. *See* **M.**, thyreohyoid
intercostal, anterior, 122, **471**
posterior, 117, 118, 122, **471**
intermuscular, of eyeball, 802
interosseous, *of forearm*, 233, 236, **329**, 391, 393, 403
nerve supply, 734
of leg, 268, 271, 274, **352**, 425, 426, 427, 433
nerve supply, 762
of larynx, 1066
limitans externa of retina, 812
of neural tube, 40, 503
mucous, of anal canal, 1219
of auditory tube, 832
of bladder, 1269
appearance, 1419
of colon, 1172, 1202
of duodenum, 1180
of gall-bladder, 1194
of ileum, 1201
of intestines, 1172, 1202
of jejunum, 1201
of larynx, 1071
of lips, 1105
end bulbs in, 857
of mouth, 1105, 1108
relation to hyoglossus, 464
to mandible, 179
to mylohyoid, 462
of nose, 798
of œsophagus, 1148
of palate, 1107, 1108
of pharynx, 1143
relation to hyoid bone, 183
of rectum, 1219
of stomach, 1168
of tongue, 1124
Membranæ, Membranes—*continued*
mucous—*continued*
of trachea, 1080
of tympanum, 836
of ureter, 1257, 1258
of urethra, 1270, 1292
of uterus, 1303
of vermiform process, 1207
nuclear, 8, 11
of mature oöcyte, 19
obturator, 254, 259, **340**, 415, 420
peri-odontal, 1110
pharyngeal (embryo), 1232
proctodæal, 1239
pupillaris, 808
of Reissner. *See* **M.** vestibularis
separating, of branchial clefts, 48
serous. *See* **Pericardium, Peritoneum, Pleura, Tunica vaginalis**
nerve endings in, 856
of spinal medulla, 104, 667. *See also* **Meninges**
sterni, 318, 319
sutural, 83, 153, 154, 301
synovial, 304
end bulbs in, 857
acromio-clavicular, 321
of ankle, 355
of carpal joints, 333
costo-vertebral, 316
of elbow, 327
of hip, 343
relation to neck of femur, 264
interchondral, 317
of knee, 350
relation to femur, 265
mandibular, 314
radio-ulnar, 329
of shoulder, 324
relation to humerus, 229
sterno-clavicular, 320
sterno-costal, 318
tarsal, 359, 360, 361
tibio-fibular, 351, 352, 353
vertebral, 309
of wrist, 331
tectoria of neck, 148, 164, 309, **313**
of spiral organ, 845
thyreohyoid, 183, 460, 465, **1066**
surgical anatomy, 1378
tracheal, 1080
tympanic, 140, **828**
secondary, **827**, 840
arteries, 829, 895, 897
at birth, 184
in child, 140
clinical examination of, 829, 1356
connexion with malleus, 834
development, 57
lymph vessels, 830
nerve supply, 690, 830
paracentesis, 1357
surgical anatomy, 1356
vestibularis, 842
vitelline, 17
Membrane-bones, 88, 188
Meninges, 135
origin, 34
of brain, 153, 665
arteries, 157, 159, 161, 166, 894, 895, 897, 898, 903, 904, 907
lymph vessels, 147, 148, 149, 151, 162, 167, **1011**

Meninges—*continued*
  of brain —continued
    nerves, 681, 685, 689, 700, 704, 726
    veins, 976
  of spinal medulla, 104, 667
    arteries, 907, 911, 928
    nerves, 713, 779
    veins, 982
Meningocele, cerebral, site of, 187
Menisci, 88, 266, 304
    development, 89
  of knee, 266, 268, 270, 347, **349**, 350
    surgical anatomy, 1455
Menstruation, 1303
Mesaticephaly, 295
Mesatikerkia, 299
Mesatipellia, 298
Mesencephalon, 580. *See also* **Mid-brain**
Mesenchyme, 35
Mesenteries, 1154
Mesentery, *the*, 1198
    development, 1241
    surgical anatomy, 1404, 1405
  dorsal, 77, 1240
  of testis, 1279
  ventral, 1188, 1240, 1242
  of vermiform process, 1206
Mesentery of cat, Pacinian corpuscles in, 857
Mesocardium, disappearance, 1033
Meso-cephaly, 295
Mesocolon, ascending, 1209
    surgical anatomy, 1411, 1412
  descending, 1211, 1212
  pelvic, **1213**, 1226
    development, 1241
    surgical anatomy, 1414
  sigmoid, 1213
  transverse, 1213
    adherent to duodeno-jejunal flexure, 1156
    development, 1241, 1403
    surgical anatomy, 1402, 1404, 1413
Mesoderm, 31
  cephalic, 34
    derivatives, 35
  cutis lamella of, 34
  intermediate cell tract, derivatives, 34
  lateral plates, derivatives, 34
  lateral plate, formation of, 32
  muscle plates of, 34
  paraxial, 123
    formation of, 32
  pericardial, 32, 44
  primary, 26, 27, 29, 30, 31
  of primitive streak, 31
  relation to yolk sac, 32
  scleratogenous, 33
  secondary, 27, 31
    differentiation, 30
    formation, 28
    relation to notochord, 29
  somatic and splanchnic, 32
Mesodont, 298, 1236
Meso-duodenum, 1241
Meso-gastrium, dorsal, 1240
  ventral, 1188
Mesognathism, 297
Mesometrium, 1301
Mesonephros, 74, 1040, 1310, **1311**
    in amphibia and fishes, 1313
  connexion with gubernaculum, 1280
Mes-orchium, 1279
Meso-rectum, 1213
Mesorrhine, 297
Meso-salpinx, 1297, **1301**
Mesoseme, 297
Meso-tendons, 368
Mesotympanum, 1358
Mes-ovarium, 1295, 1301
Mesurania, 298
Metacarpal bones, 217, **242**
    first, second, and third, 243
    fourth and fifth, 244
  attachments, 243, 244, 245
  at birth, 246, 289
  compared with metatarsals and phalanges, 243, 284
  homology, 293
  joints, 244, 334, 335
  movements, 336
  ossification and structure, 246
  surgical anatomy, 1446
  use of opposability, 294
  variations, 247
Metacarpus, 217, **242**
Metacoracoid, 292
Metanephros, 1040, 1312, 1313
Metaphase of cell division, **10**, 13, 18
Metatarsal bones, 248, **285**
    fifth, 281, **285**
    first, 282, **285**
    fourth, 281, 283, 286
    second, 283, **286**
      relation to tarsus, 283
    third, 283, 286
  attachments, 286
  at birth, 289
  compared with metacarpals, 243
  homology, 293
  joints, 363
  movements, 364
  ossification, 288
  structure, 290
  surgical anatomy, 1459
  variations, 290
Metatarsus, 248, **284**
Metathalamus, 607
  development, 39, 606
  function, 518
Metazoa, position of sensory cells, 500
Metencephalon, 516
  development, 38
Metopic ossicles, 191
Metrio-cephaly, 296
Micro-cephaly, 295
Microdont, 298, 1236
Microseme, 297
Mid-brain, 515, 543, **580**
  arteries, 904, 908
  development, 38, 515, 590
  relation to arteries, 904, 908
    to basal vein, 977
    to thalamus, 608, 611
  structure, 583
  veins, 977
Mid-gut, derivatives, 52, 1232
  formation, 42
Middle ear. *See* **Cavity**, tympanic
Migration of muscles, 496
  of neuroblasts of cerebellum, 571
      in cerebellum, 578
    of rhombencephalon, 554, 556
  of sensory cells, 500
Miniature long bones, 84

Mito-chondria, 8
  of spermatids and spermatozoa, 21
Mitosis, **9**, 25
  heterotype, 10, **12**, 13
  homotype, **10**, 11, 13, 15, 18
Moderator band, 873
Modiolus of cochlea, 838
Mons pubis (Veneris), 486, 952, 1293, **1306**
  arteries, 952
  nerves, 751
Morgagni's sinus, 1142
Morphology, 2. *See also* **Development**
  of abducent nerve, 709
  of accessory nerve, 711
  of acoustic nerve, 708
  of alar ligament of dens, 123
  of aorta, 1056
  of arches of palm, 1056
  of arteria comitans N. ischiadici, 946, 1041
  of arteries, 1052
  of arteries of limbs, 1056, 1057
  of ascending cervical artery, 1055
  of axillary artery, 1056
  of axillary vein, 1058
  of azygos vein, 1058
  of basilic vein, 1058
  of bronchial artery, 1056
  of bronchial veins, 1058
  of cardiac veins, 1058
  of carpal ligaments, 307
  of cephalic vein, 1058
  of cerebral veins, 707
  of cervical plexus, 727
  of cœliac artery, 1056
  of collateral ligaments of knee, 307
  of coraco-humeral ligament, 307, 374
  of coronary sinus, 1058
  of coronary vein, 1058
  of costo-cervical trunk, 1054
  of cranium, 186
  of cricoid cartilage, 1098
  of deep cervical artery, 1055
  of diaphragm, 497
  of digital arteries, 1056
  of digital veins, 1058
  of dorsal venous arch, 1058
  of duct of Cuvier, 1057
  of epigastric arteries, 1054
  of facial nerve, 710
  of facial veins, 1058
  of femoral vein, 1059
  of gastric arteries, 1056
  of gastric veins, 1058
  of glossopharyngeal nerve, 710
  of gluteal artery, 1057
  of gluteal vein, 1058
  of hæmorrhoidal veins, 1058
  of hemiazygos vein, 1058
  of hepatic artery, 1056
  of hepatic vein, 1058
  of hypogastric artery, 1056
  of hypogastric vein, 1058
  of hypoglossal nerve, 709
  of iliac arteries, 1056, 1057
  of iliac veins, 1058
  of inferior epigastric artery, 1054
  of inferior vena cava, 1058
  of innominate vein, 1057
  of intercostal arteries, 1053, 1054
  of interosseous arteries, 1056, 1057
  of jugular veins, 1057, 1058
  of laciniate ligament, 307
Morphology—*continued*
  of ligaments, 307
  of ligamentum apicis dentis, 123
  of ligamentum ovarii, 1280
  of limb arteries, 1056, 1057
  of lower limb, 290
  of lumbar arteries, 1053, 1054
  of mammary artery, 1054
  of maxillary vein, 1058
  of median artery, 1056
  of mesenteric arteries, 1056
  of mesenteric vein, 1058
  of middle sacral artery, 73, 1055
  of muscles, 495
  of oblique popliteal ligament, 307
  of oblique vein of left atrium, 1058
  of oculomotor nerve, 709
  of œsophageal arteries, 73, 1056
  of olfactory nerve, 708
  of optic nerve, 36, 38, 708, 821
  of ovarian artery, 1055
  of ovarian ligament, 1280
  of peroneal artery, 1057
  of pineal body, 39, 606, 1341
  of platysma, 368, 497
  of popliteal artery, 1057
  of popliteal vein, 1058
  of portal vein, 1058
  of postcardinal veins, 1057
  of posterior rami of nerves, 718
  of precardinal veins, 1057
  of pudendal plexus of nerves, 770
  of pulmonary artery, 1056
  of pulmonary veins, 1058
  of radial artery, 1056
  of rami of nerves, 718
  of renal artery, 1055
  of round ligament of femur, 307, 344
  of round ligament of uterus, 1280
  of sacro-spinous ligament, 260, 339
  of sacro-tuberous ligament, 338
  of saphenous veins, 1058
  of skull, 186
  of spermatic artery, 1055
  of spheno-mandibular ligament, 307
  of spinal arteries, 1053
  of splenic artery, 1056
  of splenic vein, 1058
  of stylo-hyoid ligament, 307
  of stylo-mandibular ligament, 307
  of subcardinal veins, 1057
  of subclavian artery, 1054
  of subclavian vein, 1058
  of superior intercostal vein, 1057
  of superior thyreoid artery, 1056
  of superior vena cava, 1057, 1058
  of suprarenal artery, 1055
  of teeth, 1235
  of thyreo-cervical trunk, 1054
  of thyreoid veins, 1058, 1059
  of thyreoidea ima, 1056
  of tibial arteries, 1057
  of transverse ligament of leg, 307
  of trigeminal nerve, 710
  of trochlear nerve, 709
  of ulnar artery, 1056
  of upper limb, 44, 290
  of vagus, 710
  of vascular system, 1052
  of veins, 1057
  of veins of heart, 1058
  of vena portæ, 1058

Morphology—*continued*
  of venæ cavæ, 1057, 1058
  of venæ comites, 1059
  of venous sinuses, 1057
  of vertebral artery, 1054, 1055
  of vesical veins, 1058
  of volar arches, 1056
Morula, **25**, 26, 61
Mother cell, 9
Mouth, 1101
  development, 53, 1232
  floor, 1103, 1104
  muscles, 451
  roof, 146, 1103, 1106
  surgical anatomy, 1371
Movements—
      at joints, 83, **305**
      of kidney, 1246
      of respiration, 474
      of stomach, 1164
    of eversion, 280, 364
    of inversion, 280, 364
    of opposition, 294, 334
    of pronation, **238**, 294, 330
    of supination, **237**, 294, 330
  of ankle, 294, **355**
  of auditory ossicles, 836
  of chin, 315
  of clavicle, 320, 321
  of elbow, 294, **327**
  of fingers, 243, 336
  of forearm, 237, 294, 327, 330
  of foot, 280, **364**
  of hand, 238, 331, **336**
  of head, 313
  of hip, 261, 294, **344**
  of hyoid bone, 182, 461, 463, 467
  of knee, 263, 294, **350**
  of larynx, 182, 467, 1062, 1072
  of lower limb, 437
  of mandible, 129, 179, **315**
  of patella, 351
  of pelvis, 340
  of radio-ulnar joints, **237**, 294, 330
  of radius, 238, 294, 330
  of ribs, 319, 474
  of scapula, 321
  at shoulder, 237, 294, 321, 325, 380
  of skull, 313
  of sternum, 319, 474
  of thorax, 311, 319, 474
  of thumb, 334
  of toes, 285, 287, **364**
  of upper limb, 404
  of vertebral column, 106, 311
  at wrist, 238, 294, 331, 336
Mulberry mass, 25
Müllerian duct. *See* **Duct**
Multangulum majus et minus, 241. *See also* **Os**
Muscles, 365
      actions, 366
      attachments, 365
      development, 495
      ends, 86
      fixation, 367
      insertion, 365
      migration, 496
      morphology, 495
      nerve supply, 367
        double, 772
      origin, 365
      tone, 367

Muscles—*continued*
      bi-penniform, 366
      biventral or digastric, 365
      cardiac, 365, **863**, 874
      fusiform, 366
      involuntary, 365
      multipenniform, 366
      penniform, 366
      plain, 365
      skeletal, typical, 365
      striped, 365
        development, 34
      synergic, 367
      unipenniform, 366
      unstriped, 365
        in eyelid, 817
      voluntary, 365
        development, 34
  of abdomen, 440, 476
  appendicular, 368, 407
  of arm, 381
  of auricle, extrinsic, 449
    intrinsic, 824
  axial, 437
  of back, **369**, 438
    development, 496
  of branchial arches, 497
  of bronchi, 1097
  of buttock, 416
  of ear, extrinsic, 449
    intrinsic, 824
  of eyelid, 450, 816
  of face, 450
    development, 497
  of foot, 427, 432, 433
  of forearm and hand, 385, 388
  of head, 448
  of hyoid arch, 497
  of hyoid bone, 459
  infra-hyoid, 459
  of larynx, 1072
    development, 497
  of leg, 425
  of limbs, 369, 407
    development, 498
    plan of innervation, 772
  of little finger, 397
  of lower limb, 407
  of mandibular arch, 497
  of mastication, 455
    afferent nerves of, 600
    development, 497
  of middle ear, 835
  of mouth, 451
  of neck, 439, 459
  of nose, 451
  of œsophagus, 1146
  of orbit, 453
    development, 497, 709
  of palate, 466
    development, 497
  of palm of hand, 394
  of pectoral region, 373
  of pelvis, 493
  of perineum, 487
  of pharynx, 464
    actions, 467
    development, 497
  prevertebral, 469
  of respiration, 471
  of scalp, 448
    development, 497

Muscles—*continued*
of shoulder, 376
of soft palate, 466
of sole of foot, 433
suprahyoid, 461
of thigh, 407
of thorax, 471
of thumb, 395
of tongue, **463**, 1123
development, 497, 498, 709
extrinsic, 463
intrinsic, 464
of trachea, 1080
tympanic, 835
of upper limb, 368
abductor *digiti quinti* of foot, 278, 287, **434**
surgical anatomy, 1459
of hand, 242, 246, **396**, 397
hallucis, 278, 287, 424, **433**
surgical anatomy, 1459
pollicis brevis, 242, 246, **395**, 403
longus, 233, 237, 244, 386, 395, 399, **402**
relation to "snuff-box," 236
surgical anatomy, 1448
tubæ auditivæ, 832
adductor *brevis*, 259, 264, 265, 413, **414**, 416
hallucis, 287, **435**
oblique head, 286, 435
transverse head, 435
longus, 259, 265, 406, 407, **413**, 416
surgical anatomy, 1453
magnus, 259, 263, 264, 265, 406, 410, 413, **414**
surgical anatomy, 1449, 1455
minimus, 415
pollicis, 246, **396**
oblique head, 242, 244, **396**, 398
transverse head, 244, 396
relation to sesamoids, 247
agitator caudæ, 417
ambiens, 307
anconeus, 229, 233, **401**
antitragicus, 824
arch, axillary, 374
nerve supply, 732, 738, 744
relation to axillary artery, 917
arrectores pilorum, 854
articularis genu, 265, 410
ary-epiglotticus, 1072, 1074
arytenoideus obliquus, 1072
transversus, 1074
auricularis anterior, 450
posterior, 140, **449**, 824
superior, 449
biceps *brachii*, 234, 236, 237, **383**
surgical anatomy, 1440, 1442, 1444
long head, 383
in groove, 227
held in place, 229
relation to labrum, 222, 323
short head, 223, 374, 380, **383**
third head, 384
femoris, 271, 274, **421**, 423
relation to tibio-fibular joint, 325
surgical anatomy, 1451, 1455
long head, 259, **421**
relation to sacro-tuberous ligament, 338
short head, 265, 417, **421**
biventer cervicis, 442

Muscles—*continued*
brachialis, 229, 231, 233, 381, **384**
relation to elbow, 326
surgical anatomy, 1442
brachio-radialis, 229, 236, 381, 384, 388, **399**, 403
surgical anatomy, 1442, 1447
bronchial, 1097
broncho-œsophageus, 1148
buccinator, 179, 180, 446, **452**, 467, 1106
bucco-pharyngeus, 465
bulbo-cavernosus, 488
caninus, 133, **452**
cerato-pharyngeus, 465
chondro-epitrochlearis, 374
chondro-glossus, 464
chondro-pharyngeus, 465
ciliaris, 807
nerve supply, 602, 683
cleido-mastoid, 459
cleido-occipitalis, 459
coccygeus, 105, 106, 339, **495**
attachments, 260
development, 497
relation to pelvis and perineum, 257
compressor bulbi, 488
radicis penis, 488
venæ dorsalis penis, 488
constrictors of pharynx, 465
inferior, 448, 465
middle, 183, 464, **465**
superior, 147, 148, 180, 452, 458, 464, **465**
constrictor pupillæ. *See* **M.**, sphincter
urethræ. *See* **M.**, sphincter
coraco-brachialis, 223, 228, 374, 380, **381**
brevis or superior, 382
surgical anatomy, 1440, 1442
corrugator cutis ani, **487**, 1219
supercilii, 132, 449, **451**
ultimate nerve supply, 588
costo-coracoideus, 374
cremaster, 260, 478, **481**, 485, 1281
crico-arytenoideus, lateralis, 1072, **1075**
posterior, 1072, **1074**
crico-pharyngeus, 465
crico-thyreoideus, 1072, **1073**
in laryngotomy, 1379
dartos, 486, 1281
nerve supply, 1282
deltoid, 223, 225, 229, 373, **376**, 381
surgical anatomy, 1439, 1441
depressor alæ nasi, 451
septi, 451
diaphragm, 115, 120, 122, **472**, 481
arteries, 914, 929, 936
development, 77, 497, 1042
fascia, 475, 1150
level, 115, 1433
in expiration, 1149
lymph vessels, 1021, 1032
surgical anatomy, 1404
morphology, 497
nerve supply, 473, 727, 746, 789
relation to œsophagus, 1145
surgical anatomy, 1430
veins, 967, 969, 990
pelvic, 493, 1150
urogenital, 200, 256, 260, **489**
relation to pelvis and perineum, 257
digastric, **461**, 464
anterior belly, 180, **462**

Muscles—*continued*
  digastric—*continued*
    posterior belly, 150, 444, **461**
      development, 497
  dilatator pupillæ, 809
      nerve supply, 683
    tubæ auditivæ, 832
  dilatores naris, 451
  dorso-epitrochlearis, 374
  epicranius, 446, **448**
  erector spinæ. *See* **M.**, sacro-spinalis
  extensor *carpi* radialis brevis, 235, 244, 245, 386, **399**
        longus, 229, 235, 244, 245, 386, **399**
          surgical anatomy, 1442, 1447
      ulnaris, 232, 233, 244, 245, 386, **401**
        surgical anatomy, 1445
    digiti quinti proprius, 246, 386, **401**
    digitorum communis, 235, 246, 386, **400**
        surgical anatomy, 1447
      brevis, 278, 287, **427**
        surgical anatomy, 1459
      longus, 271, 274, 287, **426**
        surgical anatomy, 1456, 1459
    hallucis brevis, 427
      longus, 274, 287, **427**
        surgical anatomy, 1459
    indicis proprius, 233, 235, 246, 386, **403**
    "origin," muscles composing, 229
    ossis metatarsi hallucis, 427
    pollicis brevis, 237, 246, 386, 399, **403**
        relation to snuff-box, 236
        surgical anatomy, 1447
      longus, 233, 235, 246, 386, 399, **403**
        relation to snuff-box, 236
    primi internodii longus, 427
  flexor *carpi* radialis, 244, 245, **388**, 396
        relation to carpal ligaments, 334
        surgical anatomy, 1447
        seen near wrist, 238
        at wrist, 240, 241
      ulnaris, 233, 242, **389**, 396
        insertion by bands, 333
        seen near wrist, 238
    digiti quinti brevis of foot, 286, 287, **436**
          of hand, 242, 246, **397**
    digitorum brevis, 278, 287, **433**
      longus, 271, 287, **431**
        relation to sustentaculum, 278
          to tibia, 268
      profundus, 233, 246, **391**
      sublimis, 233, 236, **390**
    hallucis brevis, 281, 287, 435
        sesamoid bones, 290
      longus, 274, 287, 432, 435
        relation to calcaneus, 277, 278
          to talus, 279
          to tibia, 268
    "origin," muscles composing, 229
    pollicis brevis, 242, 246, **396**
        deep head, 244
        relation to sesamoids, 247
      longus, 233, 237, 246, 388, **393**
  frontalis, 446, 449
  gastrocnemius, 347, 421, 429
      surgical anatomy, 1456, 1457
    lateral head, 263, 265, **429**
      sesamoid bone, 290
    medial head, 264, 265, 423, **429**
  gemelli, 264, 416, **420**
    inferior, 259, 420
    superior, 259, 420

Muscles—*continued*
  genio-glossus, 181, 183, **463**, 464
    surgical anatomy, 1374
  genio-hyoideus, 180, 182, **462**
    nerve supply, 706
  glossopalatinus, **464**, 466
  glossopharyngeus, 465
  gluteus maximus, 106, 259, 264, 407, **416**, 421
      sesamoid bone, 290
      surgical anatomy, 1449
    medius, 259, 264, 407, 416, **418**
    minimus, 259, 264, 416, **419**
  gracilis, 259, 271, 406, **413**, 423
  hamstring, 413, 415, 420
    surgical anatomy, 1451
  helicis major et minor, 824
  hyoglossus, 183, **463**
  iliacus, 105, 259, 264, **412**
      position, 251
    minor, 412
  ilio-capsularis, 412
  ilio-coccygeus, 491, 492, 495
  ilio-costalis, 118, **440**
    cervicis, 109, 122, **440**
    dorsi, 122, **440**
    lumborum, 122, **440**
  ilio-psoas, 407, 411
    surgical anatomy, 1454
  incisivi, 179, **451**
  infra-hyoid, 459
    development, 497
    surgical anatomy, 1378, 1379
  infraspinatus, 222, 229, 376, **378**
    relation to shoulder capsule, 323
  intercostal, 471
      development, 497
      serial homology, 2
    external, 117, 119, 122, **471**
    internal, 117, 118, 119, 122, **471**
  interosseous, of foot, 286, 287, **436**
      dorsal, of foot, nerve supply (sensory), 760
    of hand, 244, 246, **397**, 400
      primus volaris, 244, 246
  interspinales, 109, **445**
    development, 496
  intertransversarii, 109, **445**
  ischio-bulbosus, 488
  ischio-cavernosus, 260, **289**
  ischio-pubicus, 490
  latissimus dorsi, 122, 229, 260, **371**, 374, 376, 380, 381, 439, 479
    relation to trapezius, 369
    slip from scapula, 222
    surface anatomy, 1428
  levator ani, 106, 260, **494**
      action, 1220
      development, 497
      relation to pelvis and perineum, 257
        to prostate, 1287
        to vagina, 1306
    glandulæ thyreoideæ, 183, **461**, 1330
    palpebræ superioris, **453**, 816
    penis, 489
    prostatæ, 492, **495**
    scapulæ, 98, 109, 222, **372**, 376, 439, 440, 447
      relation to trapezius, 369
      surface anatomy, 1428
    veli palatini, 152, 458, **466**, 1138
      action, 832
      nerve supply, 688

Muscles—*continued*
  levatores costarum, 109, 122, **472**
  longissimus, 442
      capitis, 109, 141, **442**
      cervicis, 109, **442**
      dorsi, 109, 122, **442**
  longitudinalis inferior, 464
    superior, 464
  longus capitis, 109, 148, 447, **469**
      development, 497
    colli, 97, 109, 447, 469
      development, 497
  lumbricales of fingers, 246, **392**, 398, 400
    of foot, 287, **432**
  masseter, 139, 141, 180, 446, **455**
    felt in mouth, 1103
  mentalis, 179, **452**
  multifidus, 106, 109, 442, **444**
  mylo-hyoid, 180, 183, **462**
  mylo-pharyngeus, 465
  nasalis, 133, **451**
  naso-labialis, 451
  obliquus *abdominis* externus, 115, 118, 122, 260, 374, 376, **477**, 484
      development, 497
      nerves and action, 486
      relation to lumbar triangle, 371
      surgical anatomy, 1398, 1401
    internus, 115, 122, 260, **480**, 484
      development, 497
      nerves and action, 486
      surgical anatomy, 1401
    auriculæ, 824
    capitis inferior, 98, 99, 109, **444**
      surgical anatomy, 1387
    superior, 98, 109, 150, **444**
    oculi inferior, 136, **454**
    superior, 135, **454**
  obturator externus, 259, 264, 413, 414, **415**, 420
      relation to acetabulum, 259
        to neck of femur, 265
    internus, 259, 260, 264, 416, **420**
  occipitalis, 150, 446, **448**
  omo-hyoid, 459
      nerve supply, 706
    anterior belly, 183, **459**
      surgical anatomy, 1381, 1382
    posterior belly, 222, **459**
      surgical anatomy, 1385
  opponens digiti quinti, 242, 244, **396**, 397
    pollicis, 242, 244, **395**
  orbicularis oculi, 132, 135, 449, **450**, 452, 453
      lacrimal part, 136, 819
      ultimate nerve supply, 588
    oris, 451, 452
      in facial paralysis, 588
      incisive slips, 134
      ultimate nerve supply, 588
  orbitalis, 455
  palato-pharyngeus. *See* **M.**, pharyngo-palatinus
  palmaris brevis, 385
    longus, 386, **389**, 395
      seen near wrist, 238
      surgical anatomy, 1447
  panniculus carnosus, 448
  papillares, 873, 874
  pectinati, 870, 871
  pectineus, 254, 259, 264, 407, **413**
  pectoralis major, 115, 122, 224, 225, 229, **373**, 374, 377, 381, 383

Muscles—*continued*
  pectoralis major—*continued*
      nerve supply, 732
      surgical anatomy, 1389, 1439, 1440, 1441
    minor, 122, 223, **374**, 381
      nerve supply, 732
      relation to coraco-acromial ligament, 322
        to shoulder joint, 324
  peronæo-calcaneus, 433
    externus, 429
  peronæo-cuboideus, 429
  peronæus accessorius, 429
    brevis, 274, 286, **429**
      relation to calcaneus, 278
        to malleolus, 272
      surgical anatomy, 1456, 1458, 1459
    digiti quinti, 429
    longus, 271, 274, 284, 286, **428**
      relation to calcaneus, 278
        to cuboid, 281
        to malleolus, 272
      sesamoid bone, 290
      surgical anatomy, 1456, 1458, 1459
    tertius, 274, 286, **427**
      surgical anatomy, 1459
  pharyngo-palatinus, 145, **466**
  piriformis, 105, 259, 260, 264, 416, **419**
  plantaris, 265, 424, **429**
  platysma, 179, **448**, 452, 456, 459
    development, 497
    morphology, 368
  pleuro-œsophageus, 1147
  popliteus, 270, 271, **431**
    exit from knee, 271, 347
    in knee, 349, 350
  prevertebral, 469
  procerus, 133, 451
  pronator quadratus, 233, 237, **393**
    teres, 229, 233, 236, 237, **388**, 401
      surgical anatomy, 1447
  psoas major, 109, 625, **412**, 438, 473, 486
      sesamoid bone, 290
      surgical anatomy, 1428
    minor, 109, 260, **412**
  pterygoideus externus, 147, 180, **456**
      relation to spheno-mandibular lig., 315
    internus, 147, 180, **458**, 465, 466
  pterygo-pharyngeus, 465
  pubo-cavernosus, 489
  pubo-coccygeus, 492, **495**
  pubo-rectalis, 495
  pubo-vesicalis, 1268, 1269, 1287
  pyramidalis abdominis, 260, **482**
      action and nerve, 486
      development, 497
    auriculæ, 824
  quadratus femoris, 259, 262, 264, 416, **420**
      surgical anatomy, 1449
    labii inferioris, 179, **448**
      superioris, 451
        angular head, 133
        infra-orbital head, 134
    lumborum, 109, 122, 259, 438, 473, **486**
      development, 497
      surgical anatomy, 1428
    plantæ, 278, **432**
  quadriceps femoris, 267, **408**
  recto-coccygeus, 1219
  recto-urethralis, **487**, 1219
    surgical anatomy, 1421, 1425
  recto-uterine, 1226, 1300

- **Muscles**—*continued*
  - recto-vesical, 1269
  - **rectus** *abdominis*, 115, 122, 260, **483**, 485
    - development, 497
    - nerves and action, 486
    - sheath, 477, 480, **484**
    - surgical anatomy, 1398, 1400, 1401
    - *capitis* anterior, 98, 148, **469**
      - lateralis, 98, 109, 149, 150, 445, **446**, 469
        - relation to arteries, 894
      - posterior major, 99, 109, 150, **444**
        - minor, 97, 150, **445**
    - *femoris*, 408
      - reflected head, 259, **408**
      - straight head, 259, **408**
      - homology, 293
      - surgical anatomy, 1454
    - *oculi* inferior, 454
      - lateralis, 135, **454**
      - medialis et superior, 454
  - rhomboid, 222, **372**, 440
    - surgical anatomy, 1428
    - major, 109, **372**
      - relation to triangle of auscultation, 369
    - minor, 109, **372**
      - relation to trapezius, 369
  - of Riolan, 817
  - risorius, 448, 452
  - rotator humeri, 382
  - rotatores, 109, **445**
    - development, 496
  - sacro-spinalis, 106, 109, 118, 122, 438, **440**, 444, 486
    - surgical anatomy, 1428
  - salpingo-pharyngeus, **466**
    - action, 832
  - sartorius, 259, 271, 346, 406, **407**, 413, 423
    - surgical anatomy, 1453
  - **scalenus**, 468
      - development, 497
    - anterior, 109, 118, 122, 447, **468**
      - abnormal relation to subclavian artery, 911
    - medius, 109, 118, 122, 447, **468**
      - relation to levator scapulæ, 372
    - posterior, 109, 122, **468**
  - semimembranosus, 259, 268, 271, 346, **423**
    - at knee, 347
    - relation to knee joint, 307
    - surgical anatomy, 1452
  - **semispinalis**, 444
    - capitis, 109, 150, **442**
      - relation to trapezius, 369
    - cervicis, 99, 109, 442, **444**
    - dorsi, 109, 442, **444**
  - semitendinosus, 259, 271, 413, **422**, 423
    - surgical anatomy, 1451, 1452
  - **serratus** anterior, 118, 122, 219, 222, **375**
    - surgical anatomy, 1389
    - posterior inferior, 122, 438, **439**
      - relation to latissimus, 371
      - superior, 122, 438, **439**
  - soleus, 271, 274, **430**
    - surgical anatomy, 1456, 1457
  - **sphincter** ani externus, 106, 487, 495
      - action, 1221
      - surgical anatomy, 1422
    - internus, 1219
      - action, 1221
      - surgical anatomy, 1422
    - pupillæ, 809
      - nerve supply, 602, 683

- **Muscles**—*continued*
  - **sphincter**—*continued*
    - of pylorus, 1159
      - during digestion, 1160
    - urethræ membranaceæ, 490
    - urogenital, 1270
    - vaginæ. *See* **M.**, bulbocavernosus
    - vesicæ, 1269, 1288
      - internus, 1292
  - spinalis cervicis, 109
    - dorsi, 109, **442**
  - **splenius**, **439**, 442, 447
    - capitis, 141, 150, **439**
      - relation to trapezius, 369
    - cervicis, 98, 109, 439
      - relation to levator, 372
  - stapedius, **836**, 1359
    - development, 497
  - sternalis, 374
  - sterno-clavicularis, 375
  - sterno-hyoid, 115, 122, 183, 225, **460**
    - nerve supply, 706
  - **sterno-mastoid**, 115, 141, 150, 225, 440, 448, **459**, 460, 461
    - arteries, 890, 891, 894, 899
    - relation to levator, 372
      - to sternalis, 374
    - surgical anatomy, 1380
  - sterno-thyreoid, 115, 122, 225, 448, **460**
    - nerve supply, 706
  - stylo-auricularis, 824
  - styloglossus, 150, **464**
  - stylohyoid, 150, 183, **462**
    - development, 497
  - stylopharyngeus, 150, 464, 465, 1075
    - development, 497
  - subanconæus, 385
  - subclavius, 119, 122, 225, **375**
    - relation to costo-coracoid membrane, 373
  - subcostales, 122, **472**
  - subscapularis, 219, 222, 226, 229, **380**
    - relation to shoulder capsule, 323
  - supinator, 231, 237, **401**
  - suprahyoid, 461
  - supraspinatus, 222, 229, **378**
    - relation to shoulder capsule, 323
  - suspensory, of duodenum, 1180
  - "tailor's," 408
  - temporalis, 139, 141, 180, **456**, 458
    - relation to brain in child, 1349
  - tensor fasciæ latæ, 259, 416, **417**
        - surgical anatomy, 1450, 1453
      - suralis, 421
    - tympani, 152, **835**
      - development, 497
      - in ear, 1358
      - nerve supply, 689
    - veli palatini, 145, 147, 152, 458, **466**
      - action, 832
      - development, 497
      - in needling mandibular nerve, 1367
      - nerve supply, 689
      - relation to buccinator, 452
  - teres major, 219, 222, 229, **379**, 384
      - relation to latissimus, 371
    - minor, 219, 222, 229, 376, **379**, 384
  - thyreo-arytenoid, 1072, **1073**
  - thyreo-epiglottic, 1072, **1075**
  - thyreo-hyoid, 183, **460**
    - nerve supply, 706
  - thyreo-pharyngeus, 465

Muscles—*continued*
tibialis anterior, 271, 282, 284, 286, **425**
sesamoid bone, 290
surgical anatomy, 1459
posterior, 271, 274, 278, 281, 282, 284, 286, **432**, 435
relation to spring ligament, 358
to sustentaculum, 278
to tibia, 268
sesamoid bone, 290
surgical anatomy, 1458, 1459
tibio-fascialis anterior, 426
trachealis, 1080
tragicus, 824
transversus abdominis, 115, 122, 260, 472, **481**, 484
actions and nerves, 486
development, 497
surgical anatomy, 1401, 1428
auriculæ, 824
linguæ, 464
perinei profundus, 490
superficialis, 260, **487**
thoracis, 115, 122, **472**
development, 497
vaginæ, 490
trapezius, 150, 223, 225, **369**, 376, 377, 378, 404
paralysed, 1383
relation to latissimus, 371
to levator, 372
surgical anatomy, 1428
triangularis, 179, 448, **452**
triceps brachii, 233, 381, **384**
relation to elbow, 326
surgical anatomy, 1442
lateral head, 229, **384**
long head, 222, 380, **384**
homology, 293
medial head, 229, **384**
suræ, 429
tympanic, 835
uvulæ, 145, **466**
nerve supply, 688
vastus intermedius, 265, 267, 410
lateralis, 264, 265, 267, **409**, 410
surgical anatomy, 1451
medialis, 264, 265, 267, 406, **410**
surgical anatomy, 1454, 1455
ventricular, of larynx, 1075
verticalis linguæ, 464
vocalis, 1072, **1074**
zygomaticus, 134, **452**, 456
Musculi papillares, 873, 874
pectinati, 870, 871
Myelencephalon, 516
development, 38
Myelin, 509
date of appearance, 510
Myeloblasts, 70
Myelospongium, 504
Myocardium, 874
Myocœle, 33
Myology, 365
definition, 3
Myotomes, 495
cephalic, 188, 497, 709
occipital, 497, 498

Nails, 3, 852
appearance, 81
development, 45, 855
at seventh month, 855
Nares, 793
Nasal bone, 124, 127, **210**
at birth, 184
in front of skull, 130, **133**
origin, 188
ossification, 210
relation to apertura piriformis, 132
to cavity of nose, 168, 169, 171
to maxilla, 128
structure and variations, 210
Nasion, 130, 133, 169, 295, 1348
Naso-pharynx, 1135
relation to choana, 145
to pterygoid process, 147
to sphenoidal sinus, 176
surgical anatomy, 1376
Naso-turbinal, 797
Natis, 247
Nature of brain, 513
Navel. *See* Umbilicus
Navicular bone of foot, 279, 280, **281**, 283
homology, 293
ossification, 288
variations, 290
of hand, 238, 239, **240**, 242
homology, 293
ossification, 246
Neck, 91
arteries, 886 *et seq.*; 905, 909
bones, 96, 182
fascia, 369, **446**, 447, 448, 468
lymph glands, 1008
lymph vessels, 1012, 1014
muscles, 439, 459
nerves, 695, 698, 703, 704, 715, 721
surgical anatomy, 1376
veins, 968, 969, 970
of bladder, 1259
level, 1260
of femur, 261, **265**, 341, 344
in child, 265
function, 294
relation to capsule, 342
to obturator externus, 259
to synovial membrane, 264, 343
in women, 265
of fibula, 272
of humerus, anatomical, 227, 229
surgical, 227
surgical anatomy, 1442, 1443
of malleus, 833
of mandible, 129, 147, 152, **179**, **180**
surgical anatomy, 1366
of radius, 234, 236
of rib, 117
of scapula, 218, 223
of stapes, 834
of teeth, 181, 1109, **1110**, 1111
of uterus. *See* Cervix
Neo-pallium, 622, 624, 642
functions, 625
Nephrectomy, 1414, 1416
Nephrotome, 495, 1311
Nerves, 253, 675, 711, 775
afferent, 507. *See also* **Fibre**
of blood-vessels, 866
cardio-motor, 780, 781
-components, 506
efferent, 506. *See also* **Fibre**
-endings, sensory, 856
gustatory. *See* **N.** of taste
of hearing. *See* **N.**, cochlear

Nerves—*continued*
- of limbs, plan of distribution, 771, 772
- muscular, ratio of motor and sensory fibres, 367
- pilomotor, 779, 780, 781, 784
- post-axial, 772
- postganglionic, 775, 777
- pre-axial, 772
- preganglionic, 775, 777
- pretrematic, 710
- secretory, 779
- sensory, development, 502
  - endings, 856
- -sheaths, origin, 36
  - primitive, 509
    - origin and formation, 27, 37
- of sight. *See* **N.**, optic
- of skin, 852
  - in fascia, 367
  - in skin, 856
- of smell. *See* **N.**, olfactory
- sympathetic, 777
- of taste, 849
- vasomotor, 779, 780, 781, 784, 785
- visceral, 774 *et seq.*
  - of pelvis, 765, 786, 791

Nerves of arteries, 866
- of aorta, 785, 786, 791
- of brachial, 734
- of carotid, 782
- of femoral, 751, 752, 753
- of iliac, 751
- of interosseous, 742
- of mammary, 784
- of maxillary, external, 782
- of meningeal, middle, 782
- of peroneal, 763
- of popliteal, 762
- of radial, 741
- of subclavian, 782
- of tibial, posterior, 763
- of ulnar, 737
- of vertebral, 784

Nerves, articular—
- Pacinian bodies on, 857
- of ankle, 760, 762, 763
- carpal, 742
- of elbow, 734, 737
- of hip, 753, 754, 756, 758
- of knee, 753, 754, 759, 760, 762
- mandibular, 689, 690
- of shoulder, 731, 739
- tarsal, 760, 762, 764, 765
- tibio-fibular, 760, 762
- of wrist, 734

Nerves of bones—
- of femur, 754
- of fibula, 763
- of humerus, 733
- of radius, 734
- of tibia, 762
- of ulna, 734

Nerves, cutaneous. *See also* **Nerves, named**
  - in fascia, 367
  - Pacinian corpuscles on, 857
  - in skin, 856
- of abdomen, 718, 746, 751
- of arm, 738, 739, 740
- of back, 717
- of buttock, 718, 747, 751, 752, 767
- of calf, 759, 760, 762, 767
- of chest, 717, 723, 744, 746

Nerves, cutaneous—*continued*
  - of face, 681 *et seq.*; 723
  - of foot, 755, 760, 761, 762, 763, 764
  - of forearm, 733, 738, 740
  - of hand, 733, 734, 737, 741
  - of head, 681 *et seq.*; 715, 723
  - of leg, 754, 759, 760, 762, 767
  - of neck, 717, 723
  - of palm, 733, 734, 737
  - of perineum, 766, 769
  - of scalp, 682, 686, 690, 715, 716, 723
  - of sole, 763, 764
  - of thigh, 749, 751, 753, 754, 765
- of axillary nerve, 739
- of cervical nerves, 715, 717, 723
- of coccygeal nerve, 718, 768
- of femoral, 754
- of genito-femoral, 751
- of ilio-hypogastric, 751
- of ilio-inguinal, 751
- of lumbar nerves, 718, 751
- of median, 734
- of musculo-cutaneous, 733
- of obturator, 753
- of peroneal, common, 759, 760
  - deep, 760
  - superficial, 761
- of pudendal, 769, 770
- of radial, 740, 741
- of sacral nerves, 718, 765, 767
- of thoracic nerves, 717, 744, 746
- of tibial, 762, 763, 764
- of trigeminal, 681, 682, 683; 686, 687; 690, 691
- of typical spinal nerve, 714
- of ulnar, 737
- of vagus, 700

Nerves to certain muscles—
- to axillary arch, 732, 738, 744
- to biceps femoris, short head, 759
- to coraco-brachialis, 732
- to diaphragm, 473, 727, 746, 789
- to digastric, 695
- to genio-hyoid, 726
- to hamstrings, 757, **758**
- to intertransverse muscles, 726
- to levator scapulæ (from 3 and 4 C.), 725
- to longus capitis, 726
- to longus colli, 726, 731
- to obturator internus, 757, **758**
- to piriformis, 757, **758**
- to psoas major, 749
- to psoas minor, 750
- to pterygoid muscles, 689
- to quadratus femoris, 757, **758**
- to quadratus lumborum, 749
- to rectus capitis anterior and lateralis, 726
- to scalenus anterior, 726, 731
- to scalenus medius and posterior, 725, 731
- to sterno-hyoid, continued into thorax, 726
- to sterno-mastoid (from 2 C.), 724
- to stylohyoid, 695
- to stylopharyngeus, 698
- to subclavius, 731
- to thyreohyoid, **705**, 726
- to trapezius (from 3 and 4 C.), 724

Nerves of organs and regions—
- to axillary arch, 732, 738, 744
- of abdomen, 700, 701, 718, 727, 746, 747, 749, 785, 789
  - anterior wall, 746, 747, 750, 751
    - sensory, 1401

Nerves of organs and regions—*continued*
of abdomen—*continued*
posterior wall, 718, 746, 747, 749, 785
of acoustic meatus, 690, 700, 826
of anal canal, 1222
of arm, 724, 732
of arteries, 866
of auditory tube, 698, 832
of auricle of ear, 690, 723, 824
of back, 717, 718
of bladder, 785, 786, 791, 1269
of blood-vessels, 866
of brachial plexus, 729
of branchial arches, 497, 710
of bulb, 770
of buttock, 718, 747, 751, 752, 757, 758, 759, 765, 767, 768
of cæcum, 791
of cervical plexus, 722
chorioid, 809
of clitoris, 770, 1309
of cochlea, **602**, **696**, 837, 838, 840, 843, **845**
of colon, 791, 1203
of conjunctiva, 681, 682, 683, 687, 818
of cornea, 805
of corpora cavernosa, 770, 791, 1285, 1309
of ductus deferens, 791, 1279
of duodenum, 789, 1180
of dura mater encephali, 681, 685, 689, 700, 704, 726
of dura mater spinalis, 713, 779
of epididymis, 1274
of epiglottis, 698, 700
of ethmoidal sinus, 157, 683
of external acoustic meatus, 690, 700, 826
of eyeball, 683, 803, 805, 809
of eyelids, 681, 682, 683, 687, 695, 818
of face, 681, 682; 686, 687; 690, 691; 692; 695; 723
of fingers, 734, 737, 741
of foot, 754, 760, 761, 762, 763, 764
of forearm, 733, 734, 737, 738, 740, 741, 742
of frontal sinus, 682
of gall-bladder, 727, 789, 1193
of genital organs, 751, 767, 769, 770, 785, 786, 791, 792; 1274, 1279, 1282, 1285, 1297, 1298, 1304, 1306, 1307, 1309
of glosso-epiglottic fold, 698
of hand, 733, 734, 737, 741
of head. *See* **Nn., cerebral, and cervical**
of heart, 701, 782, 784, 876
of hyoid arch, 497, 710
of hypophysis cerebri, 782, 1339
of internal ear, **602**, **696**, 837, 838, 840, 843, **845**
of interosseous membranes, 734, 762
of intestines, 791, 1172, 1203
of iris, 809
of kidney, 789, 1254
of labium majus, 751, 767, 769, 1307
of lacrimal ducts, 820
of lacrimal gland, 681, 819
of lacrimal sac, 820
of larynx, 700, 701, 1072
of leg, 754, 759, 760, 761, 765
of ligamentum latum uteri, 791
of limbs, plan of distribution, 771, 772
of lips, 687, 690, 691, 695, 1105
of liver, 727, 789, 1192
of lower limb, 749, 757

Nerves of organs and regions—*continued*
of lumbar plexus, 749
of mamma, 1320
of mandibular arch, 497, 710
of mastoid air cells, 689, 698
of maxillary sinus, 685, 687
of meatus acusticus externus, 690, 700, 826
of middle ear, 697, 836
of mons pubis, 751
of muscles, ratio of motor and sensory fibres, 367
of naso-lacrimal duct, 820
of neck, 695, 698, 703, 704, 715, 721
of nipple, 746
of nose, 677; 682; 687, 688; 695; 799
of œsophagus, 701, 703, 785, 789, 1148
of orbit, 678, 679, 681, 686, 687, 688, 692, 782
of ovary, 791, 1297
of palate, 688, 698, 1109
of palm of hand, 733, 734, 737
of pancreas, 789, 1198
of parotid gland, 690, 1131
of pelvis, 718, 756, 765, 786, 791
of penis, 770, 791, 1285
of pericardium, 703, 727
of perineum, 766, 767, 768
of pharynx, 688, 698, 700, 781, 1143
of prostate, 786, 791, 1288
of pterygoid canal, 162, **688**, 694, 782
connexion with otic ganglion, 691
of rectum, 786, 791, 1222
of saccule, 602, 837, 840, 846
of sacral plexus, 757
of scalp, 682, 686, 690; 695; 715, 716, 723
of sclera, 803
of scrotum, 751, 767, 769, 1282
of semicircular ducts, **602**, **696**, 837, 838, 839, 840, **846**
of seminal vesicle, 791, 1279
of skin, 852. *See also* **N., cutaneous**
in fascia, 367
in skin, 856
of sinuses (air), 157, 682, 683, 685, 687
of sole of foot, 764
of sphenoidal sinus, 157, 683
of spleen, 789, 1343
of stomach, 701, 789, 1170
of sublingual gland, 691, 1133
of submaxillary gland, 691, 1132
of suprarenal gland, 727, 789, 1328, 1329
of teeth, 136, 685, 687, 691
of tentorium cerebelli, 681
of testis, 791, 1274
of thigh, 751, 752, 753, 757, 759, 761, 765
of thorax, 698, 701, 717, 723, 726, 742, 784, 787
of thumb, 734, 737, 741
of thymus, 1336
of thyreoid gland, 783, 1331
of toes, 760, 761, 762, 764, 765
of tongue, 690, 698, 700, **1125**
of tonsil (palatine), 688, 698, 1140
of trachea, 701
of tuba auditiva, 698, 832
of tympanic cavity, 697, 836
of tympanic membrane, 690, 830
of umbilicus, 746
of upper limb, 723, 727, 744
of ureter, 791, 1258
of urethra, 770, 791, 792

- **Nerves of organs and regions**—*continued*
  - of uterine tube, 791, 1298
  - of uterus, 785, 786, 791, 1304
  - of utricle of ear, 602, 837, 839, 840, 846
  - of vagina, 792, 1306
  - of veins, 866
  - of vena cava inferior, 789
  - of vermiform process, 791
- **Nerves, named**—
  - **abducent**, 692
    - arterial supply, 902
    - development and morphology, 709
    - exit from cranial cavity, 135
    - at pons, 549
    - in pons, 568, **598**
    - relation to basilar artery, 908
      - to cavernous sinus, 158
      - to sphenoidal sinus, 176
      - to skull, 158, 164
  - **accessory**, 703
    - *cerebral part*, 703
      - origin, 594
    - *spinal part*, 703
      - in foramen magnum, 148
    - development and morphology, 711
    - fila, 545
    - in jugular foramen, 166
    - on jugular tubercle, 164
    - relation to arteries, 907
      - to levator scapulae, 372
      - to petrosal sinus, 981
      - to trapezius, 369
    - surgical anatomy, 1383, 1385
  - **acoustic**, 696. *See also* **N.**, cochlear, and **N.**, vestibular
    - deep connexions, 602
    - development and morphology, 708
    - in ear, 845
    - in meatus, 167
    - origin, 602
    - at pons, 549
    - relation to cerebellar growth, 517
      - to subdural space, 671
  - **alveolar**, *inferior*, 458, **691**
      - connexion with lingual, 691
      - relation to spheno-mandibular ligament, 315
      - surgical anatomy, 1366
    - *superior*, anterior and middle, 687
      - relation to maxillary sinus, 176
    - posterior, 685
      - relation to maxillary sinus, 175
  - ampullares, 696
  - anastomotic peroneal, 760
  - ano-coccygeal, 768
    - posterior, 718
  - **anterior cutaneous**, of ilio-hypogastric, 751
    - of thoracic nerves, 744, 746, 747
      - second, anomaly, 743
    - of typical spinal nerve, 720
  - anterior thoracic, of brachial plexus, 732
  - aortic, of sympathetic trunk, 785
  - **auricular**, great, 723
      - homology, 727
    - of occipital, 723
    - posterior, 449, **695**
    - of vagus, 151, **700**
      - in medulla, 596
  - auriculo-temporal, 130, **690**
    - relation to mandible, 180
      - to spheno-mandibular ligament, 315
    - surgical anatomy, 1349
- **Nerves, named**—*continued*
  - axillary, 739
    - surgical anatomy, 1442, 1443
  - azygos, of knee, 762
  - bigeminus, 756, 757
  - buccal, of facial, 695
  - buccinator, 452, 456, 689, **690**
    - relation to mandible, 180
  - calcanean, 424
    - medial, 763
  - **cardiac**, 701, 782, 784
      - in heart, 876
    - of recurrent, 701
    - of sympathetic, inferior, 784
        - middle and superior, 782
    - of vagus, 701
  - carotico-tympanic, 151, 697, 782
  - carotid, external and internal, 782
  - caudal, 528
    - inferior, 768
    - superior, 718
  - **cerebral**, 676
    - character of fibres, 706
    - classification, 676
    - deep connexions, 590
    - development, 37, 707
    - distribution, 706
    - functions, 675, 706
    - morphology, 707
    - name and number, 675
    - piercing meninges, 665, 669, 671
    - primitive exit from skull, 188
    - relation to subarachnoid space, 671
      - to subdural space, 668, 671
    - serial homology, 2
  - cerebro-spinal, 675
  - **cervical**, 97, 715, 721
      - anterior rami, 721
      - posterior rami, 715, 717
    - *first*, 97, 99, 715, 721
      - anterior ramus, 470, **721**
      - posterior ramus, 313, 444, **715**
    - *second*, 99, 715, 722
      - anterior ramus, 722
      - posterior ramus, 715
    - *third*, posterior ramus, 715
    - descending, 705, **726**
    - of facial, 695
  - **chorda tympani**, 141, **694**
    - connexion with submaxillary ganglion, 691
    - exit from skull, 152
    - origin, 597
    - surgical anatomy, 1356, 1358
    - in tongue, 690, 849
  - **ciliary**, 683
      - piercing fascia bulbi, 802
      - piercing sclera, 803
      - within eyeball, 809
    - long and short, **683**, 809
  - coccygeal, 104, 768
    - anterior ramus, 747, 765, 768
    - posterior ramus, 718
  - **cochlear**, 696. *See also* **N.**, acoustic
    - at brain, 602
    - connexions, 605
    - in ear, 845
    - in meatus, 200
  - collateral, ulnar, 385, 740
  - **cutaneous**, of arm, lateral, 739
      - medial, 738
      - posterior, 740

Nerves, named—*continued*
cutaneous—*continued*
of calf. *See* **N.**, cutaneous, of leg
of forearm, dorsal, 740
lateral, 733
medial, 381, **738**
surgical anatomy, 1442
of leg, lateral, 759
medial, 756, 760, **762**
of neck. *See* **N.** cutaneus colli
of thigh, intermediate, 754
lateral, 749, **751**
medial, 754
posterior, 765
surgical anatomy, 1450, 1451
anterior, of ilio-hypogastric, 751
of thoracic nerves, 744, 746, 747
second, anomaly, 743
twelfth, 747
of typical spinal nerve, 720
dorsal, of foot, 761
of forearm, 740
of hand, 737
intermediate, of thigh, 754
intermediate dorsal, of foot, 761
lateral, of arm, 739
of forearm, 733
of leg, 759
of thigh, 749, **751**
of ilio-hypogastric, 751
of thoracic nerves, 744, 746, 747
second, anomaly, 743
of typical spinal nerve, 719
medial, of arm, 738
of forearm, 381, **738**
surgical anatomy, 1442
of leg, 756, 760, **762**
of thigh, 754
medial dorsal, of foot, 761
palmar, of median, 734
of ulnar, 737
perforating, **767**, 769
posterior, of arm, 740
of thigh, 765
surgical anatomy, 1450, 1451
of cervical nerves, 715, 717
of lumbar nerves and sacral nerves, 718
of thoracic nerves, 717
of typical spinal nerve, 715
cutaneus antibrachii. *See* **N.**, cutaneous, of forearm
brachii. *See* **N.**, c., of arm
femoris. *See* **N.**, c., of thigh
suræ. *See* **N.**, c., of calf
colli, 723
homology, 727
descendens cervicalis, 705, **726**
hypoglossi, 705
origin from vagus, 726
digital, of foot, 760, 761, 764, 765
of hand, 734, 735, 737, 741
connexion with Pacinian bodies, 735
of median, 734
of peroneal, 760, 761
of radial, 741
of ulnar, 737
dorsal, of foot, 760, 761
of hand, 735, 737, 741
plantar, common, 764
proper, 764, 765
volar, of median, 734
of ulnar, 737

Nerves, named—*continued*
digital—*continued*
volar—*continued*
common, 734, 737
proper, 735, 737
surgical anatomy, 1449
dorsal, of clitoris, 770
of penis, 490, 770
of ulnar nerve, 737
dorsal cutaneous, of foot, 761
of forearm, 740
of hand, 737
dorsalis manus, 737
scapulæ, 468, **731**
relation to fascia, 448
to levator scapulae, 372
surgical anatomy, 1385
ethmoidal, anterior, 157, **682**
exit from cranial cavity, 157
in nose, 169, 172
posterior, 157, **683**
facial, 693
in child, 1362
constituents, 596
development and morphology, 710
roots, 167, 693
sensory. *See* **N.** intermedius
exit from skull, 150
in meatus, 167, 200
at pons, 549, 596
within pons, 567, 597
connexion with hypoglossal nucleus, 588
with oculomotor nucleus, 588, 602
relation to medial longitudinal bundle, 588
to neck of mandible, 180
surgical anatomy, 1361, 1367
surgical relation to ear, 1359
femoral, 749, **753**
variations in origin, 749
frontal, 135, **682**
furcalis, 749, 756
genicular, 759, 760, 762
genio-hyoid, 726
genito-femoral, 749, **751**
glosso-palatine, 677, **696**
glosso-pharyngeal, 466, **697**
development and morphology, 710
fila, 545
in jugular foramen, 166
on jugular tubercle, 164
in medulla, 594, 595
in tongue, 849
relation to petrosal sinus, 981
to spinal tract of fifth, 599
gluteal, inferior, 757, 759
superior, 757, **758**
of posterior cutaneous, 767
hæmorrhoidal, inferior, 768, **769**
to hamstrings, 757, 758
of hearing. *See* **N.**, **cochlear**
hypogastric, 791
hypoglossal, 462, 463, **704**
development and morphology, 709
fila, 545
exit from skull, 149, 164
in medulla, 564, **593**
relation to arteries at brain, 907
to dura mater, 164
to petrosal sinus, 981
surgical anatomy, 1383
ilio-hypogastric, 749, **750**
surgical anatomy, 1401

- **Nerves, named**—*continued*
  - ilio-inguinal, 749, **751**
    - surgical anatomy, 1401
  - incisor, 691
  - infra-orbital, 452, **687**
      - Pacinian bodies on, 857
    - exit from skull, 133
    - in floor of orbit, 135
    - surgical anatomy, 1366
  - infrapatellar, of saphenous, 755
  - infratrochlear, 683
    - relation to ophthalmic artery, 903
  - **intercostal**, 742
      - communications, 743, 744, 746, 747, 784
      - Pacinian bodies on, 857
    - first, 743
    - second, 743, 744
    - third to sixth, 744
    - seventh to eleventh, 746
      - relation to transversus, 482
      - surgical anatomy, 1401
  - **intercosto-brachial**, 744
    - anomaly, 743
  - intermediate cutaneous, of thigh, 754
  - intermediate dorsal cutaneous, of foot, 761
  - **intermedius**, 693
      - origin, 596
      - termination, 597
    - in medulla, 596
    - at pons, 550, 596
  - interosseous, dorsal, 742
      - surgical anatomy, 1447
    - volar, 393, **734**
  - to intertransverse muscles, 726
  - jugular, 781, 782
  - labial (of mouth), superior, 689
    - (of vulva) anterior, 751
      - posterior, 769
  - lacrimal, 135, 681
  - **laryngeal**, external, 700
      - source of fibres, 594
    - inferior, 465, **701**
      - paralysis of, 1073
    - internal, 465, 700
      - in pharyngotomy, 1378
    - recurrent. *See* **N., recurrent**
    - superior, 700
  - **lateral cutaneous**, of arm, 739
      - of forearm, 733
      - of leg, 759
      - of thigh, 749, **751**
    - of ilio-hypogastric, 751
    - of thoracic nerves, 744, 746, 747
      - of second, anomaly, 743
    - of typical spinal nerve, 719
  - **lingual**, 152, 458, 462, 463, **690**
      - surgical anatomy, 1366, 1374
    - of glossopharyngeal, 698
    - of hypoglossal, 705
    - of vagus, 700
  - long thoracic, 468, **731**
    - relation to fascia, 448
    - surgical anatomy, 1387, 1441
  - **lumbar**, anterior rami, 747, **749**, 756
      - posterior rami, 718
    - fifth, 105
      - anterior ramus, relation to ligaments, 337
  - lumbo-inguinal, 751
    - in femoral sheath, 951
  - lumbo-sacral. *See* **Trunk**

- **Nerves, named**—*continued*
  - mandibular, 141, 152, **688**
      - concealed by external pterygoid, 458
      - exit from skull, 147, 163
      - relation to auditory tube, 152
      - surgical anatomy, 1367
  - marginal mandibular, 695
  - masseteric, 456, **689**
    - relation to mandible, 180
  - masticatorius, 677, 681, 689
  - maxillary, 135, 141, **685**
    - exit from skull, 159, 163
    - operation in neuralgia, 142
    - relation to sphenoidal sinus, 176
    - surgical anatomy, 1367
  - **medial cutaneous**, of arm, 738
    - of forearm, 381, **738**
      - surgical anatomy, 1442
    - of leg, 756, 760, **762**
    - of thigh, 754
  - medial dorsal cutaneous, of foot, 761
  - **median**, 388, 389, **734**
    - communication with musculo-cutaneous, 733
    - homology, 759, 763, 1057
    - relation to anomalous arteries, 917
    - surgical anatomy, 1442, 1443, 1444, 1448
    - unusual course, 230
  - **meningeal**—
    - of first cervical, 726
    - of gray rami communicantes, 779
    - of hypoglossal, 704
    - of maxillary, 685
    - of mandibular, 689
    - middle, 685
    - of ophthalmic, 681
    - of spinal nerve trunks, 713
    - of vagus, 167, 700
  - mental, 179, **691**
    - surgical anatomy, 1366
  - musculo-cutaneous, 381, 383, 384, **732**
  - mylohyoid, 691
  - **nasal**, 799
      - external, 169, 682
      - inferior and lateral, 688
      - posterior, 688
      - superior, 142, 688
    - of infra-orbital, 687
  - naso-ciliary, 135, 682
    - relation to ophthalmic artery, 903
  - naso-palatine, 142, 145, 688
    - on septum, 169
  - **obturator**, 413, 749, 752
      - exit from pelvis, 254
      - relation to distended bladder, 1264
        - to ductus deferens, 1276
        - to ovary, 1295
      - variations of origin, 749
    - accessory, 413, 756
  - to obturator internus, 757, 758
  - **occipital**, greater, 715
      - surgical anatomy, 1387
    - lesser, 723
      - homology, 727
      - surgical anatomy, 1385
    - third, 716
  - **oculomotor**, 679
    - arterial supply, 902
    - in brain, 601
    - development and morphology, 709
    - exit from cranial cavity, 135
    - relation to arteries, 904, 908

Nerves, named—*continued*
  oculomotor—*continued*
    relation to cavernous sinus, 158
      to sphenoidal sinus, 176
  olfactory, 27, 169, **677**, 799
      character of fibres, 509
      connexions, 621
      development and morphology, 708
    exit from nose, 127, 157
    on septum, 169
    on side wall of nose, 172
    relation to subarachnoid space, 671
  ophthalmic, 158, 163, **681**
    arterial supply, 902
    relation to sphenoidal sinus, 176
  optic, 542, 678
      axis of, 801
      character of fibres, 509
      development and morphology, 36, 38, 708, 821
      in optic foramen, 136, 158
      piercing choroid, 806
      piercing sclera, 803
    relation to carotid artery, 902
      to fascia bulbi, 802
      to ophthalmic artery, 903
      to sphenoidal sinus, 176
      to subarachnoid space, 668, 671
    in tumour of hypophysis, 1365
  orbital, of spheno-palatine ganglion, 688
  palatine, anterior. *See* **N.**, palatine, greater
      external or middle. *See* **N.**, palatine, lesser
      posterior or small. *See* **N.**, palatine, lesser
    greater and lesser, 145, **688**
  palmar cutaneous of median, 734
    of ulnar, 737
  palpebral, 818
      inferior, 687
    of facial, 695
    of infra-orbital, 687
    of infra-trochlear, 683
    of lacrimal, 681
    of supra-orbital and supratrochlear, 682
  perforans coccygeus major, 767
  perforating cutaneous, **767**, 769
  pericardiac, of phrenic, 727
    of vagus, 703
  perineal, of fourth sacral, 767
      of posterior cutaneous, 766
      of pudendal, 769
    superficial, 766, 769
  peroneal, anastomotic, 760
    common, 756, 757, **759**
      felt on fibula, 272
      homology, 759
      surgical anatomy, 1451, 1455
      variations in origin, 749
    deep, 760
    superficial, 423, 761
      surgical anatomy, 1457
  petrosal, deep, great, 162, 688, 694, **782**
      small, 697
    superficial, external, 694
      greater, 688, **694**
        origin, 596
        relation to skull, 160, 162, 163, 200
      lesser, 691, **694**, 698
        relation to skull, 147, 163, 200
  pharyngeal, of glossopharyngeal, 698
    of sphenopalatine ganglion, 146, **688**, 832

Nerves, named—*continued*
  pharyngeal—*continued*
    of sympathetic cervical ganglion, 781
    of vagus, 700
  phrenic, **726**, 789
      branches to thymus, 1336
      connexion with subclavian plexus, 784
        with suprarenal plexus, 1328
      relation to arteries, 911, 912
        to fascia, 448
        to scalenus anterior, 468
      root from fifth, 731
      surgical anatomy, 1384
    right, piercing diaphragm, 473
  pilomotor, 779
  to piriformis, 757, **758**
  plantar, lateral, 764
    medial, 763
      surgical anatomy, 1459
  post-axial, 772
  posterior cutaneous, of arm, 740
      of thigh, 765
        surgical anatomy, 1450, 1451
    of cervical nerves, 715, 717
    of lumbar nerves, 718
    of sacral nerves, 718
    of thoracic nerves, 717
    of typical spinal nerve, 715
  post-ganglionic, 775, 777
  pre-axial, 772
  pre-ganglionic, 775, 777
  pre-trematic, 710
  of pterygoid canal, 162, **688**, 694, 782
    connexion with otic ganglion, 691
  pudendal, 768
  pulmonary, 703, 785
    in lung, 1095
  to quadratus femoris, 757, 758
  radial, 381, 384, **739**
      homology, 759
      relation to humerus, 229
      surgical anatomy, 1442, 1443, 1444
    deep branch, 402, **742**
    superficial branch, 388, **741**
      surgical anatomy, 1448
  recurrent, of gray rami communicantes, 779
    of hypoglossal, 704
    laryngeal, 701
        connexion with ansa subclavia, 784
        source of fibres, 594
        surgical anatomy, 1380, 1384
      left, in aortic aneurysm, 1073
    of maxillary, 685
    of mandibular, 689
    of spinal nerve trunks, 713
    tibial, 760
    of vagus, 167, 700
  saccularis, 696
  sacral, 106, 718, 756
      arterial supply, 941, 942, 944, 946
    anterior rami, 102, 105, 747, **756**, 765, 768
    posterior rami, 103, 106, **718**
  saphenous, 408, 754
    surgical anatomy, 1455, 1457, 1459
  sciatic, 415, 756, 757
    artery of, 946, 1041
    surgical anatomy, 1450, 1451
  scrotal, anterior, 751
    posterior, 769
  secretory, 779
  of sight. *See* **N.**, optic

- **Nerves, named**—*continued*
  - of smell. *See* **N.**, olfactory
  - spermatic, external, 751, 1281
  - sphenoidal, of otic ganglion, 691
  - spheno-palatine, 685, 687
  - spinal, 99, 711
      - connexion with medulla, 520
      - development, 37, 773
      - distribution, 714
      - levels, 1433
      - relation to subdural space, 668
      - serial homology, 2
    - anterior rami, 713, **719**
    - posterior rami, 713, **714**
      - distribution, 718
      - morphology, 718
    - roots. *See* **Roots** of nerves, *spinal*
  - spinosus, 147, **689**
  - splanchnic, 473
    - greater, 785, 789, 1328
    - lesser, 785, 789
    - lowest, 785
    - pelvic, 713, 748, 765, 786, 791, 1222
  - stapedius, 694
  - to subclavius, 731
  - submaxillary, 691
  - suboccipital. *See* **N.**, cervical, first
  - subscapular, 742
  - supraclavicular, 723
    - homology, 727
  - supra-orbital, 132, 682
    - surgical anatomy, 1348, 1366
  - suprascapular, 731
    - surgical anatomy, 1385
  - supratrochlear, 135, 682
    - surface anatomy, 1348
  - sural, lateral, 759
    - medial, 760, 762
  - suralis, 762
    - surgical anatomy, 1459
  - sympathetic, 777
  - of taste, 849
  - temporal, deep, 139, **689**
    - of facial, 139, **695**
  - tentorii, 681
  - terminalis, 606, 677
  - thoracic, of brachial plexus, anterior, 732
      - long, 468, **731**
        - relation to fascia, 448
        - surgical anatomy, 1387, 1441
  - thoracic, spinal, 717, 742
    - anterior rami, 742
        - communications, 743, 744, 746, 747, 784
      - of first, 118, 743
      - of second, 743, 744
      - of third to sixth, 744
      - of seventh to eleventh, 746
        - relation to transversus, 482
        - surgical anatomy, 1401
      - of twelfth, 473, 746
    - posterior rami, 717
  - thoraco-dorsal, 742
    - surgical anatomy, 1441
  - thymic, 1336
  - thyreoid, inferior, 783
  - tibial, 423, 756, 757, **761**
      - homology, 759, 1057
      - surgical anatomy, 1452
      - variations in origin, 749
    - recurrent, 760
  - tonsillar, of glossopharyngeal, 698

- **Nerves, named**—*continued*
  - trigeminal, 681
        - in brain stem, 598
        - at pons, 549
      - mesencephalic root, 569, **600**
        - in pons, 569
      - motor root, 163, **681**, **688**
        - exit from skull, 147
        - origin, 600
      - sensory root, 163, **681**
        - in brain, 599
        - blood supply, 897, 908
      - spinal tract. *See* **Tract**
    - arterial supply, 897, 902, 908
    - development and morphology, 710
    - relation to skull, 159, 163
      - to tentorium and petrosal sinus, 166
    - summary, 691
  - trochlear, 681
    - arterial supply, 902
    - in brain, 601
    - development and morphology, 709
    - exit from brain, 550
      - from cranial cavity, 135
    - relation to arteries, 908
      - to cavernous sinus, 158
      - to mesencephalic root of fifth, 600
      - to sphenoidal sinus, 176
  - tympanic, of glossopharyngeal, 151, 697
  - ulnar, 381, 389, **736**
      - felt entering forearm, 231
        - entering palm, 238
      - homology, 759, 764, 1057
      - relation to epicondyle, 227
      - surgical anatomy, 1443, 1444, 1448
    - collateral, 385, 740
  - utricularis, 696
  - vagus, 473, **698**, 789
        - asymmetry, 702
        - development and morphology, 710
        - fila, 545
      - auricular branch, 151, 700
      - meningeal branch, 167, 700
      - thymic branches, 1336
    - connexion with suprarenal, 1328
    - in jugular foramen, 166
    - on jugular tubercle, 164
    - in medulla, 594, 595
    - relation to arteries at brain, 907
      - to inferior petrosal sinus, 981
      - to spinal tract of fifth nerve, 599
    - surgical anatomy, 1383, 1384
  - vasomotor, 779, 780, 781, 784, 785
  - vesical, 785, 786, 791, 1269
  - vestibular, 696. *See also* **N.**, acoustic
      - connexions, 603
      - descending root, 565
    - at brain, 602
    - in ear, 846
    - in meatus, 200
    - in pons, 567
  - visceral, 774
  - visceral, of pelvis, 765, 786, 791
  - volaris manus, 737
  - vomero-nasal, 677
  - zygomatic, 135, **686**
    - of facial, 695
  - zygomatico-facial, 134, 686
  - zygomatico-temporal, 139, **686**
    - surgical anatomy, 1349
- Nerve-fibres. *See* **Fibres**
- Network. *See* Plexus, Rete, and Reticulum

Neuralgia, occipital, 1348
  temporal, 1349
Neurobiotaxis, 555
Neuroblasts, 503, 504, 511
    development, 46
    migration, 554, 556
      in cerebellum, 571, 578
  of retina, 821
Neuroglia, 503, 512
    origin, 41
  of spinal medulla, 529, 533
Neuro-lemma, 509
Neurology, 3, 499
"Neuron," 253
Neurone theory, 504
Neurones, olfactory, 622
  parasympathetic 775, 777
Neuropores, 36, 41, 78, 502, 515
Nipple, 1318
      nerve supply, 746
      position, 122, 1397
        in child, 1397
    Pacinian corpuscles of, 857
    tactile corpuscles of, 858
  accessory, 1319
Nodules, lymph. *See* **Lymph nodules**
  of cerebellum, 575
    development, 571, 572
  of semilunar valve, 873
Norma, 129
  basalis, 142
  frontalis, 130
  lateralis, 137
  occipitalis, 136
  verticalis, 129
Nose, 168, 793
        external, 128, 132, 133, 137, 171, 793
          muscles, 451
          root, 130, 793
      chondrification, 187
      development, 53
    arteries, 799, 893, 899, 904
    lymph vessels, 800, **1012**, 1013
      connexion with subarachnoid space, 671
    mucous membrane, 798
    nerve supply, 677; 682; 687, 688; 695, 799
    relations, 174
    surgical anatomy, 1369
    veins, 799, 800, 974
      connexion with sagittal sinus, 157, 978
  apertures from and into, 173
  bony boundaries, 168
  cartilages, 87, 168, 169, **794**
  cavity, 146, **168**, 795
      at birth, 184
      boundaries, 168
      development, 54
      digital examination, 1369
      relation to cranial cavity, 155, 157
        to ethmoid, 127
        to maxilla, 128
        to maxillary sinus, 174, 175
        to orbit, 134, 135
        to palatine bone, 128
        to pterygo-palatine fossa, 141
        to sinuses, 176
      section to open, 153
      seen from behind, 145
        from the front, 124, 132, 133
          through speculum, 1369
    floor, 133, 145, **169**, 798
Nose—*continued*
  cavity—*continued*
    lateral wall, 170, 171, 797
        seen from behind, 145, 146
        from the front, 133
    roof, 127, **168**, 798
      level, 169
      seen from behind, 145, 146
        from the front, 133
    septum, 127, 132, **169**, **796**
      seen from behind, 145
        from the front, 133
          through speculum, 1369
    vestibule, 795
Nostrils, 168, 793
  blood supply, 800
  relation to naso-lacrimal duct, 820
Notch. *See also* Incisura
  acetabular, 254, 259
    absence, 255
  angular, of stomach, 1160
  cardiac, of lung, 1094
    of stomach, 1158
  of cerebellum, anterior and posterior, 574
  clavicular, 114, 115
  ethmoidal, of frontal bone, 190
  fibular, of tibia, 268, 271
  for gall-bladder, 1183
  infrasternal, 1389, 1398
  intercondylar, 262, 265
  jugular, of occipital bone, 149, 150, 194
    of sternum, 114, 115
  of lung, cardiac, 1094
  mandibular, 179, 180
    in old age, 180
  mastoid, 141, **150**, 199
  nasal, of frontal, 189
    of maxilla, 211
  of pancreas, 1195
  parietal, 197
  popliteal, of tibia, 267, 268, 270
  radial, of ulna, 231, 233, 234
  of Rivinus, 828, 1358
  scapular, 219
    great, 220
  sciatic, 251
      in female, 258
    greater, 251, 259, 260
    lesser, 251
  semilunar, of ulna, 231, 234
  sphenopalatine, 128, 142
  of stomach, angular, 1160
    cardiac, 1158
  supra-orbital, 132, 135, 189
    at birth, 191
    surface anatomy, 1348
    variations, 191
  suprasternal. *See* **N.**, jugular
  thyreoid, 1062
  trigeminal, 159, 163
    relation to tentorium, 166
  ulnar, of radius, 236
  umbilical, of liver, 1182, 1183, 1188
  vertebral, inferior and superior, 95
Notochord, 27, **28**, 32, 44, 124, **186**, 313, 495, 496
    development, 28, 31
  in base of skull, 186, 187
  relation to brain, 515
  remains in adult, 30, 124, 313
  surrounded with mesoderm, 29, 33
"Nucha," 136

- **Nuclei of cells**, 8, 10
  - daughter, 11
  - of oöcyte, 16
    - mature, 17, 19
  - of ovum, 16, 21
  - segmentation, first, 24
- **Nuclei of Gray Matter**—
    - afferent and efferent, 507
    - intermediate efferent, 507
    - motor, 591
      - origin in medulla and pons, 552, 553
    - sensory or terminal, 507, 592
        - origin in medulla and pons, 553, 555
      - acoustico-lateral, 507
      - of optic tract, 618
      - of vagus and glossopharyngeal, 594, 595
    - somatic, 507, 591, 592, 594
    - splanchnic, 507, 592, 594, 602
  - of **abducent nerve**, 552, **568**, 587, 589, 597, 598, 604
    - connexion with oculomotor nucleus, 589
      - with vestibular nucleus, 604
    - relation to facial nerve, 597
      - to medial longitudinal bundle, 587
  - of **accessory nerve**, **593**, 604
      - origin, 552
    - connexion with vestibular nucleus, 604
  - ambiguus, 594
    - origin, 552, 591
  - **amygdaloid**, 627, 633, 638
    - arterial supply, 904
    - connexion with caudate nucleus, 635
    - relation to anterior commissure, 645
      - to internal capsule, 639
  - arcuate, 566
      - origin, 553, 555, 556
    - of thalamus, 610
  - of Bechterew. *See* **N.** of vestibular nerve, superior
  - caudate, 631, 633, **634**
    - arterial supply, 904, 905
    - connexions, 637
      - with amygdaloid nucleus, 638
      - with putamen, 636
      - with thalamus, 610
    - functions, 637
  - central, of Luys, 610, 612
  - of **cochlear nerve**, 551, 564, **602**
      - effect of destruction, 584
      - origin, 553, 555
    - dorsal and ventral, 602
  - cuneatus, 548, 549, **560**
      - origin, 553, 555
    - accessory or lateral, 560
  - of Deiters. *See* **N.** of vestibular nerve, lateral
  - dentatus, 576, 577
    - connexion with tænia pontis, 613
    - development, 579
  - dorsalis of spinal medulla, 530, 532
      - connexion with motor fibres, 539
        - with posterior roots, 536
    - of vagus, 594
  - emboliformis, 576
    - development, 579
  - of facial nerve, 567
    - connexions, 598
    - constituents, 597
    - origin, 552, 553
  - fastigii, 576
    - connexion with vestibular nerve, 603
- **Nuclei of Gray Matter**—*continued*
  - fastigii—*continued*
    - development, 579
  - globosus, 576
    - development, 579
  - of **glossopharyngeal nerve**, 564, **594**, 596
    - origin, 553
  - gracilis, 548, 549, **560**
    - origin, 553, 555
  - gustatory, 507
  - habenulæ, 589
  - of **hypoglossal nerve**, 564, **593**
      - origin, 552
    - connexion with facial nerve, 588
  - hypothalamicus, 610, 612
  - intercalatus, 552
  - of intermedius nerve, 597
    - origin, 553
  - laryngeal, 594
  - lemnisci lateralis, 570, 605
  - **lentiform**, 635
    - arterial supply, 904, 905
    - connexions, 637
      - with thalamus, 610, 611
    - function, 637
    - relation to ansæ, 611
      - to anterior commissure, 645
  - of Luys, 610, 612
  - motor, 591
  - of **nervus intermedius**, 597
    - origin, 553
  - of **oculomotor nerve**, 583, 586
    - connexion with abducent nucleus, 589, 598
      - with facial nerve, 588
      - with vestibular nucleus, 589, 604
  - **olivary**, accessory, 556
    - inferior, 548, 556
      - origin, 553, 555
    - superior, 567, 570
        - pedicle, 556, 598
          - connexions, 606
      - connexion with corpus trapezoideum, 604
        - with oculomotor nuclei, 606
      - relation to abducent nerve, 598
  - pontis, 565, 566
    - migration, 556
    - origin, 553, 555, 571
  - ponto-bulbaris, 549, 550
    - origin, 553, 556
  - of posterior commissure, 587
  - postremus, 552
  - **red** or ruber, 586
      - development, 590
      - function, 518
    - connexion with central nucleus, 610
      - with corpus striatum, 637
      - with cortex cerebri, 639
    - in hypothalamus, 611
    - relation to fasciculus retroflexus, 612
  - roof, 576
    - development, 579
  - of thalamus, 609, 610
      - connexion with lemniscus, 589
    - anterior and arcuate, 610
    - lateral and medial, 609
    - ventral, 610
  - of tractus descendens of vestibular, 603
  - of tractus solitarius, 596
  - of tractus spinalis of trigeminal, 560, 599
  - trapezoideus, 604

Nuclei of Gray Matter—*continued*
of trigeminal nerve, 569, 599, 600
motor, 600
origin, 552
mesencephalic, 583, 600
pontine, 569, 600
sensory, 599
origin, 553
pontine, 567, 569, 599
of spinal tract, 560, 599
of trochlear nerve, 583, 586, **601**
connexion with vestibular nucleus, 589, 604
relation to medial longitudinal bundle, 587
of vagus, 564, **594**, 596
origin, 553
of vestibular nerve, 564, **603**, 604
origin, 553, 555
connexion with oculomotor nuclei, 589
with medial longitudinal bundle, 587
Nucleoli, 8, 10
appearance, 11
disappearance, 10
karyo-plasmatic, 16
Nucleolus of oöcyte, 17
mature, 19
Nucleus lentis crystallinæ, 814
pulposus of fibrocartilage, 309
Number of bones, 91
Nurse-cells, 21
of spermatocytes, 20
Nutrition of embryo, 25, 58

Obelion, 130, 295
Obex, 578
"Obturator," 254
Occipital bone, 124, 126, **147**, 153, **193**
in back of skull, 136
in base, 142, 147, 163
in cavity, 154, 163
in side of skull, 137, 140
in top of skull, 129, 154
at birth, 184, 196
in child, 185
chondrification, 186, 187
development, 186
at maturity, 186
origin, 188
ossification, 195
structure, 196
variations, 196
basilar part, 142, **148**, 161, 163, 193
connexion with temporal, 152
relation to foramen lacerum, 161
to notochord, 186, 187
lateral part (or condylar), 148, 163, 193
squamous part, **149**, 163, 166, **193**
Occiput, 126
Oculus. *See* **Eye**
Odontoblasts, 1112, 1233
Œdema glottidis, 1071
of scrotum, 1421
of tongue, 1373
Œsophagus, 465, 473, **1143**
arteries, 911, 927, 932, 937, 1148
lymph vessels, **1014**, **1021**, 1148, 1398
nerve supply, 701, 703, 785, 789, 1148
veins, 966, 1000, 1148, 1398
constrictions, 1144
development, 49, 1237
distance from teeth, 1145
Œsophagus—*continued*
post-mortem, 1144
structure, 1146
variations, 1146
pulsion diverticulum, 1384
relation to carotid artery (abnormal), 889
to pleura, 1146, 1393
to vas aberrans, 929
surgical anatomy, 1384, 1396
Olecranon, **231**, 233, 234
analogy, 293
surgical anatomy, 1443
Oligolecithal oöcytes, 17
Olive of medulla oblongata, 547, **548**, 549
superior. *See* Nucleus
Omentum, 1154
greater, 1154, 1230
adherent to ascending colon, 1156
arterial supply, 933
development, 1240
functions, 1231
surgical anatomy, 1413
lesser, **1155**, 1230
development, 77, 1042, 1240, 1242
Ontogeny, 1, 7
Oöcytes, 12, 14, 15, 16, 17, 1296
maturation of, 17
position in ovary, 15
eutelolecithal, 17
of first order, 13, 14, 15, 16, 19, 20, 23
constituents, 16
difference from zygote, 24
division of, 18
number of chromosomes, 25
mature, 12, 13, 14, 17, **19**, 23, 24
difference from ordinary cell, 17
number of chromosomes, 25
oligolecithal, 17
of second order, 18, 19, 23
telolecithal, 17
Oölemma, 15, 16, 17, 18, 19, 20, 24, 25
Opaque meal, 1165, 1407
Opercula insulæ, 652
of precervical sinus, 79
Ophryon, 132, 295
Opisthion, 148, 295
Opisthotic centre, 200
Opposition of metacarpals, 334
function, 294
Ora serrata, 809
Orbiculus ciliaris, 807
Orbit, 124, **125**, 128, 130, 133, **134**, 155, 158
at birth and in child, 185
arteries, 897, 898, 903
fascia, **453**, 454, **802**
lymph vessels, 1012
muscles, 453, 497, 709
nerves, 678, 679, 681, 686, 687, 688, 692, 782
veins, 135, 973, **974**
axis, 135
floor, 135
measurements, 297
operation to enter, 1369
relations, 134
to ethmoid, 127
to nose, 174
to pterygo-palatine fossa, 141
to sinuses, 174, **176**
roof, 135, 157
variations, 297
Orbito-sphenoid, 205

- **Organs**—
    - growth, atrophy, and death, 9
  - adamant, 1233
  - auditory, 822
    - origin, 55
  - chromaffin, 1323
    - origin, 36
  - end, sensory, 27
    - special, of nerves, 856
  - endocrine, 1321
  - excretory, embryonic, 1311
  - genital, 3
      - female, 1293
      - male, 1271
    - external, female, 1306
      - male, 1281
  - gustatory, 848. *See* **O.** of taste
  - of hearing, 822
  - olfactory, 793
  - parietal, 1342
  - reproductive, 3
    - female, 1293, 1306
    - male, 1271, 1281
  - of respiration, 1061
  - of Ruffini, 858
  - of sense, 3, **793**
  - of sight, 800
  - spiral, of Corti, 843, 844
    - development, 848
    - nerves, 602
  - of taste, 848
  - urinary, 3, 1245
  - urogenital, 1245
    - development, 34, 35, 1310
  - of voice, 1061
  - vomero-nasal, 796
- **Orifices**—
  - anal, 1220
  - aortic, of diaphragm, 473
    - of heart, 869, 872, **874**
  - atrio-ventricular, left. *See* **O.**, mitral
    - right. *See* **O.**, tricuspid
  - of auditory tube, pharyngeal, 1138
    - tympanic, 828
  - of heart, 866, 869, 870, 872, 874
    - development, 1034
    - level, 1396
    - surface anatomy, 1396
  - ileo-cæcal, 1204
  - mitral, 866, 872, 874
  - œsophageal, of diaphragm, 473
  - pulmonary, 872, 873
  - pyloric, 1158, **1159**
  - tricuspid, 866, 870, 872, 873
  - umbilical, 44, 59
    - origin, 42
  - urethral, *external*, female, 1270, 1308
      - surgical anatomy, 1426
      - male, 1283, **1292**
    - *internal*, 1259
      - at birth, 1266
      - position, 1260
  - of uterus, external and internal, 1299
  - of vagina, 1308
  - of vena cava inferior, 870
      - level, 1433
    - superior, 870
  - of vermiform process, 1204, 1206
- Origin of muscles, 365
  - extensor, muscles composing, 229, 399
  - flexor, muscles composing, 229
- Orthocephaly, 296
- Orthognathism, 297
- Orthorrhachia, 299
- **Os, Ossa**—
  - acetabuli, 255
  - basi-oticum, 196
  - capitatum, 239, **241**, 242
    - homology, 293
    - ossification, 246
  - centrale of carpus, 247
  - clitoridis, 1309
  - coccygis. *See* **Coccyx**
  - cordis, 872
  - coxæ. *See* **Hip bone**
  - cranii, 189
  - cuboideum. *See* **Cuboid bone**
  - cuneiformia. *See* **Cuneiform bones**
  - faciei, 211
  - hamatum, 239, **241**
    - homology, 293
    - ossification, 246
    - variation, 294
  - ilium. *See* **Ilium**
  - Incæ, 196.
  - interfrontalia, 191
  - ischii. *See* **Ischium**
  - Japonicum, 217
  - lunatum, 239, **240**, 242
    - homology, 293
    - ossification, 246
  - metacarpalia. *See* **Metacarpal bones**
  - metatarsalia. *See* **Metatarsal bones**
  - multangulum majus, 238, 239, **241**
      - homology, 293
      - ossification, 246
    - minus, 240, **241**, 242
      - homology, 293
      - ossification, 246
  - naviculare. *See* **Navicular bone**
  - odontoideum, 112
  - penis, 1285
  - pisiforme. *See* **Pisiform bone**
  - pre-basi-occipitale, 196
  - pubis. *See* **Pubis**
  - sacrum. *See* **Sacrum**
  - trigonum, 288, 290, 354
  - triquetrum, 239, **240**, 242
    - homology, 293
    - ossification, 246
- **Ossicles**, auditory, 91, 124, 826, **832**
    - development, 57, 835
    - movements, 836
    - ossification, 835
  - of Kerkring, 196
  - mental, 181
  - metopic, 191
  - tympanic. *See* **O.**, auditory
- Ossific centres, 88
- Ossification of bone, 88
    - in cartilage, 88
    - in membrane, 89
  - centres of, 88
- Osteoblasts, 89
- Osteoclasts, 89
- OSTEOLOGY, 3, 83
- Ostium. *See also* **Orifice**
  - maxillare, 798
- Otoconia, 841
- Outlet of pelvis, 257
- Ova, primitive, 1315
- Ovariotomy, 1426
- **Ovary**, 12, 13, 15, 16, 18, 1293, **1294**
    - at birth, 258

- **Ovary**—*continued*
    - in childhood and old age, 1296, 1297
    - descent, 258, 1296
    - development, 1315
  - artery, **931**, 943, 1297
  - lymph vessels, **1026**, 1297
  - nerves, 791, 1297
  - structure, 1296
  - surgical anatomy, 1425
  - veins, 931, **991**, 1297
- Ovules of Naboth, 1303
- Ovum, 1, **15**
    - entrance into tube, 18
    - mature, 12
    - fertilisation, 23
    - segmentation, 25
- Oxygen, 862
- Oxygenation of blood in different animals, 862

- Pad, incisive, 1108
  - infrapatellar, 347, **550**
  - suctorial. *See* **Corpus** adiposum
- **Palate**, 1106
      - cleft, 213, 1371
        - hæmorrhage, 1376
    - arteries, 892, 895, 899, 1108
    - lymph vessels, 1109
    - nerves, 688, 698, 1109
  - hard, 125, 128, 133, 142, **144**, **145**, 146, 168, 1103, **1107**
    - measurements, 297
    - surgical anatomy, 1375
    - variations, 213, 297
  - soft, 146, 147, 1103, **1107**
    - level, 1433
    - muscles, 466
- **Palatine bone**, 124, **128**, 141, **214**
      - origin, 188
      - ossification, 215
      - relation to maxillary sinus, 175
      - structure and variations, 215
    - **horizontal part**, 128, 214
      - seen in nose, 133, 169, 171
      - seen in palate, 144, 145
    - **perpendicular part**, 128, 214
      - relation to maxillary sinus, 175
        - to pterygo-palatine fossa, 171, 173
      - seen in nose, 145, 171, 173, 175
    - **pyramidal process**, 129, **146**, 215
      - in infratemporal fossa, 141
      - in palate, 145
      - in pterygoid fossa, 146, 147
- Pallium of hemisphere, 619
- **Palm of hand**, 217
    - arteries, 921, 923, 925
    - fascia, 385, 386
    - lymph vessels, 1017
    - muscles, 394
    - nerves, 733, 734, 737
    - veins, 984
  - incisions, 1449
  - in pronation and supination, 237
- Palpebrae. *See* **Eyelids**
- **Pancreas**, 3, 1194
      - accessory and lesser, 1198
    - arteries, 932, 933, 935, 1198
    - lymph glands, 1028
    - lymph vessels, 1031, 1198
    - nerves, 789, 1198
    - veins, 1000, 1198
  - development, 52, 1242, 1433, 1434
  - structure, 1198
- **Pancreas**—*continued*
  - surgical anatomy, 1404, 1405, 1406, 1413, 1417, 1434
  - variations, 1198
- Panniculus adiposus, 367, 850
  - carnosus, 368, 448
- **Papilla** dentis, 1233
  - duodeni, 1179, 1194
    - surgical anatomy, 1406
  - of hair, 854
  - incisive, 1107
  - lacrimalis, 816
  - mammæ. *See* **Nipple**
  - nervi optici, 809
  - renal, 1252
  - of skin, 850
    - development, 855
  - of tongue, 1121
    - conical and filiform, 1121
    - foliatæ and fungiform, 1122
    - lenticular and vallate, 1122
- Paracentesis pericardii, 1396
  - pleuræ, 1393
  - of tympanic membrane, 1357
- Paradidymis, 1272
  - development, 1310, 1316
  - homologue in female, 1298
- Paraflocculus, development, 571
- Paraganglia, 1324
  - development, 1326
- Paralysis of laryngeal nerves, 1073
  - obstetrical, 1386
- Parametrium, 1302
- Parathymi. *See* **Gland**, parathyreoid
- Paraxial mesoderm, 123
- Parenchyma testis, 1273
- "Paries," 126
- **Parietal bone**, 124, 126, 153, **191**
    - at birth, 184
    - origin, 188
    - ossification, 192
    - relation to brain, 192
    - structure and variations, 192
  - in back of skull, 136
  - in cavity of skull, 154, 163, 166
  - in side of skull, 138, 140
  - in top of skull, 129, 154
- Par-oöphoron, 1298
  - development, 1310, 1317
- Parovarium. *See* Ep-oöphoron
- **Pars** analis recti, 1218
    - origin, 55
  - ciliaris retinæ, 807, 809
    - structure, 812
  - intermedia of clitoris, 1309
  - iridica retinæ, 809
    - structure, 812
  - mamillaris hypothalami, 606, 607
  - membranacea septi, 874
    - development, 1036
  - optica hypothalami, 606, 607
  - optica retinæ, 809
  - triangularis of cerebrum, 652
- Passage of Eustachian catheter, 1376
  - of female catheter, 1426
  - of male catheter, 1218, 1292, 1419, 1424
    - in child, 1424
    - false, 1419
- **Patella**, 85, 248, 262, 263, **266**
  - analogy, 293
  - articular surface, 345
  - fracture, 1455

- **Patella**—*continued*
  - movements, 351
  - ossification, 267
  - structure and variations, 267
  - surgical anatomy, 1454
- Patellar surface of femur, 262, **263**, 266, 267
- Path, auditory, 605
  - of motor conduction, 649
  - of sensory conduction, 648
- Pecten, 253
- Pedicle of superior olivary nucleus, 598
    - connexions, 606
  - of vertebral arch, 94, 95
- **Peduncles**, cerebellar, inferior. *See* **Body**, restiform
    - middle. *See* **Brachium** pontis
    - superior. *See* **Brachium** conjunctivum
  - cerebral, 542, 543, 580, **581**
      - development, 38, 515, 590
      - functions, 518
    - arterial supply, 904, 908
    - constituents, 583, 585, 590
    - relation to arteries, 904, 908
      - to basal vein, 977
      - to thalamus, 608
    - veins of, 977
  - corporis mamillaris, 613
  - olivary. *See* Pedicle
  - of pineal body, 609
- **Pelvis**, 91, 94, 248, **255**
        - dolichopellic, 298
        - mesatipellic, 298
        - platypellic, 298
      - attachments, 259
      - at birth, 258
      - growth, 258
      - measurements, 298
      - mechanism and movements, 340
      - sex differences, 258
      - at sixth year, 258
      - surgical anatomy, 1419, 1425
      - uses, 255
    - arteries, 931, 936, 938, 941
    - extraperitoneal tissue, 490, 1151
    - fascia, 491, 1150
    - joints and ligaments, 259, 337
    - lymph glands, 1023
    - lymph vessels, 1025
    - muscles, 493
    - nerves, 718, 756, 765, 786, 791
    - peritoneum, 1217, 1225
    - distance from surface, 1217, 1226, 1424
    - veins, 991
  - major, 257
  - minor, 257
        - cavity, **257**, 1149, **1150**
      - relation to ilium, 251
        - to ischium, 252
        - to pubis, 253
    - in female, 258
      - bi-manual examination, 1427
      - surgical anatomy, 1425
- Pelvis, renal (or of ureter), 1255
  - surgical anatomy, 1416
- **Penis**, 1271, 1282
    - development, 1311, 1318
    - homologue in female, 1308
    - structure, 1284
    - surgical anatomy, 1418
  - arteries, 945, 946, 952, 1285
  - epidermis, 851
  - fascia, 486, 487, 1284
- **Penis**—*continued*
  - lymph vessels, **1023**, 1285
  - nerves, 770, 791, 1285
  - veins, 993, 997, 1285. *See also* **Veins**
- Periblast of cartilage, 88
- **Pericardium**, 115, 877
    - arteries, 914, 927
    - development, 32, 34, 77, 1042
    - lymph vessels, 1021
    - nerves, 703, 727
    - relation to cœlom, 32
    - surgical anatomy, 1396
    - veins, 966
  - fibrous, 877, 963
  - serous, 878
- Perichondrium, 87
  - formation, 88
- Pericranium, 153, 1347
- Perilymph, 840
- Perimetrium, 1302
- Perimysium externum, 365
  - internum, 365
- **Perineum**, 247, 248, 253
    - central point, **487**, 492, 493
    - compartments, 1418
    - distance from peritoneum, 1217, 1226, 1424
  - arteries, 945
  - boundaries, 257
  - development, 28
  - fascia, 257, 260, **340**, **486**, 487, 488, **489**, 490, 492
  - lymph vessels, 1022, 1025, 1026
  - muscles, 487
  - nerves, 766, 767, 768
  - surgical anatomy, 1418, 1427
  - veins, 992
- Period of cell life, 12
- **Periosteum**, 85
    - formation, 89
  - alveolar, 182, 1110, 1112
    - development, 1233
  - of ribs, 1389
  - of sternum, 1389
- **Peritoneum**, 1148, 1153, **1223**
      - of bladder, 1223, 1226, 1258, 1263, 1265, **1266**
        - at birth, 1266
      - of cæcum, 1203
      - of colon, 1209, 1210, 1211, 1212
      - of duodenum, 1177, 1178, **1179**
      - of gall bladder, 1192
      - of ileum and jejunum, 1154, 1198
      - of kidney, 1225, 1229, 1247, 1251
      - of liver, 1188, 1225
      - of pancreas, 1196, 1197
      - of rectum, 1216, 1226
      - of spleen, 1343
      - of stomach, 1163
      - of suprarenal gland, 1328
      - of uterine tube, 1297
      - of uterus, 1226, 1300
      - of vagina, 1226, 1300, 1306
      - of vermiform process, 1206
    - adhesions, 1155
    - development, 75, 1240
    - in sections, 1225, 1227
    - surgical anatomy, 1400
    - variations, 1155
  - parietal, 1153, 1223
    - Pacinian bodies in, 857
  - visceral, 1153, 1223

Peritoneum—*continued*
    cavity of, 1148, **1223**
      surgical anatomy, 1402
      surgical divisions, 1404
  pelvic, 1217, 1225
    at birth, 1217
    distance from perineum, 1217, 1226, 1424
    level in pelvis, 1217, 1226
"Peroneal," 271
Pes, 248
  anserinus, 695
Petit, triangle of. *See* **Triangle**, lumbar
Petrous temporal, 126, 199
      quadrate area, 151, **152**, 200
    in child, 185
    chondrification, 187
    in skiagram, 1365, 1370
  seen from below, 150, 152
    in middle cranial fossa, 158, 161, 163
    in posterior fossa, 163, 166, 167
Peyer's patches. *See* Lymph nodules, aggregated
Phænozygon, 297
Phalanx, Phalanges, 245, 286
      homologies, 293
      ungual, 217, 248
    of fingers, 217, **245**
      attachments, 245, 246
      compared with toes, 287
      joints, 245, 336
      movements, 243, 336
      ossification, 246
      structure, 246
      variations, 247
    of *great toe*, 287
    of *thumb*, 245, 246
    of toes, 248, 285, 286
      attachments, 287
      compared with fingers, 245
      joints, 363
      movements, 285, 287, **364**
      ossification, 289, 290
      structure and variation, 290
  of *spiral organ*, 845
Pharyngotomy, subhyoid, 1378
Pharynx, 148, **1134**
        development, 46, 1232, 1236
        relations, 1141
      arteries, 892, 893, 895, 899, **1143**
      lymph vessels, **1014**, 1143
      mucous membrane, 1143
      muscles, 464
      nerves, 688, 698, 700, 781, 1143
      relation to hyoid bone, 183
      veins, 146, 971, 974, 1143
    cavity, 145, 1134
        in laryngoscopic examination, 1076
        openings, 1135
        roof, 145, 146
          level, 148
      laryngeal part, 1141
      nasal part, 1135
        relation to choana, 145
          to pterygoid process, 147
          to sphenoidal sinus, 176
        surgical anatomy, 1376
      oral part, 1138
    wall, 1142
  primitive, 46
    relation to notochord, 30
Philtrum of upper lip, 1105
    development, 1232
Phylogeny, 1

Pia mater, 519, 671
    development, 41
  encephali, 671
  spinalis, 104, 519, 533, 672
Piles, 1222, 1422
Pili. *See* **Hairs**
Pillars of fauces. *See* **Arch**, glosso- and pharyngo-palatine
"Piriform," 125
Pisiform bone, 239, 241, 242
  homology, 293
  joint, 333
  ossification, 246
  seen on wrist, 238
Pits. *See also* Foveolæ
  for arachnoid granulations, 154
  auditory, 847
  granular, 154
  for ligamentum teres, 261, 341
      absence of, 265
  olfactory, 54, 79
  for popliteus, 263
  rectal, 1219
  of stomach, 113, 114
Placenta, 27, 59, **61**
Placode, dorso-lateral, 502
  epibranchial, 502, 710
Planes of abdomen, 1151, 1401
    intertubercular and lateral, 1151, 1401
    subcostal, 1151, 1401
    transpyloric, 1152, 1402
  of the **body**—
    coronal or frontal, 5
    horizontal and sagittal, 5
    median, 4
    vertical, 4
  of **pelvis**, 257
    in female, 258
"Plantar," 248
Planum, 87
Plasma, blood, 861
Plasmosomes, 8
  disappearance, 10
Plastin, 8
Plate, basal, of neural tube, 35, 40, 502, 503
  chorion, 63, 67
  cribriform, of ethmoid, 127, **207**. *See also* **Ethmoid bone**
      in child, 185
      chondrification, 187
  equatorial, of prophase, 10
    daughter, 10, 11
  floor, of neural groove, 35, 40, 502, 503
  lateral, of mesoderm, 495
      derivatives, 34
      formation, 32
  muscle, 34
  neural, 27, 35
    formation of, 35
  orbital, of frontal bone, 125, 135, 155
      relation to ethmoid, 176
  roof, of neural tube, 35, 40, 503
      formation of, 35
    of rhombencephalon, derivatives, 553
  tympanic, 126, 144, 150, **152, 198**
      relation to meatus, 140, 152
    fibrous, 826
    in women, 186
Platelets, blood, development, 70
Platyhieria, 299
Platyknemia, 271, 300
Platymeria, 266, 300

- Platypellia, 298
- Platyrrhine, 297
- **Pleuræ**, 115, 117, 118, 473, 1061, **1082**
  - apex, 118, 120, **1083**
  - lower border, level, 1433
  - *parietal*, 1083
    - cervical, 468, **1083**
      - surgical anatomy, 1385
    - costal, 1084
    - diaphragmatic, 1084
    - mediastinal, 1084
    - pericardial, 1085
  - *pulmonary*, 1083
  - arterial supply, 914
  - development, 34, 75, 1099
  - lymph vessels, 1021
  - relation to kidney, 1249
    - to œsophagus, 1146, 1393
  - structure, 1089
  - surgical anatomy, 1385, 1391
    - in tapping pericardium, 1396
  - veins, 969
  - X-ray examination, 1098
- **Plexuses of arteries**—
  - hæmorrhoidal, 1221
  - subperitoneal, 938
  - subpleural, 914
- **Plexuses, chorioid**—
  - of fourth ventricle—
    - arteries, 907
    - development, 553
  - of inferior horn, 634
    - arteries of, 904, 908
    - veins of, 976
  - of lateral ventricle, 631, 672
    - artery of, 908
    - development, 619
    - veins of, 976
  - of third ventricle, 615, 672
    - artery of, 908
    - development, 619
    - veins of, 672, 976
- Plexuses of lymph vessels, 1002, 1030
- **Plexuses of nerves**—
  - of limbs, 727, 747, 756
    - composition, 772
    - development, 774
    - significance, 773
  - prevertebral, 787
  - sympathetic, 787
    - pelvic, 490, 786, 791
  - aortic, 786, 791
  - annular, of cornea, 805
  - of Auerbach, 1172
  - brachial, 468, 498, 727
    - branches, 731
    - relation to anomalous arteries, 917
      - to fascia, 447
      - to first rib, 118
    - surgical anatomy, 1386, 1439
    - variations, 730
  - cardiac, 787
    - connexion with nerve to sternohyoid, 726
    - deep, 782, 784, 787
    - superficial, 782, 787
  - carotid, external, 782
    - internal, 151, 158, 162, 782
      - connexion with cerebral nerves, 680, 681, 693
  - cavernous. *See* **Pl.**, carotid, internal
    - of clitoris, 792
    - of penis, 791
- **Plexuses of nerves**—*continued*
  - cervical, 459, 722
    - distribution, 727
    - morphology, 727
    - surgical anatomy, 1384, 1385
    - posterior, 713, 715
  - coccygeal, 768
  - cœliac, 785, 789
    - Pacinian corpuscles in, 857
  - of corneal stroma, 805
  - coronary, anterior or right, 787
    - posterior or left, 787, 788
  - dental, inferior, 691
    - superior, 685
  - diaphragmatic. *See* **Pl.**, phrenic
  - gastric, left, 789
  - hæmorrhoidal, 791
  - hepatic, 789, 1192
  - hypogastric, 791
  - infra-orbital, 687, 695
  - of limbs, composition, 772
    - development, 774
    - significance, 773
  - lumbar, 747, **749**
  - lumbo-sacral, 747
    - variations, 749
  - mammary, internal, 847
  - maxillary, external, 691, 782
  - of Meissner, 1172
  - meningeal, middle, 691, 694, 782
  - mesenteric, inferior, 791
    - superior, 790
  - myenteric, of Auerbach, 1172
  - œsophageal, 700, 703, 1145
  - obturator, 753, 754, 755
  - ovarian, 791
  - parotid, 695
  - patellar, 754, 755, 756
  - pelvic, sympathetic, 490, 786, 791
  - pharyngeal, 698, 700
    - ascending, 781
  - phrenic, 727, 789
  - prevertebral, 787
  - prostatic, 791
  - pudendal, 747, 765
    - morphology, 770
  - pulmonary, anterior, 703, 787, 788
    - posterior, 700, **703**, 785
  - renal, 785, 789
  - sacral, 747, **756**
    - posterior, 713, **718**
  - solar. *See* **Pl.**, cœliac
  - spermatic, 751, 791
  - splenic, 789
  - subclavian, 784
  - subepithelial, of cornea, 805
  - subsartorial. *See* **Pl.**, obturator
  - suprarenal, 789, 1328
  - sympathetic, 787
    - pelvic, 490, 786, 791
  - thoracic, 703
  - tonsillar, 1140
  - tympanic, 151, 697, 782, 832
  - uterine, 791
  - utero-vaginal, 1304
  - vaginal, 792
  - vertebral, 148, 784
  - vesical, 791
- **Plexuses of veins**—
  - basilar, 164, 979
  - carotid, internal, 982
  - cavernous, of nose, 800

- **Plexuses of veins**—*continued*
  - dorsal, of foot, 996
  - emissary, of foramen ovale. *See* **Vein**
  - hæmorrhoidal, 992, 1219
    - external and internal, 1222
  - of hypoglossal canal. *See* **Vein**, emissary
  - meningeal, 976
  - ovarian, 992
  - of palm of hand, 984
  - pampiniform, 990, 1274, 1281
      - surgical anatomy, 1421
    - female, **991**, 1297
  - pharyngeal, 149, 151, 161, 971, 974, **1143**
  - prostatic, 992
  - prostatico-vesical, 492, 993, 1287
  - pterygoid, 135, 141, 147, 971, **974**
  - pudendal, 492, **992**, 993, 1287, 1288
    - surgical anatomy, 1420
  - of sole of foot, 996
  - suboccipital, 149, 969, 970, 971, 974
  - tonsillar, 1140
  - uterine, 992
  - vaginal, 992
  - around vertebral artery, 969
  - of vertebral column, 982
    - surgical anatomy, 1434
  - vesical, 992, 993, 1288
- **Plicæ**. *See also* **Folds**
  - cæcalis, 1208
  - circulares, 1173
  - epigastricæ, 1224
  - fimbriatæ, 1123, 1104
  - gastro-pancreaticæ, 1164, 1177, 1228
  - inguinalis (fœtal), 1280
  - inguino-mesonephrica, 1280
  - lacrimalis, 820
  - longitudinalis duodeni, 1179
  - palatinæ, 1107, 1108
  - palmatæ of uterus, 1299
  - prepylorica, 1168
  - pubo-vesicalis, 1226
  - recto-uterina, 1226, 1300
  - salpingo-palatina, 832, **1138**
  - salpingo-pharyngea, 832, **1138**
  - semilunares coli, 1202
    - conjunctivæ, 816
  - sublingualis, 1104
  - testis inferior, 1280
  - triangularis of tonsil, 1139
    - development, 1236
  - umbilicalis, lateral and middle, 1224
  - uretericæ, 1265
  - urogenitalis, 1316
  - vesicalis transversa, 1227, 1268
  - villosæ of stomach, 1169
- Pneumatic bones, 85
- Pogonion, 296
- **Point**, alveolar, 295
  - central, of perineum, **487**, 492, 493
    - surgical anatomy, 1418
  - jugal, 139, 142, 296
  - lateral, of cerebrum, 1349
  - occipital, maximum, 295
  - post-auricular and pre-auricular, 1349
  - of shoulder, 226
  - subnasal, 295
  - supra-auricular, 296
- Polar bodies. *See* **Body**
- Polar projection, first and second, 18
- Poles of cerebrum, 644
  - of crystalline lens, 814
  - of eyeball, 801
- Pollex, 217
- Polymasty, 1319
- Polythely, 1319
- **Pons** of brain, 541, 542, 549
    - arteries, 908
    - development, 38, 553
    - growth, explanation of, 517
    - relation to arteries, 908
      - to skull, 164
      - to sphenoidal sinus, 177
    - structure, 552, 565
    - veins, 978
- Pons hepatis, 1184, 1186
- Ponticulus auriculæ, 824
- "Popliteal," 248
- Pore, gustatory, 849
- Porta hepatis, 1183
- Porus of acoustic meatus, 198
  - crotaphitico-buccinatorius, 206
  - sudoriferus, 852
- Position of acetabulum, 253
  - fœtal, 291
  - of pelvis, 255
  - prone and supine, 237
- Post-axial, 5, 291
- "Posterior," definition, 5
- Posterior region of lower surface of skull, 147
- Post-sphenoid, 205
- Posture, erect, 4, 107, 258, 340, 349, 1165
  - kneeling, 267
  - sitting, 249, 251
- **Pouches**, branchial, 46
      - derivatives, 49
      - formation, 46
    - first, derivatives, 57
  - of duodenum, 1180
  - gill, 1
  - hepato-renal, 1404, 1414
  - inguinal. *See* **Foveæ**
  - perineal. *See* Compartment
  - pharyngeal. *See* **P.**, branchial
  - "pressure," of œsophagus, 1146
  - of Prussak, 836
  - Rathke's, 1339
    - origin, 53
  - recto-genital, 1217, 1258, 1277
  - recto-uterine, 1226, 1300
    - surgical anatomy, 1425, 1427
  - recto-vaginal, 1217
  - recto-vesical, 493, 1217, 1226, 1258, 1268, 1277
    - distance from surface, 1217, 1226, 1424
    - in fœtus, 493
    - surgical anatomy, 1425
  - Seessel's, 51
    - origin, 46
  - utero-vesical or vesico-uterine, 1227, 1258, 1300
    - surgical anatomy, 1425
- Pre-axial, 5, 291
- Pre-basi-occipital bone, 196
- Precoracoid, 292
  - of amphibians, 292
- Precuneus, 659, 662
  - arteries, 905, 909
- Pre-embryonic development, 7
- Prehallux, 294
- Pre-interparietal bone, 196
- Premaxilla, 145
  - absence, 214
  - ossification, 213
  - persistence, 210
- Prepollex, 294

Prepuce of penis, 1283
    veins, 993
  of clitoris, 1307, 1308
Presphenoid, 205
Prisms, adamantine, 1111
Pro-atlas, 196
Pro-cartilage, 88
Processes or **Processus**, 87
  accessory, of lumbar vertebræ, 102, 109
    homology, 113
    variations, 112
  alar, of ethmoid, 157, 206
  alveolar, of maxilla, 128, **144**, 145, 212. *See also* **Maxilla**
  angular, medial, 132, 135, 189
  articular, of vertebræ, 95, 96, 108, 109
    homology and variations, 112
  auditory, 198
  of calcaneus. *See* **Tubercle**
  caudate, of liver, 1184, 1185, 1186
  central, of nerve cells, 499
    of sensory cells, 511
  ciliary, 807
  clinoid, anterior, 155, 158, 203
      connexion with tentorium, 157, 166
      in tumour of hypophysis, 1365
    middle, 158, 202
    posterior, 158, 166, 202
  cochleariformis, 1358
  condyloid, of mandible, 129, 179
    at birth and in old age, 180
    surgical anatomy, 1366
  coracoid, 218, 221
    attachments, 223
    homology, 292
    mistaken for lesser tubercle, 226
    surgical anatomy, 1439
  coronoid, of mandible, 129, 141, **179**, **180**
      at birth, 180, 184
      felt in mouth, 1103
      surgical anatomy, 1366
    of ulna, 231, 233
      surgical anatomy, 1443
  costal, of cervical vertebræ, 97
  descending, of lacrimal, 209
    of squamous temporal, 198
  ethmoidal, of concha, 208
  facial (of parotid), 1128
  falciform, of sacro-tuberous ligament, 259, 260, 338
  frontal, of maxilla, 128, 212. *See also* **Maxilla**
    of zygomatic bone, 128, 132, 135, **216**
  fronto-nasal, 53
  fronto-sphenoidal of zygomatic bone, 128, 135, 139, **216**
  globular, 54, 79
  "head," of notochord, 28
  intra-jugular, 149
  jugular, of occipital bone, 149, 194
      pneumatic condition, 831
    seen from below, 149
    seen inside skull, 163, 166
  lacrimal, of concha, 208
  lenticular, of incus, 834
  of malleus, anterior and lateral, 834
  mamillary, of vertebræ, 102, 109
    homology and variations, 112
  marginal, of zygomatic bone, 139, 216
  mastoid, 141, 199
      seen on back of skull, 136
        on base of skull, 144, 148, 150
        on side of skull, 140, 141
Processes or **Processus**—*continued*
  mastoid—*continued*
    appearance, 201
    at birth, 141, 184, 201
    in child, 141, 201
    infantile and sclerotic, 1360
    structures at level of, 141, **150**
    surgical anatomy, 1360
    variations, 831
    in women, 141, 186
  maxillary, of concha, 208
    of mandibular arch, 53, 79
    of palatine bone, 215
  muscular, of arytenoid, 1064
  nasal, lateral, 54, 79
    median, 54, 79
  odontoid, 97, 98
    connexion with second vertebra, 313
    development, 123
    homology and variations, 112
  orbital, of palatine bone, 128, 173, 215
      relation to ethmoid, 176
        to orbit, 135, 173
      variations, 215
    of zygomatic bone, 216
  palatine (embryonic), 54
    of maxilla, 128, 213. *See also* **Maxilla**
  papillary, of liver, 1185
  paramastoid, 149, 196
  para-occipital, 111, 149, 196
  peripheral, of sensory cells, 499, 511
  petrosal, of sphenoid, 202
  phalangeal, of rods of Corti, 844
  plantar, of navicular, 283
  post-auditory, 198, 201
  protoplasmic, of nerve cells, 508, 511
  pterygoid, 127, 144, **146**, 204
      chondrification of root, 187
      ossification, 205
      relation to foramen lacerum, 161
        to palatine bone, 128, 129
        to pterygoid canal, 142, 162
        to pterygo-palatine fossa, 141
        to sphenoidal sinus, 176
    lateral lamina, 127, 144, **146**, **147**, 204
      in infratemporal fossa, 141, 146, 147
    medial lamina, 127, 144, 146, 147, 204
      in nose, 128, 145, 146, 147, 171
  pterygo-spinous, 204
  pyramidal, of palatine bone, 129, **146**, 215
    in infratemporal fossa, 141
    in palate, 145
    in pterygoid fossa, 146, 147
  retro-mandibular (of parotid), 1127, 1128
  sphenoidal, of palatine bone, 129, 215
      in roof of nose, 146, 169, 173
    of septal cartilage, 795
  spinous, of vertebræ, 94, 95, 96, 108
    development, 123
    homology, 112
    levels, 99, 1433
    surface anatomy, 1427
  styloid, of fibula, 271
    of metacarpal, third, 243, 244
      variation, 247
    of radius, 235, 236
      surgical anatomy, 1445
    of *temporal bone*, 126, 140, 144, **150**, 198, 199
      level of root, 151
      ossification, 200
      relation to pharynx, 1142

Processes or **Processus**—*continued*
  styloid—*continued*
    of ulna, 232, 233
      compared with radius, 236
      surgical anatomy, 1445
  of talus. *See* **Tubercle**
  temporal, of zygomatic bone, 128, 138, 216
  of Tomes, 1234
  transverse, of vertebræ, 95, 96, 108
      development, 123
      homologies and variations, 112
    of atlas, **97**, 149
      surgical anatomy, 1383
    of fifth lumbar, 102
        surgical bearing of, 1438
  trochlear, of calcaneus, 278
    surgical anatomy, 1458
    variations, 290
  tubal, of pterygoid process, 147, 832
  uncinate, of ethmoid, 173, 207
      relation to maxillary sinus, 175
    of pancreas, 1194, 1195
      separate, 1198
  vaginal, of pterygoid lamina, 145, 146, 205
  vaginalis testis, 1224, 1280
    in child, 1399
    homologue in female, 1302
  vermiform, 1205
      at birth, 1206
      in child, 1207
      development, 52, 1238
    artery, 935, 1207
      surgical anatomy, 1411
    lymph glands, 1028
    lymph vessels, **1031**, 1207
    nerve supply, 791
    structure, 1207
    surgical anatomy, 1404, **1411**, 1425
    veins, 1000
  vocal, of arytenoid, 1065
    in laryngoscopic examination, 1076
  xiphoid, 87, 114, 120
  zygomatic, of frontal, **132**, 134, 138, 139, 189
      relation to brain, 155
      surgical anatomy, 1348
    of maxilla, 128, 211, **212**
      relation to maxillary sinus, 174
    of temporal, 126, 138, 197
      variations, 202
Proctodæum, derivative, 55
  formation, 46
Prognathism, 297
Projection, polar, first, 17
    second, 18, 19
Prominence, laryngeal, 96, 1062
Prominentia canalis facialis, 827
  spiralis of cochlea, 843
  styloidea, 828
Promontory of ear, 140, 167, **827**, 1358
      seen through tympanic membrane, 1357
      surgical anatomy, 1361
    of sacrum, 103
        in female, 258
      level, 1402
      in pelvic brim, 257
Pronation, **237**, 330
  function, 294
Pronephros, 1040, 1310, 1313
Pronucleus, female, 19, 23, 24
  male, 19, 24
Pro-otic centre, 200
Prophase of cell division, **10**, 12, 13
Prosencephalon, 515, 518, 606
  development, 38
Prostate, 487, 494, 1271, **1285**
    arteries, 943, 1288
    lymph vessels, 1026
    nerves, 786, 791, 1288
    sheath, 487, 490, 491, **492**, 1285, **1287**
    structure, 1287, 1420
    surgical anatomy, 1420
    veins, 992, 993, 1288
  in child, 1424
  development, 1317
  homologue in female, 1270, 1317
  hypertrophy, 1419, 1420
  in old age, 1288
Prostatectomy, 1420, 1421
Prosthion, 133, 295
Protoplasm, 8
Protuberance, mental, 177
  occipital, external, **136**, 149, 193, 1348
      attachments, 150
      in child, 1348
      relation to internal protuberance, 163, 164
    internal, 163, 165, 193
      attachments and relations, 164, 166
"Proximal," definition, 5
Prussak's pouch, 836
Pterion, 138, **139**, 296
  at birth, 184
  in lower races, 202
  relation to brain, 157, 161
    to meningeal artery, 159, 161
    to small wing, 159, 161, 203
  surface anatomy, 139, 1349, 1350
"Pterygoid," 127
Ptyalin, 1134
Pubes, 253
Pubis (bone), 249, **252**, 259
    homology, 292
    ossification, 254
Pubis (region), 252
Pudendum muliebre, 1306
Pulled-elbow, 1444
Pulmo. *See* **Lung**
Pulp of spleen, 1344
  of tooth, 182, 1110, **1112**
    development, 1233
Pulvinar, 609
  connexion with occipital lobe, 618
    with optic tract, 617
Puncta lacrimalia, 819
    surgical anatomy, 1368
Puncture, lumbar, 102, 1435
Pupil of eye, 808
    in fœtus, 808
Purkinje's cells of cerebellum, 579
  fibres of heart, 875
Purple, visual, 810
Putamen, 636
  connexion with amygdaloid nucleus, 638
Pylorectomy, 1409
Pylorus, 1158
  development, 1433
  in skiagrams, 1408
  surgical anatomy, 1407, 1430
Pyramid of cerebellum, development, 573
  of medulla oblongata, 547, 549, 562
      decussation, 544, **546**, 556, **568**
  of middle ear, 828
Pyramids, renal, 1252

Pyramis ossis temporalis. *See* **Petrous temporal**
vestibuli, 837, 840

Radiation, acoustic, 654
in internal capsule, 639
of corpus callosum, 629
optic, 610, **618**, 632, 656
connexion with oculomotor nucleus, 602
in internal capsule, 639
thalamic, 608, 610
thalamo-occipital, 656
thalamo-temporal, 654
Radiograms. *See* Skiagrams
Radius, 217, **234**
compared with humerus, 299
fracture, 236, 237
homology, 293
movements, 238, 294, 330
nerve supply, 734
nutrient artery, 924
ossification, 237
in pronation and supination, 237, 238
structure and variation, 237
surgical anatomy, 1443, 1445
Radix. *See* **Root**
Rami communicantes of ganglia of fifth nerve, 597
communicantes, *gray*, 719, 778
development, 792
cervical, 725, 730, 743, 781, 782, 783
coccygeal, 765, 786
lumbar, 747, 785
sacral, 747, 765, 786
thoracic, 744, 746, 784
white, 506, **713**, 719, **778**
development, 532
lumbar, 748, 785
sacral, 748, 765, **778**, 791
thoracic, 744, 746, **784**
connexion with splanchnic nerves, 785
thoracico-lumbar, 778
conjoined, of pubis and ischium, **253**, 256, 259
of ischium, 249, **251**, 259, 260
of lateral fissure, 651
of mandible, 129, 141, **178**, **180**
surgical anatomy, 1366
of pubis, inferior, 249, **253**, 259, 260
superior, 249, **253**, 259
of spinal nerves, 713, 714, 719
anterior, 713, 719
cervical, 721
first, 470, **721**
second, 722
coccygeal, 747, 765, 768
lumbar, 747, **749**, 756
sacral, 102, 105, 747, **756**, 765, 768
thoracic, 742
communications, 743, 744, 746, 747, 784
first, 118, 743
second, 743, 744
third to sixth, 744
seventh to eleventh, 746
relation to transversus, 482
surgical anatomy, 1401
twelfth, 473, 746
posterior, 713, **714**
distribution, 718
morphology, 718

Rami—*continued*
of spinal nerves—*continued*
posterior—*continued*
cervical, 715, 717
first, 313, 444, **715**
second and third, 715
fourth to eighth, 717
coccygeal, 718
lumbar, 718
sacral, 103, 106, **718**
thoracic, 717
Raphe, ano-coccygeal. *See* **Body**
median, of medulla oblongata, 555, 561, 564
of mid-brain, 586
of pons, 555, 567
of palate, 1107
palpebral, lateral, 135, **816**
pharyngeal, 148, 465
pterygo-mandibular, 147, 180, 452
of rhombencephalon, development, 555
of scrotum, 1281
of tongue. *See* **Septum**
Rays, medullary, of kidney, 1253
Recesses or **Recessus**—
cameræ posterioris of eyeball, 813
cochlearis of vestibule, 837
duodeno-jejunal, 1179
ellipticus, 837, 840
epitympanic, **826**, 827
surgical anatomy, 1358, 1359
frontal, of nose, 797
ileo-cæcal, 1208
infundibular, 607, 616
intersigmoid, 1213
surgical anatomy, 1414
labyrinthi, 55
lacrimalis of maxilla, 214
naso-palatine, 798
of omental bursa, 1228, 1229
optic, 606, 616
paracolic, 1209
pharyngeal, 832, 1136, **1138**
surgical anatomy, 1376
pineal, 606, **616**, 1341
piriform, 1069
in laryngoscopic examination, 1076
pneumato-enteric, 1240
retro-cæcal, 1208
surgical anatomy, 1412
sacciformis, 329
sphæricus, 837, 840
spheno-ethmoidal, **171**, **172**, 176, **797**
supratonsillar. *See* **Fossa**
of Tröltsch, 836
utriculi (of ear), 840
of ventriculus quartus, lateral, 550
development, 553
relation to cerebral nerves, 550
tertius, 616
infundibular, 616
development, 607
optic, 616
pineal, **616**, 1341
development, 606
suprapineal, **616**, 1341
origin, 39
Rectum, 105, **1213**
ampulla, 493, **1215**
at birth, 1239
in child, 1217, 1218
development, 52, 53, 1239, 1311
digital examination, 1422, **1423**, 1427

Rectum—*continued*
examined by sigmoidoscope, 1424
excision, 1420, **1424**
arteries, 936, 939, 943, 944, 1221
lymph vessels, **1026**, 1222
nerves, 786, 791, 1222
peritoneal relations, 1216, 1226
sheath, 491
structure, 1171, 1218
variations, 1223
veins, 992, 1000, 1222
Regeneration of epidermis, 851
of nails, 855
Regions, abdominal, 1152, 1401
epigastric and hypochondriac, 1152, 1401
hypogastric and iliac, 1152, 1402
lumbar and umbilical, 1152, 1402
axillary, 1389
frontal, of cerebrum, 663, 664
of skull, 130
at puberty, 185
gluteal, 247
hypothalamic, 611. *See also* Hypothalamus
infra-axillary and infraclavicular, 1389
inframammary and infrasternal, 1389
inguinal, 248, 1152
fascia, 404
surgical anatomy, 1453
interscapular, 1428
of loins, 1428
of lower surface of skull, anterior, 144
posterior, 147
mammary, 1389
maxillary, of skull, 133
olfactory, of nose, 796
parietal, of cerebrum, 660
pectoral, 217
precentral, 664
of pubis, 252
respiratory, of nose, 796
scapular, 217
of spinal medulla, 520
different characters, 528
suprapubic, 1152
suprascapular, 1428
suprasternal, 1389
Reidel's lobe, 1187
Renes. *See* **Kidneys**
Reniculi, 1252
Reproduction of cells, 9
Reptiles, Permian, 292
Resection of cæcum and ascending colon, 1412
of ribs, 1393, 1396, 1406
of stomach, 1408, 1413
Respiration, 474
in laryngeal paralysis, 1073
RESPIRATORY SYSTEM, 1061
Resting stage of cells, 9, **11**
of spermatids, 20
Rete testis, 1273
development, 1315, 1316
Reticulum of cells, 8
linin, 8, 10
of oöcyte, 16
mature, 19
sustentacular of spinal medulla, origin, 41
Retina, 809
artery, 812, 903
development, 36, 38, 502, 820, 821
pars ciliaris, 807, 809
iridica and optica, 809
Retinacula of hip joint, 342
ocular, 802
peroneal, inferior, 278, **424**
superior, 274, **424**
of skin, 850
Retroversion of tibia, 267, 271
of uterus, 1302
Retzius' space. See **Space**, retropubic
striæ of teeth, 1111
Rhinencephalon, 625
Rhinion, 133, 295
Rhinoscopy, anterior, 1369
posterior, 1376
Rhodopsin, 810, 812
Rhombencephalon, 515, 516,
development, 38, 553, 555
explanation of shape, 516
alar lamina, derivatives, 553
basal lamina, derivatives, 552
Ribs, 2, 5, 85, 91, 99, **116**, 119
bicipital, 123
cervical, 99, 112, **123**
surgical anatomy, 1385, 1387
false and floating, 116
lumbar, 102, 123
true, 116
typical, 117
first, 118, 120, 122
nutrient artery, 915
surgical anatomy, 1386, 1387, 1389
second, 114, 119, 122
nutrient artery, 915
twelfth, 119, 120, 122
relation to pleura, 1393
attachments, 117, 122
development, 124
epiphyses, 91, 123
joints, 315, 316
movements, 319, 474
ossification, 122
periosteum, 1389
relation to abdomen, 1150
resection, 1393, 1396, 1406
serial homology, 2
structure and variations, 123
surface anatomy, 122, 1389, 1428
Ridge, genital, 1315
on multangulum majus, 238
surface anatomy, 239
pronator, 233
trapezoid, 224, 225
Wolffian, 44, 78
Rima glottidis, **1070**, 1074
closure, 1066, 1070, 1075
muscles acting on, 1072
opening, 1066, 1070
surface anatomy, 1379
oris, 1101
palpebrarum, 815
pudendi, 1293, **1306**
development, 1310
vestibuli, 1070
Ring, crural. *See* **R.**, femoral
end-, of spermatozoon, 21
femoral, **407**, 478
inguinal, abdominal, 407, 482, **484**
surface anatomy, 1398
subcutaneous, **478**, 484
method of finding, 1398
pyloric, 1158
tympanic, 201, 825
Rings of trachea, 1080

Rod-bipolars of retina, 811
Rod-granules of retina, 812
Rods of Corti, 844
  of retina, 812
Roof of cranial cavity, 154
  of infratemporal fossa, 141
  of mouth, 146, 1103, 1106
  of nose, **168**, 798. See also **Nose**
  of orbit, 135, 157
  of pharynx, 145, 146
    level, 148
Roof-plate of neural tube, 35, 40
Roots, formation of, 35
  of coracoid process, 221
    attachments, 223
  of ganglion ciliare, 680, **683**
      oticum, 691
      spheno-palatinum, 688
      submaxillare, 691
  of little toe, 287
  of lung, 1094
    level, 1433
    surface anatomy, 1394
  of **nerve**, *facial*, 167, 693
      sensory. *See* **Nervus** intermedius
    spinal, 711, 712
        connexion with medulla, 520
        development, 37, 773
        length, 521
        piercing meninges, 668, 669, 673
        surgical anatomy, 1434, 1435
      anterior, 525, 530, 545, **712**
      posterior, 545, **711**
        development, 37
        termination, 535
    trigeminal, 681
        arterial supply, 897, 908
      motor, 147, 163, **681**, 688
          origin, 600
        descending, or mesencephalic, 569, **600**
          in pons, 569
      sensory, 163, **681**
        in brain, 599
  of nose, 130, 793
  of penis, 1283
    surgical anatomy, 1418
  of teeth, 181, **1109**
  of tongue, 1123
  of vertebral arch, 94, 95
  of **zygoma**, 139, **197**
    anterior, 138, 144, **197**
    middle, 139, **198**
    posterior, 138, 144, 165, **197**
      surgical anatomy, 1349
Rostrum of corpus callosum, 628
    arterial supply, 904
  sphenoidale, 202
Rotation of intestine, 1238
  at joints, 305
  of limbs, 291
  of stomach, 1237, 1240
Rudiment of bone, 88
  parapineal and pineal, 1342
  of processus vaginalis, 1280
  of tongue, 50
Rugæ of palate. *See* **Plicæ**
  of scrotum, 1281
  of stomach, 1168
  of vagina, 1306
Running, 437
Rupture of urethra, 1418, 1419

Sac, entodermal, 28
  of hernia, 1399, 1400
  lacrimal, 127, 134, 451, **820**
    arteries, 820, 898
    development, 822
    surgical anatomy, 1368
  peritoneal, general, 1223
  tooth, 1233, **1235**
  yolk, 60
    formation, 42
    relation to mesoderm, 32
Sacs, air, of lung, 1097
Saccule of ear, 840
    development, 56, 848
    nerves, 602, 837, 840, 846
Saccules, alveolar, of lung, 1097
Saccus endo-lymphaticus, 167, **841**
    development, 55, 56, 847
Sacrum, 94, **102**, 108, 259, 260
    dolichohieric and platyhieric, 299
  changes with erect attitude, 258
  in female, 106, 258
  homologies, 112, 113
  measurements, 299
  ossification, 111
  relation to hip bone, 249
    to pelvis, 248, 255
  sexual differences, 106, 258
  variations, 112
Saddle. *See* Sella
Sagitta, 130
Sagittal plane, 5
Saliva, 1127
Salts of bone, 84
Sand, brain-, 1341
Sarcolemma, 365
Scala media, 57
  tympani, 57, 839, 840
  vestibuli, 57, 839, 840
Scalp—
  arteries, 894, 895, 896, 897, 903, 904; 1347
  fascia, 446
  hæmorrhages, 1347
  lymph vessels, **1011**, 1347
  muscles, 448
  nerves, 682, 686, 690; 695; 715, 716, 723
  surgical anatomy, 1347
  veins, 973, 1347
Scapha auriculæ, 823
"Scaphoid," 146
Scapula, 85, **217**, 218
    angle, inferior, 219
        level, 99, 122, 219
        relation to latissimus, 371
      lateral, 219
      medial, 219
        level, 1433
    borders and surfaces, 219
  attachments, 222
  at birth, 298
  connexion with axial skeleton, 217, 294
  epiphyses, 91, 223
  fracture, 1439
  homology, 292
  ligaments, 322
  measurements, 298
  movements, 321
  ossification, 223
  structure and variations, 223
  surgical anatomy, 1439
  "winging," 376
Scapus of hair, 853

Scarpa's foramen, 145, 169
Schindylesis, 302
Schreger's lines, 1111
"Sciatic," 251
Sclera, 454, **802**
  blood-vessels, 803
  development, 821
  fusion with fascia bulbi, 802
  nerves, 803
Sclerotome, 495
Scoliosis, 1438
Scrotum, 1271, **1281**
    development, 1311, 1317
    in fœtus, 1282
    homologue in female, 1306
    surgical anatomy, 1421
  arteries, 945, 952, 953, 1282
  fascia, 486, 487, 1282
  lymph vessels, 1023
  nerves, 751, 767, 769, 1282
  septum, 486, 487, 1282
  veins, 997
Sebaceous secretion, first appearance, 81
Sebum cutaneum, 854
Section of kidney, 1252
  of skull, 153
Seessel's pouch, 51
  development, 46
Segment, scleratogenous, 33
  of spinal medulla, 520
    distribution, 1435
Segmental type of animals, 2
Segmentation, 2
  of ovum, 25
  of skull, 188
Sella turcica, **157**, 202
  in skiagrams, 1365
  surgical anatomy, 1364
Semi-canal. *See* **Canal**
SENSE ORGANS, 3, **793**
Separation of epiphysis, 91
Septula testis, 1273
Septum atriorum, 869
      primum et secundum, 1034
    development, 1034
    malposition, 966
    variations, 876
  canalis musculo-tubarii, 827, 828
  of clitoris, 1308
  femoral, 407
  of heart, 869, 872, 874
      of birds and mammals, 3
    development, 1034, 1036
    malposition, 966
    variations, 876
  interatrial. *See* **S.** atriorum
  intermuscular, 367
      nerve endings in, 856
    of arm, 229, **381**, 384, 399
      surgical anatomy, 1442
    of leg, 274, **423**
      surgical anatomy, 1456, 1457
    peroneal, 274, **423**
      surgical anatomy, 1456, 1457
    of thigh, 265, 406, 409, 410, 417, 421
      surgical anatomy, 1450, 1451
  intersegmental, 123
  interventricular. *See* **S.** ventriculorum
  mediastinal, 1082
  of musculo-tubal canal, 827, 828
  of nose, 127, 132, **169**, **796**
      mobile, 795
Septum—*continued*
  of **nose**—*continued*
    chondrification, 187
    seen from behind, 145
      from the front, 133
        through speculum, 1369
  orbital, 816
  pectiniforme of penis, 1284
  pellucidum, **629**, 631
    arteries, 904
    development, 626
  peroneal, 274, **423**
    surgical anatomy, 1456, 1457
  posterius of spinal pia mater, 670
  primum of atria, 1034
  recto-vesical, 493
  of rhombencephalon, development, 555
  of scrotum, 486, 487, 1282
  secundum of atria, 1034
  of spinal medulla, postero-median, **523**, 524
    development, 523
  of tongue, 1123
  transversum, 72, 73, 74, 77, 1033
      connexion with liver, 1241, 1242
      derivatives, 1042
      origin, 75
    of semicircular duct, 842
  urethral, 1314
  ventriculorum, 872, 874
    development, 1036
    variations, 876
Serial homology, definition, 2, 3
Sesamoid bones, **85**, 91
  of great toe, 285, **290**, 363, 435
  of hand, **247**, 335, 396
  of index, 335
  of lower limb, 290
  of thumb, 247, 335, 396
    articulation, 243
Sesamoid cartilages, 88
  of larynx, 1065
Sex, external manifestations, 81
Sex-chromosomes, 24, 25
Sex-determination, 24
Sex-differences in larynx, 1071 1076
  of pelvis, 258
  of sacrum, 106
  of skull, 186
Shape of heart, 867
  of skull, 295
Sharpey's fibres, 85
Sheath of arteries, 865
    axillary, 373, 447, 916
    carotid, **448**, 460, 469, 888
      surgical anatomy, 1377
    femoral, 405, **407**, 475, **951**
      surgical anatomy, 1453
  dentinal, 1111
  of **nerves**, *fibrous*, development, 36, 37
      of cerebral nerves, 665, 669, 671
      of spinal nerve-roots, 668, 669, 673
    medullary, 509
      date of appearance, 510
    primitive, 509
      origin and formation, 27, 37
  of Neumann, 1235
  of rectus abdominis, 477, 480, **434**
    surgical anatomy, 1400, 1401
  of spermatozoon, axial, 21, 22
    mitochondrial, 21, 22
    spiral, 21, 22

- **Sheath**—*continued*
  - of tendons, *fibrous*—
    - of flexors of fingers, 246, **387**
      - of toes, 287, **425**
    - of peroneus longus, 435, 436
    - *mucous* or *synovial*, 305, 368
      - of extensor digitorum longus, 424
        - hallucis longus, 424
      - of flexor carpi radialis, 387, 388
        - digitorum longus, 424, 431
      - of flexors of fingers, 387
        - surgical anatomy, 1448
      - of flexor hallucis longus, 424, 432
        - pollicis longus, 385, 393
      - of peroneus brevis and longus, 424, 429
        - tertius, 424
      - of tibialis anterior, 424
        - posterior, 424, 433
  - of viscera—
    - of parotid gland, 446
    - of prostate, 487, 490, 491, **492**, 1285, **1287**, 1420
    - of rectum, 491
    - of submaxillary gland, 446
    - of thyreoid gland, 448
    - of ureter, 1257
- Shin-bone. *See* **Tibia**
- Shin of leg, 268
- Short bones, 85
  - growth, 89, 90
- Shoulder, 217. *See also* **Joint**
  - dislocation, 1439
  - fascia, 376
  - movements, 237, 294, 321, 325, 380
  - muscles, 376
  - surgical anatomy, 1438
- Shoulder-blade. *See* **Scapula**
- Sibson's fascia, 109, 119, 122, **1084**
- Side of skull, 137
- "Sigmoid," 165
- Sigmoidoscope, 1424
- Sinciput, 126
- Sino-spiral system, 875
- **Sinuses**, 87
  - **air**, 124, **174**, 800
    - at birth, 183
    - functions, 85, 174
    - lymph vessels, 1013
    - measurements, 800
    - in old age, 186
    - at puberty, 185
    - in skiagrams, 1364, 1365
    - structure, 85, 174
    - **ethmoidal**, 127, **176**, 207, 800
      - arteries, 899, 904
      - at birth, 207
      - nerves, 157, 683
      - relation to cranial cavity, 155
        - to nose, 174
        - to orbit, 134
      - in skiagrams, 1364
      - *anterior*, 172
        - opening, 173
        - relation to frontal sinus, 176
          - to lacrimal sac, 820
        - surgical anatomy, 1363
      - *middle*, 173
      - *posterior*, 172
        - relation to sphenoidal sinus, 176
    - **frontal**, 126, 173, **176**, 191, 800
      - arteries, 904
      - growth, 191
- **Sinuses**—*continued*
  - **air**—*continued*
    - **frontal**—*continued*
      - measurements, 800
      - nerve supply, 682
      - relation to cranial cavity, 155
        - to ethmoidal sinuses, 176
        - to nose, 168, 169, 173, 174
        - to orbit, 134, 135
        - to superciliary arch, 130, 132
      - in skiagrams, 1363
      - surgical anatomy, 1362
      - trans-illumination, 1363
    - **maxillary**, 128, **174**, 800
      - arteries, 800, 898, 899
      - development, 213
      - empyema, 1370
      - measurements, 800
      - nerves, 685, 687
      - openings, 133, 171, 172, 173, 174, 212
      - relation to nose, 174
        - to orbit, 134, 135
      - in skiagram, 1370
      - surgical anatomy, 1369
      - variations, 214, 215
    - **palatine**, 173, 177
      - relation to ethmoidal sinuses, 176
    - paranasal, 174
    - **sphenoidal**, 126, 153, **176**, 202, 800
      - arteries, 800, 899
      - development, 205
      - measurements, 800
      - nerves, 157, 683
      - opening in nose, 169, 172
      - relation to cranial cavity and contents, 158, 159
        - to ethmoidal sinuses, 176
        - to nerve of pterygoid canal, 688
        - to nose, 168, 174
        - to orbit, 134
      - in skiagrams, 1364
      - variations, 206, 210
  - of aorta, 880
  - of Arlt, 820
  - central, of villi, 1173
  - coronary, of heart, 963, **964**
    - abnormalities, 967
    - absence, 966
    - development, 1037
    - morphology, 1058
  - of epididymis, 1272
  - of kidney, 1245, **1252**
  - lactiferous, 1319
  - of lymph glands, 1003
  - of Maier, 819
  - of Morgagni, 1142
  - oral. *See* Stomatodæum
  - of pericardium, oblique, 867, **878**
    - transverse, 878
      - development, 1033
  - phrenico-costal, 1092
  - of portal vein, 998
  - precervical, 47, 79
  - prostatic, 1288, **1289**
  - of pulmonary artery, 878
  - rectal, 1220
    - surgical anatomy, 1422
  - renal, 1245, **1252**
  - tarsi, 280
  - tonsillaris, **1138**, 1236
  - tympani, 828
  - of utricle, 840

- **Sinuses**—*continued*
  - utricularis sacculi, 840
  - venosus of heart, 73, 74, 1033
      - derivatives, 1037
      - origin, 72
      - in septum transversum, 1042
    - scleræ, **803**, 804, 805, 809, 1012
  - **venous**—
    - coronary, 963, **964**
      - abnormalities, 966, 967
      - development, 1037
      - morphology, 1058
    - of skull, 975
        - connexion with subarachnoid space, 671
          - with veins outside, 1347
        - development, 1041, **1047**
        - morphology, 1057
      - basilar. *See* **Plexus**
      - cavernous, 135, 147, 151, 162, 164, 166, **981**
          - development, 1041
        - in needling mandibular nerve, 1367
        - in operation on hypophysis, 1365
        - relation to sphenoidal sinus, 176
        - surface anatomy, 158
      - circular, 979
      - intercavernosus, 158, 978, 979
      - occipital, 164, **981**, 983
        - absence, 981
      - parasinoidal, 1354
      - petrosal, *inferior*, 164, 971, **981**
            - development, 1047
          - connexion with ear, 847
          - in jugular foramen, 166
        - *superior*, 159, **666**
            - development, 1047
          - connexion with ear, 847
          - relation to tentorium, 166
      - petro-squamosal, 202, **981**
      - rectus. *See* **S.**, straight
      - sagittal, *inferior*, 666, **978**
          - absence, 981
          - development, 1047
        - *superior*, 130, 133, 154, 157, 164, 166, **978**, 1354
          - development, 1047
          - relation to granulations, 670
      - sigmoid, 136, 149, 151, 163, **980**
          - development, 1047
        - arterial supply, 894
        - in jugular foramen, 166
        - relation to antrum, 165
          - to mastoid air-cells, 166
        - surgical anatomy, 1355, 1361
      - spheno-parietal, 157, 976, **981**
        - absence, 981
      - straight, 164, 666, **979**
        - development, 1047
      - transverse, 136, 140, 151, 163, 164, 666, 976, **980**
          - abnormality, 981
          - development, 1047
          - diploic tributary, 976
        - in jugular foramen, 166
        - surgical anatomy, 165, 1350, 1354, 1361
    - vertebral, longitudinal, 982
  - of villi, central, 1173
- Sinusoids of liver, 1042
- Sitting, 249, 251
- Size of heart, 876
  - of skull, 295
  - of stomach, 1156
- Skein, chromatic, 10
- Skeleton, 83, 91
- Skiagrams of air sinuses, 1363, 1364, 1365, 1370
  - of cervical rib, 1387
  - of elbow, 1444
  - of hypophyseal fossa, 1364, 1365
  - of petrous temporal, 1365, 1370
  - of stomach, 1165, 1407
- **Skin**, 3, **849**
  - appendages, 852
  - arteries, 367, 851
  - development, 855
  - lymph vessels, 852
  - nerve endings in, 852, 856
  - veins, 852
- **Skull**, 91, 124. *See also* **Cranium**
            - in elasmobranchs and mammals, 186
          - as a whole, 129
        - back, 136
        - base, external, 142
            - internal, 155
          - weak areas, 1349
        - bones, 85, 125, 189
          - growth, 90
        - cap, 85, 153, 154
        - cavity, 153
        - front, 130
        - interior, 153
        - lower surface, 143
          - anterior region, 144
          - posterior region, 147
        - maxillary region, 133
        - side, 137
        - top, 129
        - vault, 88, 154
        - vertex, 130
      - age changes, 185
      - base line, 1350
      - at birth, 183
      - capacity, 295
      - in child, 153
      - chondrification, 186
      - circumference, 296
      - definition, 125
      - development, 186
      - diameters, 296
      - fracture, 159, 1349
      - growth, 90, 185
      - human characters, 189
      - indices, 295
      - joints, 83, 302, 312, 314
      - landmarks, 1348
      - longitudinal arc, 296
      - at and after maturity, 186
      - measurements, 295
      - morphology, 186
      - movements, 313
      - in old age, 186
      - at puberty, 185
      - section, 153
      - segmentation, 188
      - sex differences, 186
      - surgical anatomy, 1347
      - tables, 124, 159, 1349
      - thickness, 153, 1349
      - veins, 975
      - in women, 186
    - cartilaginous, 186
        - derivatives, 188
      - chordal part, 186

Skull—*continued*
    cartilaginous—*continued*
      evertebral part, 189
      prechordal part, 186
      vertebral part, 189
    membranous, 186
      derivatives, 188
    primordial, 186
  acrocephalic, 296
  brachycephalic, 295
  brachyfacial, 297
  brachy-uranic, 298
  chamæcephalic, 296
  chamæprosopic, 297
  cryptozygous, 297
  dolichocephalic, 295
  dolichofacial, 297
  dolicho-uranic, 298
  hypsicephalic, 296
  leptoprosopic, 297
  leptorrhine, 297
  macrodont, 298, 1236
  megacephalic, 295
  megadont, 298, 1236
  mesaticephalic, 295
  mesocephalic, 295
  mesodont, 298, 1236
  mesognathous, 297
  mesorrhine, 297
  mesuranic, 298
  metopic, 191
  metriocephalic, 296
  microcephalic, 295
  microdont, 298, 1236
  orthocephalic, 296
  orthognathous, 297
  phænozygous, 297
  platyrrhine, 297
  prognathous, 297
  tapeinocephalic, 296
Skull-cap, 85, 153, 154
Slit, nasal, **157**, 207
Smegma embryonum, 855
    præputii, 1283
"Snuff-box," anatomical, **236**, 238, 403
Sole of foot, 248
    arteries, 958, 962
    fascia, 423
    lymph vessels, 1022
    muscles, 433
    nerves, 764
    surgical anatomy, 1459
    veins, 996
  in eversion and inversion, 280, 364
  resting on ground, 277, 287
Somatopleure, 43, 495
Somites, mesodermal, 44, 72, 73, 78, 123, 495
  formation of, 32
Sounds of heart, 1396
Spaces—
  of angle of iris, 805
  epidural, of skull, 665
    of vertebral canal, 667
  episcleral, 802
  intercostal, 121
  interglobular, of teeth, 1111
  interpleural, 1082
  intervillous, of placenta, 63
  mediastinal, 1082
  of Nuel of spiral organ, 844
  perichorioidal, of eyeball, 803, 806

Spaces—*continued*
  perilymphatic, 840
    development, 848
  perivitelline, 17
  quadrilateral, of shoulder, 380, 918
    surgical anatomy, 1442
  retropharyngeal, 1142
  retropubic (Retzius), 1287
    surgical anatomy, 1400, 1420
  semilunar, of Traube, 1408
  sinusoidal, of liver, 1042
  subarachnoid, of brain, 669
      connexion with sinuses, 671
      origin, 41
      surgical anatomy, 1352
    spinal, 519
      subdivisions, 673
      surgical anatomy, 1435
  subdural, 668
    origin, 41
    surgical anatomy, 1435
  suprasternal, 447
    surgical anatomy, 1377
  triangular, of shoulder, 380
Spatia anguli iridis, 805
  zonularia of eye, 814
Sperm cells, 12, 1315
Spermatids, **20**, 22
  difference from ordinary cell, 21
Spermatocytes, 13, 14
    nurse cells of, 20
  of first order, 13, 14, 19, **20**, 24
    number of chromosomes, 25
  of second order, 20
Spermatozoon, 1, 12, 13, 14, 18, 19, 20, **21**, 23, 24, 1273
  mature, 12
  number of chromosomes, 25
Sphenoid bone, 124, 126, 153, **202**
      at birth, 184, 205
      in child, 185
      at twenty-five, 186
    chondrification, 187
    development, 188
    ossification, 205
    variations, 206
  body, 126, 128, 202
    junction with occipital, 148
    relation to choanæ, 145
      to anterior cranial fossa, 155, 157
      to middle cranial fossa, 157, 158, 159, 161
      to posterior cranial fossa, 163
      to ethmoid, 176
      to nose, 146, 168
      to notochord, 30, 187
      to orbit, 134, 136
      to spheno-palatine foramen, 142
      to vomer, 128
  great wing, 127, 128, 203
    relation to sphenoidal sinus, 176
    seen in orbit, 135
      inside skull, 158, 161
      in lower surface of skull, 141, 144, 146, 147, 151, 152
      in side of skull, 138, 139, 141, 144
  pterygoid process, 127, 146, 204. *See also* **Process**
  small wing, 126, **157**, 203, 205
    in anterior cranial fossa, 155, 157
    in middle cranial fossa, 157, 161
    in orbit, 135

- **Sphenoid**—*continued*
  - **small wing**—*continued*
    - relation to sphenoidal sinus, 176
    - in skiagram, 1365
- Sphenotic centre, 205
- Sphere, attraction, 8
- Sphincter. *See* **Muscle**
- Spinal medulla. See **Medulla**
- Spindle, achromatic, 10, 11, 13, 17, 19
    - rotation of, 18
    - of spermatocytes, 20
  - neuro-muscular, 859
  - neuro-tendinous, 859
- **Spina** or **Spine**, 87
  - angular, of sphenoid, **146**, **147**, 150, 152, 202, 204
  - bifida, origin, 124
  - of epistropheus, 99
    - surgical anatomy, 1387
  - frontal, 133, 169, 190
  - helicis, 823
  - **iliac**, *inferior*, anterior, **250**, 259
      - posterior, **251**, 259, 260
    - *superior*, anterior, **249**, 259
        - in female, 258
        - relation to pubic tubercle, 253
        - surgical anatomy, 1449, 1453
      - posterior, **249**, 259, 260
        - surgical anatomy, 1427, 1449
  - **ischial**, **251**, 259
      - in female, 258
      - ossification, 255
      - surgical anatomy, 1450
  - mental, 178, 180
  - nasal, anterior, **133**, 211, 213
    - posterior, 144, 145, 214
  - recti lateralis, 204
  - of sacrum, second, level, 249
    - surgical anatomy, 1427
  - of scapula, 99, 218, **219**, 222
  - of sphenoid (angular), **146**, **147**, 150, 152, 202, 204
  - suprameatal, 140, 198, 1356, 1359
  - trochlearis, 135, 190
  - tympanica, anterior and posterior, 826
  - of vertebræ, 94, 95, 96, 108
    - development, 123
    - homologies, 112
    - levels, 99, 1433
    - surface anatomy, 1427
- Splanchnology, definition, 3
- Splanchnopleure, 495
- **Spleen**, 4, 70, **1342**
      - accessory, 1343
      - floating, 1434
    - development, 1345
    - excision, 1434
    - function, 1321
    - level, 1433
    - structure, 1343
    - surgical anatomy, 1404, **1430**
  - arteries, 932, 1056, 1343, 1344, 1408
  - lymph vessels, **1032**, 1343
  - nerves, 789, 1343
  - veins, 1000, 1343
- Splenium of corpus callosum, 626, **628**
- Splinter-bone. *See* **Fibula**
- Spongioblasts, 504
  - of retina, 821
    - origin, 40
- Spongy bone, 84, 85
- Spot, blind, of eye, 809
- Spot—*continued*
  - germinal, 17
  - yellow, of retina, 809, 812
- Spur of malleus, 833
  - scleral, 805, 807
- **Squama**, 87, 126
  - **occipitalis**, **149**, 166, **193**
      - chondrification, 187
    - in back of skull, 136
    - inside skull, 154, 163
    - in side of skull, 137, 140
    - in lower surface of skull, 142, 147
    - in top of skull, 129, 154
- **Squamous temporal**, 126, 197
  - relation to meningeal artery, 159
  - seen in cranial cavity, 154, 158
    - in lower surface of skull, 150
    - in side of skull, 138, 139, 140, 141
- Stage, resting, of cells, 9, **11**
  - of spermatids, 20
- **Stalk**, allantoic, 43, **59**, 64, 77
  - body. *See* **Stalk**, allantoic
  - of hypophysis, 542
  - optic, 820
  - of thalamus, frontal, 610
      - in internal capsule, 639
    - occipital and parietal, 610
    - ventral, 610, 611
- **Stapes**, 140, 826, **834**
  - development, 57, 183, 835
  - movements, 836
  - ossification, 835
  - surgical anatomy, 1358
- Staphylorrhaphy, 1375
- Stem, brain. *See* **Medulla oblongata**, **Mid brain**, and **Pons**
  - of lateral fissure, 651
- Stensen's foramen, 145, 169, 213
- Stephanion, 139, 296
- **Sternum**, 87, 91, **113**, 121
  - development, 124
  - fracture, 1389
  - movements, 319, 474
  - ossification, 115
  - periosteum, 1389
  - relation to clavicle, 224
  - structure and variations, 116
  - veins, 969
- Stigmata of endothelium, 865
- **Stomach**, 1156
        - bilocular and "hour-glass," 1164
        - "steer-horn," 1408
      - bare area, 1164, 1229, 1231
      - body, 1158, **1161**
      - cardia, 1158
      - curvatures, 1158, **1160**
      - fundus, 1158, **1161**
      - pyloric part, 1158, **1162**
      - pylorus, 1158
    - accessory pancreas in, 1198
    - capacity, 1156
    - development, 52, 1237
    - resection, 1408, 1413
    - rotation, 1237, 1240
  - at birth, 1157
  - in different postures, 1166
  - displaced, 1164
  - distended, 1165, 1185, 1187, 1193, 1342, 1407
  - during digestion, 1166
  - empty, 1164, 1166, 1185, 1187, 1342, 1407
  - movements, 1164

Stomach—*continued*
    in radiograms, 1407
    in screen examinations, 1408
    X-ray examination, 1165
  arteries, 932, 933, 935, 1169
  connexions, 1163
  level, 1433
  lymph glands, 1027
  lymph vessels, **1030**, 1169
  nerves, 701, 789, 1170
  peritoneum, 1163
  position, 1164
  relations, 1163
  structure, 1166
  surgical anatomy, 1404, **1407**, **1430**
  veins, 1000, 1169
Stomach bed, 1163
Stomach chamber, 1163
Stomach pit, 113, 114
Stomata of endothelium, 865
Stomatodæum, 29, 32, 79, 1232
  derivatives, 53
  formation, 46
Stratum compactum of decidua, 62
  corneum of epidermis, 851
    of nail, 852
  filamentosum of epidermis, 851
  germinativum of epidermis, 851
    of nail, 852
  granulosum of epidermis, 851
    of nail, 852
    of ovarian follicle. *See* **Membrana** granulosa
  griseum of superior corpus quadrigeminum, 585
    centrale of mid-brain, 583
  intermedium of chorioid, 807
    of epidermis, 851
  lemnisci of superior corpus quadrigeminum, 585
  lucidum of nail, 853
    of skin, 851
  marginale embryonale of cerebellum, 579
  mucosum of epidermis, 851
      nerve endings in, 856
    of nail, 852
  opticum of retina, 810
    of superior corpus quadrigeminum, 585
  papillare of skin, 850
  pigmenti of retina, 812
  radiatum of tympanic membrane, 829
  reticulare of skin, 850
  spongiosum of decidua, 62
  synoviale. *See* **Membrane**
  zonale of superior corpus quadrigeminum, 585
    of thalamus, 609
Streak, primitive, 27, **31**, 32, 35, 77
  derivatives of, 28
  relation to embryonic area, 28
    to neural folds, 35
Striæ—
  of Gennari, 642, 656
    relation to calcarine fissure, 657
  longitudinales of corpus callosum, 627
  medullares of fourth ventricle, 551, **605**
      connexion with lemniscus, 589
      relation to abducent nerve, 589
        to vestibular nucleus, 603
    of thalamus, 609, **612**
  olfactory, lateral, 621
  of Retzius, of teeth, 1111
Striæ—*continued*
  terminalis, 608, 631, 633, **638**
  vascularis of cochlea, 843
Stripe, Hensen's, of spiral organ, 845
Stye, 1368
Stylo-hyal, 201
"Styloid," 126
Subcoracoid, 223, 292
Subdivisions of abdomen proper, 1151
  of the body, 91
Substance, vitelline, 16
Substantia adamantina. *See* Adamantine
  eburnea. *See* Ivory
  ferruginea, 552, 570
  gelatinosa, 525, 526, **529**, 536
    in medulla oblongata, 548, 560, 565
    in pons, 567, 599
  grisea centralis (of spinal medulla), 529
  nigra, 582, **583**
    connexion with corpus striatum, 637
    in hypothalamus, 612
  ossea of tooth, 1110, **1111**
    development, 1233
  perforata, *anterior*, 542, 621
      arteries piercing, 904, 905
      connexion with amygdaloid nucleus, 638
        with caudate nucleus, 635
        with cingulum, 646
        with claustrum, 638
        with lentiform nucleus, 636
        with nervus terminalis, 678
      relation to carotid artery, 900
        to internal capsule, 639
      vein piercing, 977
    posterior, 542, 613
      arteries piercing, 908
      origin, 39
      veins, 977
  reticularis of medulla oblongata, 560, 564
      of pons, 567
      of spinal medulla, 525
    alba of piriform area, 622
Suctorial pad. *See* **Corpus** adiposum
"Sugar-loaf" shoulder, 1439
Sulci, 87. *See also* **Fissure** and **Groove**
  alar, of nose, 793
  alveolo-glossal, 1373
  alveolo-labial, 1232
  antihelicis transversus, 824
  arteriosi, 154, **159**, 165, 166, 190, 192, 197, 204
  auris anterior, 823
  basilaris of pons, 549
  of brachial nerve, 1387
  of cerebellum, 572
    valleculæ, 575
  of cerebrum, 650
    angularis, 662
    axiales, 643
    calcarine, lateral and posterior, 657
        development, 657
        relation to calcar avis, 632
    centralis, 660
        relation to temporal muscle in child, 1349
        surgical anatomy, 1349, **1350**
      insulæ, 652
    cinguli, 663
    circularis (of insula), 651
    collateralis, 658, **659**
      transversus, 660
    diagonalis, 663

Sulci—*continued*
  of **cerebrum**—*continued*
    frontal, inferior, 663
        surgical anatomy, 1349, 1350
      middle, 663
      superior, 663
        surgical anatomy, 1350
    fronto-marginal, 663
    hypothalamicus, 606, **615**
    interparietalis, 662
      proprius, 662
      ramus horizontalis, 662
        occipitalis, 658, 662
    lunatus, 643, **658**
    occipitalis anterior, 562
      lateralis, 643, 658
      paramedialis, 658
      transversus, 662
    olfactory, 621, **663**
    operculati, 643
    orbital, 663
    paracentralis, 661
    parietalis superior, 662
    parieto-occipital. *See* **Fissure**
    par-occipitalis, 658, 662
    polares, 657
    post-centralis, 662
      surface anatomy, 1350
    precentral, 663
      surface anatomy, 1350
    precunei, 662
    retrocalcarine, 643
    sagittalis of gyrus lingualis, 660
    simialis, 658
    subcentral, 663
    subparietalis, 662
    temporalis, anterior, 655
      inferior and middle, 655
      superior, 655
        surface anatomy, 1349, 1350
    terminales, 643
  chiasmatis. *See* **Groove**, optic
  circularis corneæ, 804
  coronary, of heart, **867**, 868, 869, 884, 885, 964
    surface anatomy, 1394
  cruris helicis, 824
  interatrial, 867
  intermedius of stomach, 1161
  intertubercular, **226**, 228
    surface anatomy, 1440
  interventricular, anterior, 867, 869, 964
    inferior, 867, 868, 884, 964
  longitudinal, of heart. *See* **S.**, interventricular
  malleolaris, 826
  of **medulla oblongata**, 545
    intermedius posterior, 548
    lateralis anterior et posterior, 545
  of **medulla spinalis**, 524
    limitans, 41, 507
    posterior, intermedius, and lateral, 524
  mento-labialis, 1105
  of mid-brain, 582
  naso-labialis, 1104
  naso-lacrimal, 54
  nervi brachialis, 1387
  oculo-motor, 582
  olfactory, of nose, 798
  petrosus inferior, 164
  of pons, basilar, 594
  pre-auricular, 258

Sulci—*continued*
  precervical, 48
  scleræ, 801
  sigmoid. *See* **Groove**
  spiralis externus et internus, 843
  of stomach, intermediate, 1161
  terminalis of heart, **869**, 870
    of tongue, 1119
  transverse, of skull. *See* **Groove**
  tympanicus, 825, 828
  valleculæ, 575
Supercilia. *See* Eyebrows
"Superior," definition, 5
Supination, **237**, 330
  function, 294
Supra-nasal bones, 191
Supra-occipital bone, 195
Surface relations of thorax, 121
Surface and Surgical Anatomy, 1347
  of abdomen, 1398, 1427
  of abductor digiti quinti, 1459
  of abductor hallucis, 1459
  of abductor pollicis longus, 1448
  of accessory nerve, 1383, 1385
  of acromio-clavicular joint, 224, 1439
  of acromion, 1439
  of aditus ad antrum, 1359
      laryngis, 1378
  of adductor canal, 1453
  of adductor longus, 1453
  of adductor magnus, 1449, 1455
  of adductor tubercle, 1455
  of air sinuses, 1362, 1363, 1364, 1365, 1369
  of alveolar nerve, 1366
  of ampulla of Vater, 1406
  of anal canal, 1422
  of angle of mandible, 1366
  of angular artery, 1368
  of angular gyrus, 1350
  of ankle joint, 1457, 1458
  of anterior central gyrus, 1349, 1350
  of antrum tympanicum, 1359, 1362
  of anus, 1421
  of aorta, 1396, 1417
  of aortic valve, 1396
  of apex of lung, 118, 1390, 1433
  of apparatus lacrimalis, 1368, 1369
  of appendicular artery, 1411
  of arch of aorta, 115, 1396
  of arches of palm, 1448
  of arm (upper), 1441
  of artery of bulb, 1419
      of eyeball, 1368
      of face, 1370
      of knee, 1455
      of lips, 1370
      of retina, 820
      of vermiform process, 1411
  of ascending mesocolon, 1411, 1412
  of atlas vertebra, 1383
  of auditory tube, 1357, 1359, 1367, 1376
  of auricle of atrium, 1394
      of ear, 1355
  of auricular lymph glands, 1367
  of auriculo-temporal nerve, 1349
  of axilla, 1440
  of axillary artery, 1439, 1440
  of axillary nerve, 1442, 1443
  of axillary vein, 1439, 1441
  of back, 1427
  of base of skull, 1349
  of basilar artery, 1365

Surface and Surgical Anatomy—*continued*
of basilic vein, 1442
of biceps brachii, 1440, 1442, 1444
  femoris, 1451, 1455
of bile duct, 1404, **1406**, 1409
of bladder, 1400, 1419, 1420, 1425, 1427
of brachial artery, 1441, 1443, 1444
of brachial plexus, 1386, 1439
of brachialis, 1442
of brachio-radialis, 1442, 1447
of brain, 155, 161, 165, 1350
of broad ligament of uterus, 1425
of bulb of urethra, 1418
  of vestibule, 1426
of bulbo-urethral gland, 1418
of bursa of gastrocnemius, 1452
  of gluteus maximus, 1452
  of psoas major, 1454
of buttock, 1449
of cæcum, 1404, 1411, 1412
of calcaneo-cuboid joint, 1458
of calcaneus, 1457, 1458
of cardiac orifices, 1396
of carotid sheath, 1377
of carotid tubercle, 1384, 1386
of carpus, 1445
of caruncula lacrimalis, 1369
of cavernous sinus, 158, 1365, 1367
of cavity of peritoneum, 1402, 1404
of central sulcus, 1349, 1350
of cephalic vein, 1439, 1443
of cerebellum, 1353
of cerebrum, 155, 161, 165, 1349, 1350
of cervical fascia, 1376
of cervical ganglia, 1384, 1390
of cervical lymph glands, 1376, 1377, 1382, 1385
of cervical plexus, 1384, 1385
of cervical ribs, 1385, 1387
of cervix uteri, 1425
of choanæ, 1376
of chorda tympani, 1356, 1358
of circumflex humeral arteries, 1442, 1443
of clavicle, 1438
of clinoid process, 1365
of cœliac artery, 1417
of colic arteries, 1179, 1413
of colic valve, 1411
of colon, 1404, 1405, 1411, 1412, **1413**, 1430
of columns of rectum, 1422
of common carotid artery, **1382**, 1384, 1396
of common peroneal nerve, 1451, 1455
of condyle of mandible, 1366
of condyles of femur and tibia, 1455
of conjoint tendon, 1399
of conjunctiva, 1368
of coraco-brachialis, 1440, 1442
of coracoid process, 1439
of coronary sulcus, 1394
of coronoid process of mandible, 1366
  of ulna, 1433
of costal cartilages, 1389, 1401
of costo-chondral joints, 122, 1389
of cranium, 1347, 1348
of cricoid cartilage, 96, 1379
of crico-thyreoid artery and ligament, 1379
of crico-thyreoideus, 1379
of cubital lymph glands, 1442
of cystic duct, 1406
of deltoideus, 1439, 1441
of diaphragma, 1430
of digital arteries and nerves, 1449

Surface and Surgical Anatomy—*continued*
of digits, 1447
of diploic veins, 1347
of diverticulum ilei, 1411
of dorsal interosseous nerve, 1447
of dorsal tubercle of radius, 1445
of dorsalis pedis artery, 1459
of dorsalis scapulæ nerve, 1385
of ductus deferens, 1421
of duodeno-jejunal flexure, 1405, 1410
of duodenum, 1404, 1405, 1406, **1409**, 1413
of elbow, 1443, 1444
of epicondyles of humerus, 1443
of epididymis, 1421
of epiglottis, 1379
of epiphyseal lines of femur, 1455
of epiphyses of humerus, 1439, 1443
of epistropheus, 1387
of epitympanic recess, 1358, 1359
of ethmoidal cells, 1363, 1364
of extensor carpi radialis longus, 1442, 1447
  carpi ulnaris, 1445
  digitorum brevis, 1459
    longus, 1456, 1459
    communis, 1447
  hallucis longus, 1459
  pollicis brevis, 1447
of external acoustic meatus, 1355
of external carotid artery, 1382
of external maxillary artery, 1140, 1366, 1381
of extraperitoneal fat, 1400
of eyelids, 1368
of face, 1366
of facial canal, 1359
of facial nerve, 1359, 1361, 1367
of facial veins, 1366, 1381, 1382, 1383
of falciform ligament, 1405
of falx inguinalis, 1399
of fascia of Colles, 1418
  transversalis, 1399
of femoral artery and sheath, 1453
of femoral triangle, 1453
of femoral vein, 1418
of femur, 1449, 1450, 1451, 1454, 1455
of fibula, 1455, 1456
of first rib, 1386, 1387, 1389
of fissures of lung, 1391
of flexor carpi radialis, 1447
of flexor sheaths, 1448
of flexures of colon, 1404, 1405, **1413**, **1430**
of folds of rectum, 1423
of foot, 1457
of foramen ovale of skull, 1367
of forearm, 1445
of fornices of vagina, 1426
of fossa ovalis of thigh, 1453
of fourth ventricle, 1352
of frenulum linguæ, 1374
of frontal artery, 1348
of frontal eminence, 1349
of frontal sinus, 1362, 1363
of frontal sulci, 1349, 1350
of fronto-zygomatic suture, 1348
of gall-bladder, 1398, 1404, 1406
of gastric arteries, 1406, 1409
of gastrocnemius, 1456, 1457
of genioglossus, 1374
of glosso-palatine arch, 1374
of gluteal arteries, 1450
of gluteal fold, 1449
of gluteus maximus, 1449

Surface and Surgical Anatomy—*continued*
of greater occipital nerve, 1387
of greater palatine artery, 1375
of greater palatine foramen, 1376
of groin, 1453
of hand, 1445
of head, 1347
of head of femur, 1453
    of fibula, 1455
    of humerus, 1439
    of mandible, 1366
of heart, 1394
of Hesselbach's triangle, 1399
of hilum of kidney, 1414
of hip joint, 1454
of humerus, 1439, 1443
of hyoid bone, 1378, 1381
of hypoglossal nerve, 1383
of hypophysis cerebri, 1364
of hypophyseal fossa, 1364
of ileum, 1410
of iliac arteries, 1414, 1417
of iliac crest, 1449
of iliac spines, 1427, 1449, 1453
of iliac veins, 1417
of ilio-hypogastric nerve, 1401
of ilio-inguinal nerve, 1401
of ilio-psoas, 1454
of ilio-tibial tract, 1449, 1450, 1453, 1455
of incus, 1358
of inferior epigastric artery, 1398, 1401, 1425
of infrahyoid muscles, 1378, 1379
of infra-orbital foramen, 1366
of infra-orbital nerve, 1366
of inguinal canal, 1398
of inguinal ligament, 253, 1453
of inguinal rings, 1398
of innominate artery, 1379, 1396
of innominate vein, 1379, 1396
of intermuscular septa of arm, 1442
    of leg, 1456, 1457
    of thigh, 1450, 1451
of internal carotid artery, 1365, 1367
of internal ear, 1361
of internal mammary artery, 1389, 1396
of internal maxillary artery, 1366
of intersigmoid fossa, 1414
of intestine, 1404, 1405, 1410, 1412, 1413, 1430
of ischial spine, 1450
of ischial tuberosity, 1449
of ischio-rectal fossa, 1422
of isthmus of thyreoid gland, 1379
of jejunum, 1410
of joints of fingers, 1447
of jugular veins, 1377, 1379, 1381, 1382, 1384, 1385
of kidney, 1404, 1405, **1414**, 1416, 1428, 1429
of knee joint, 1454, 1455
of knuckles, 1446
of labial arteries and glands, 1370
of labyrinth of ear, 1361
of lacertus fibrosus, 1444
of lacrimal apparatus, 1368, 1369
of lambda, 1348
of lambdoid suture, 1348, 1350
of laryngeal arteries, 1378
of laryngeal nerves, 1378, 1380, 1384
of lateral circumflex artery, 1454
of lateral fissure, 161, 1349, 1350
of lateral thoracic artery, 1441
of lateral ventricle, 1349, 1352

Surface and Surgical Anatomy—*continued*
of latissimus dorsi, 1428
of leg, 1456
of lesser occipital nerve, 1385
of levator scapulæ, 1428
of ligament of heads of metatarsals, 1459
of ligamentum latum uteri, 1425
    patellæ, 1454
    teres hepatis, 1405
    teres uteri, 1425
of linea alba, 1398, 1401
of linea semicircularis, 1401
of lines of pleural reflexion, 1392
of lingual artery, 1381, 1382
of lingual gland, 1373
of lingual nerve, 1366, 1374
of lingual tonsil, 1372
of lingual veins, 1373, 1374
of lips, 1370
of liver, 1186, 1404, **1405**, 1430
of loins, 1428
of long thoracic nerve, 1387, 1441
of lower limb, 1449
of lumbar triangle, 1428
of lumbar vertebræ, 1437
of lumbo-sacral joints, 1436
of lungs, 1390
of lymph vessels of diaphragm, 1404
of malleolar folds of ear, 1356
of malleoli, 1457
of malleus, 1358
of mammary gland, 1440
of mandible, 1366
of mandibular joint, 1356
of mandibular nerve, 1367
of mastoid cells and process, 1360
of masto-squamosal suture, 1359
of maxillary nerve, 1367
of maxillary sinus, 1369, 1370
of medial circumflex artery, 1449
of medial cutaneous nerve of forearm, 1442
of median basilic and median cephalic veins, 1444
of median lines of neck, 1378, 1387, 1427
of median nerve, 1442, 1443, 1444, 1448
of median vein, 1444
of menisci of knee, 1455
of mental foramen and nerve, 1366
of mesenteric arteries, 1404, 1417
of mesentery, 1404, 1405
of metacarpo-phalangeal joints, 1446
of metacarpus, 1446
of metatarso-phalangeal joints, 287, 1458, 1459
of metatarsus, 1457
of middle ear, 1358
of middle frontal gyrus, 132, 1349
of middle meningeal artery, 139, 1349, 1350, 1353
of mitral valve, 1396
of motor area, 1349, 1350
of mouth, 1371
of naso-lacrimal duct, 1368
of naso-pharynx, 1376
of natal cleft, 1450
of neck, 1376
of neck of humerus, 1442, 1443
of nervus suralis, 1459
of nose, 1369
of obliqui abdominis, 1398, 1401
of obliquus capitis inferior, 1387
of occipital lobe, 1350

Surface and Surgical Anatomy—*continued*
of œsophagus, 1384, 1393, 1396
of olecranon, 1443
of omental bursa, 1408, 1409, 1413
of omentum, 1413
of omo-hyoideus, 1381, 1382, 1385
of optic groove and nerve, 1365
of orbit, 1369
of orifices of heart, 1396
of ovary, 1425
of palate, 1371, 1375
of palatine arches and tonsil, 1374
of palm of hand, 1445, 1449
of palmaris longus, 238, 1447
of palpebral ligaments, 1368
of pampiniform plexus, 1421
of pancreas, 1404, 1405, 1406, 1413, 1417, 1434
of pancreatic duct, 1406
of papilla duodeni, 1406
of parathyreoid glands, 1380
of parietal eminence, 1349
of parieto-occipital fissure, 136, 1348, 1350
of parotid duct and gland, 1356, 1367
of patella, 1454
of pectoralis major, 1389, 1439, 1440, 1441
of pelvic mesocolon, 1414
of pelvis, 1419, 1425
of penis, 1418
of pericardium, 1396
of perinephric fat, 1416
of perineum, 1418, 1427
of peritoneum, 1400, 1402, 1404
of peronæi, 1456, 1458, 1459
of peroneal artery, 1457
of petro-squamous suture, 1358
of pharyngeal recess and tonsil, 1376
of pharyngo-nasal isthmus, 1374
of pharyngo-palatine arch, 1374
of pharynx, 1376, 1378
of phrenic nerve, 1384
of phrenico-colic ligament, 1413
of plantar arteries and nerves, 1459
of plantar calcaneo-navicular ligament, 1459
of pleura, 1385, 1391, 1396
of popliteal artery and fossa, 1452
of portal vein, 1406
of post-central sulcus, 1350
of posterior cutaneous nerve of thigh, 1450, 1451
of precentral sulcus, 1350
of pretracheal lymph glands, 1379
of prevertebral triangle, 1384
of profunda linguæ artery, 1373, 1374
of promontory of ear, 1361
of pronator teres, 1447
of prostate, 1420
of psoas major, 1428
of pterion, 1349, 1350
of pterygoid hamulus, 1376
of pubic crest, 1453
of pubic tubercle, 1398, 1453
of pudendal artery, 1418, 1450
of pudendal plexus of veins, 1420
of pulmonary artery and valve, 1396
of puncta lacrimalia, 1368
of pylorus, 1407, 1430
of quadratus femoris, 1449
    lumborum, 1428
of quadrilateral space, 1442
of radial artery, 1448
of radial nerve, 1442, 1443, 1444, 1448

Surface and Surgical Anatomy—*continued*
of radius, 1443, 1445
of ramus of mandible, 1366
of rectal sinuses, 1422
of recto-urethralis, 1421, 1425
of recto-uterine pouch, 1425, 1427
of recto-vesical pouch, 1425
of rectus abdominis, 1398, 1400, 1401
    femoris, 1454
of recurrent nerve, 1073, 1380, 1384
of renal arteries, 1416, 1417
of renal fascia, 1414
of renal pelvis, 1416
of retro-cæcal fossa, 1412
of retro-pubic space, 1400, 1420
of rhomboidei, 1428
of ribs, 122, 1385, 1386, 1387, 1389, 1393, 1428
of rima glottidis, 1379
of root of lung, 1394
    of penis, 1418
    of spinal nerves, 1434, 1435
    of zygoma, 1349
of sacral spines, 1427
of sacro-iliac joint, 1449
of sacro-spinalis, 1428
of saphenous nerve, 1455, 1457, 1459
of saphenous veins, 1453, 1455, 1457, 1459
of sartorius, 1453
of scalp, 1347
of scapula, 1439
of sciatic nerve, 1450, 1451
of scrotum, 1421
of sella turcica, 1364
of semicircular canals, 1359, 1361
of semilunar ganglion, 1355
of semimembranosus, 1452
of semitendinosus, 1451, 1452
of sheath of prostate, 1420
    of rectus, 1400, 1401
of shoulder, 1438
of shoulder joint, 1440
of sigmoid arteries, 1414
of sigmoid sinus, 1355, 1361
of sinuses of nose, 1364, 1365
of skull, 1347, 1348
of sole of foot, 1459
of soleus, 1456, 1457
of spermatic artery, 1413, 1421
of spermatic cord, 1398
of spermatic fascia, 1399, 1421
of sphenoidal sinus, 1364
of sphincter ani, 1422
of spinal medulla, 1434
of spinal nerves, 37, 773
of spine of epistropheus, 1387
of spines of sacrum, and vertebræ, 1427
of spleen, 1404, **1430**, 1434
of splenic artery, 1408
of stapes, 1375
of sterno-clavicular joint, 1438
of sterno-mastoid, 1380
of sternum, 1389
of stomach, 1404, **1407**, 1408, 1413, **1430**
of styloid process of radius and ulna, 1445
of subarachnoid cisterns, 1352
of subarachnoid space, 1352, 1435
of subclavian artery, 1385, 1390, 1439
of subclavian vein, 1385, 1439
of subdural space, 1435
of subinguinal lymph glands, 1453
of sublingual gland, 1374

Surface and Surgical Anatomy—*continued*
of submaxillary duct, 1374
of submaxillary gland, 1381
of submental triangle, 1378
of suboccipital triangle, 1387
of superficial peroneal nerve, 1457
of superficial temporal vessels, 1347, 1349
of superior epigastric artery, 1401
of supraclavicular lymph glands, 1382
of supracondylar triangle, 1442
of supramarginal gyrus, 130, 1349
of suprameatal spine, 1356, 1359
of suprameatal triangle, 1359
of supra-orbital artery and foramen, 1348
of supra-orbital nerve, 1348, 1366
of suprarenal gland, 1404, 1430
of suprascapular nerve, 1385
of suprasternal space, 1377
of supratrochlear nerve, 1348
of suspensory ligament of ovary, 1426
of sympathetic trunk, 1377, 1384
of talo-calcanean joint, 1458
of talo-navicular joint, 1459
of talus, 1457
of tarso-metatarsal joints, 285, 1458, 1459
of teeth, 1371
of tegmen tympani, 1358
of temporal lobe, 1350
of temporal sulcus, 1349, 1350
of tendo calcaneus, 1457
of tensor fasciæ latæ, 1450, 1453
veli palatini, 1367
of tentorium cerebelli, 165, 1350
of thigh, 1451
of thoracic duct, 1384, **1385**
of thoracic nerves, 1401
of thoraco-dorsal nerve, 1441
of thorax, 121, 1387
of thyreo-glossal duct, 1372
of thyreo-hyoid membrane, 1378
of thyreoid arteries, 1377, 1382
cartilage, 1378
gland, 1379
veins, 1379
of tibia, 1456
of tibial arteries, 1457
of tibial nerve, 1452
of tibialis anterior, 1459
posterior, 1458, 1459
of tongue, 1372
of tonsil, lingual, 1372
palatine, 1374
pharyngeal, 1376
of trachea, 115, **1379**, 1394
of transversalis fascia, 1399
of transverse mesocolon, 1402, 1404, 1413
of transverse sinus, 165, 1350, 1354, 1361
of transversus abdominis, 1401, 1428
of trapezius, 1383, 1428
of Traube's space, 1408
of triangle of auscultation, 1428
of triangles of neck, 1380, 1381, 1384, 1385
of triceps brachii, 1442
of tricuspid valve, 1396
of trochanters, 1449
of trochlear process, 1458
of tubercles of humerus, 1439
of iliac crest, 1449
of navicular bone of foot, 282, 1457
of hand, 238, 1445
of tuberculum sellæ, 1365
of tunica vaginalis testis, 1400

Surface and Surgical Anatomy—*continued*
of tympanic antrum, 1359, 1362
of tympanic cavity, 1358
of tympanic membrane, 1356
of ulna, 1445
of ulnar arteries, 1448
of ulnar nerve, 1443, 1444, 1448
of umbilicus, 1398, 1402
of upper limb, 1438
of ureter, 1405, 1413, 1414, **1416**, 1417, 1425, 1426, **1429**, 1430
of urethra, female, 1425, 1426
male, 1418, 1419
of uterine artery, 1426
of uterus, 1425
of vagina, 1425, 1427
of vagus, 1383, 1384
of valve of colon, 1411
of valves of heart, 1396
of vasti, 1451, 1454
of veins of scalp, 1347
of vena cava inferior, 1417
superior, 1396
of ventriculus lateralis, 1349, 1352
quartus, 1352
of vermiform process, 1404, **1411**, 1425
of vertebral artery, 150, 1384, 1387
of vertebral column, 1435, 1436
of vertebral venous plexus, 1434
of vestibular gland, 1426
of vestibule of ear, 1361
of mouth, 1374
of vocal folds, 1379, 1433
of volar arches, 1448
of volaris indicis radialis artery, 1448
of wrist, 1443
of wrist joint, 234, 1445
of zygoma, 1349
of zygomatic arch, 161, 1349
of zygomatico-temporal nerve, 1349
Sustentacular reticulum of spinal medulla, origin, 41
Sustentaculum lienalis. *See* **Lig.**, phrenico-colic
tali, **277**, 279, 358
relations, 278
surgical anatomy, 1457
variations, 290
Sutural bones, 129, 138, 191, **211**
Sutures, 124, **129**, 301, **302**
ligaments, 83, 153, 154, 301
obliteration, 186
varieties, 302
coronal, **129**, 130, 137, 139, 192
seen on side of skull, 137, 139
on top of skull, 129, 130
frontal, 132, 185, 190, 191, 302
persistence, 191
fronto-nasal, 133, 1348
fronto-squamosal, 202, 211
fronto-zygomatic, 132
surface anatomy, 1348
intermaxillary, 133, 212, 302
internasal, 133
lambdoidal, **129**, **136**, 137, 140, 154, 192, 194
seen on back of skull, 136
on side of skull, 137, 140
on top of skull, 129, 130
in vault, 154
surface anatomy, 1348, 1350
masto-squamosal, 198
surgical relation to antrum, 1359

- **Sutures**—*continued*
  - maxillo-zygomatic, 134
  - metopic, 132. *See also* **S.**, frontal
  - naso-maxillary, 133
  - occipito-mastoid, 136, 137, 198
  - palatine, 144
  - parieto-mastoid, 140, 198
  - petro-occipital, 164
  - petro-squamous, 163, 197, 826
    - surgical relation to ear, 1358
  - sagittal, **130**, 136, **154**, 192, 302
    - seen on back of skull, 136
      - on top of skull, 130
      - in vault, 154
  - squamo-mastoid. *See* **S.**, masto-squamosal
  - squamous, 138, **154**, 302
- Swallowing, 182, 467, 1062, 1072, 1138
- Swellings, arytenoid, 1098
  - of spinal medulla. *See* Enlargement
- Swim-bladder of fishes, 862
- Symmetry, 4
- Sympathoblasts, 1326
- Symphysis, 177
  - menti, 177
  - pubis, 83, 88, 249, 253, 259, 260, **339**
    - depth, 257
    - level, 261
  - sacro-coccygeal, 310
- Synarthroses, 301
- **Synchondroses**, 124, 301, 302, 306
  - neurocentral, 110
  - petro-occipital, 194, 199
  - of skull, 188
    - disappearance, 186
  - sternalis, 319
- Syndesis of chromosomes, 13
- SYNDESMOLOGY, 301
- Syndesmosis tibiofibular, 353
  - arterial supply, 958
  - nerve supply, 762
  - relation to peroneal artery, 957
- Syngamy, 23
- Synizesis, 10
- Synovia, 303
- **Systems**, definition, 3
    - bulbo-spiral, of heart muscle, 875
    - chromaffin or chromaphil, 1323
      - comparative anatomy, 1330
      - development, 1326
    - cortical, 1326
      - comparative anatomy, 1330
      - development, 1329
    - Haversian, 84
      - development, 89
    - phæochrome, 1323
    - portal, 963, **998**
    - sino-spiral, of heart muscle, 875
  - articulatory, 3, 301
  - digestive, 3, **1101**
    - development, 1231
  - genital, 1271
    - origin, 34
  - integumentary, 3, 849
  - lymph vascular, 3, **1001**
  - muscular, 3, **365**
  - nervous, 3, **499**
      - development, 35, 501
      - summary, 512
    - autonomic, 777
    - *central*, 499
      - absence of lymph vessels, 1001
      - origin, 36
- **Systems**—*continued*
  - nervous—*continued*
    - enteric, 777
    - *peripheral*, 675
    - splanchnic, 775
    - *sympathetic*, 774. *See also* **Trunk**
        - development, 792
      - abdominal part, 785
      - cephalic and cervical part, 780
      - pelvic part, 786
      - thoracic part, 784
    - visceral, 775
  - reproductive, 1271
  - respiratory, 3, **1061**
    - development, 46, 1098
  - skeletal, 3, 83
  - urinary, 1245
  - urogenital, 3, **1245**
    - development, 34, 55, 1310
  - **vascular**, 3, **861**
      - tissues of, 863
    - *blood*, 861
        - development, 68, 1032
        - morphology, 1052
      - primitive, 68
      - pulmonary, 862
      - systemic, 862
    - *lymph*, 862, **1001**
      - development, 1050

- Tabatière anatomique. *See* "Snuff-box"
- Tables of skull bones, 124
    - in fracture, 159, 1349
    - relative thickness, 1349
  - vitreous, of skull, 159
- Tæniæ coli, 1171, **1201**, 1202
    - on pelvic colon, 1213
  - pontis, 613
  - thalami, 608
    - development, 606
- Tail-fold, 78
- Tail-gut, origin, 53
- Talipes equinovarus, 1459
- **Talus**, 248, 268, **278**, 437
  - attachments, 280
  - felt at ankle, 280
  - homology, 293
  - ossification, 288
  - relation to malleolus, 272
  - surgical anatomy, 1457
  - variations, 290
- Tapeinocephaly, 296
- Tapetum of chorioid, 807
  - of corpus callosum, **629**, 632, 633
- Tapping pericardium, 1396
  - pleura, 1393
- **Tarsal bones**, 248, **276**
  - at birth, 289
  - growth, 90
  - homology, 293
  - joints, 356
  - movements, 280, **364**
  - ossification, 288
  - structure and variations, 290
- Tarsus, of foot, 248, **275**
    - compared with carpus, 294
  - of eyelid, 453, **816**
- Tartar of teeth, 1110
- Taste, organ of, 848
- Taste-buds, 848, 1122
- Tears, 134
- Tectum, 518

Teeth, 3, 46, 128, **181**, 1103, **1109**
      heterodont and homodont, 1235
      supernumerary and supplementary, 1117
      of lower races, 1235
      after maturity, 186
      in women, 186
    arteries, 898
    development, 55, 1233
    eruption, 182, 185, **1116**
      method of, 1233, 1235
    extraction, 1371
    lymph vessels, 1013
    morphology, 1235
    nerves, 136, 685, 687, 691
    structure, 1110
    surgical anatomy, 1371
    variations, 1117
  deciduous or milk, 181, 1116
    method of shedding, 1235
  permanent, 181, 1112
  bicuspid. *See* **T.**, premolar
  canine, 133, 136, 144, 145, **1114**
  eye. *See* **T.**, canine
  incisors, 133, 136, 144, 145, **1112**
    absence, 214
    supernumerary, 213
  molar, 141, 144, **1115**
    relation to maxillary sinus, 174, 175
  premolar, 136, 144, **1114**
    relation to maxillary sinus, 174, 175
  wisdom. *See* Dens serotinus
Teeth, auditory of Huschke, 843
Tegmen tympani, **160**, 200, 1358
  in child, 826
  relation to petro-tympanic fissure, 152
Tegmentum of mid-brain, 543, **582**
  connexion with thalamus, 611
  development, 590
  structure, 583, 585
  of pons, 567
Tela chorioidea of fourth ventricle, 571, **671**
  of third ventricle, 614, **671**
    arterial supply, 908
    veins, 672, 976
  subserosa of abdomen. *See* **Tissue**, extra-peritoneal
Telencephalon, 606
  derivatives, 618
  development, 38, 618
Telolecithal oöcyte, 17
Telophase of cell division, **11**, 13, 18
Temple, 138
Temporal bone, 124, 126, 129, **151**, 153, **196**
    at birth, 184, 201
    in child, 185
    chondrification, 187
    origin, 188
    ossification, 200
    structure and variations, 202
    weakest part, 202
  mastoid part, 126, **140**, **198**
    seen from behind, 136
      from below, 150
      from inside skull, 163, 166
  petrous part, 126, 199
    quadrate area, 151, **152**, 200
    seen from below, 150, 152
      in middle cranial fossa, 158, 161, 163
      in posterior fossa, 163, 166, 167
      in skiagrams, 1365, 1370
Temporal bone—*continued*
  squamous part, 126, 197
    relation to meningeal artery, 159
    seen in cranial cavity, 154, 158
      in lower surface of skull, 150
      in side of skull, 138, 139, 140, 141
  tympanic part, 126, 144, 150, **152**, 198
      relation to meatus, 140, 152
    fibrous, 826
    in women, 186
Tendencies, transmission of, 22, 25
Tendo calcaneus, 268, 277, 278, 421, **429**
  surgical anatomy, 1457
Tendon, central of diaphragm, 473
  conjoint. *See* **Falx** inguinalis
  extensor, common, 399
    muscles composing, 229
  flexor, common, muscles composing, 229
Tendons of muscles, 365
Tenotomy of tibialis posterior, 1459
Tentorium cerebelli, 157, **163**, 164, 542, **666**
  attachments, 166
  function, 163
  nerve supply, 681
  surface anatomy, 165, 1350
"Teres," 261
Terms and definitions, 4, 87
Testis, 12, 13, 20, 481, **1271**
      in lower animals, 1280
    descent, 1279
    development, **1315**, 1316
    in fœtus, 1279
    structure, 1273
  arteries, **930**, 943, 1040, 1055, 1273, **1274**, 1281, 1413, 1421
  lymph vessels, **1026**, 1274
  nerve supply, 791, 1274
  veins, 990, 1274
Thalamus, 542, 544, **607**, 631
  arteries, 904, 905, 908
  connexions, 610
    with corpus striatum, 637
    with hippocampus, 623
    with lemniscus, 589
    with red nucleus, 587
  development, 39, 606
  function, 518
  structure, 609
Theca folliculi, 1297
  of spinal medulla, 519
Thenar, 394
Theory of nerve-components, 50
  neurone, 504
Thickness of skull, 153, 1349
Thigh, 248
  arteries, 943, 946, 950
  bone. *See* **Femur**
  fascia, 404. *See also* **Fascia** lata
  incisions, 1451, 1454
  lymph glands, 1021
  lymph vessels, 1022
  muscles, 407
  nerves, 751, 752, 753, 757, 759, 761, 765
  surgical anatomy, 1451
  veins, 994, 996, 997
Thorax, 5, 94, 119
  arteries, 878, 880, 884, 912, 927
  apertures, 120
  at birth and in child, 121
  bones, 99, 106, 113, 116, 119
  cavity, 1082
  fascia, 372

- **Thorax**—*continued*
  - in fœtus, 121
  - joints, 307, 315
  - lymph glands, 1018
  - lymph vessels, 1021
  - measurements, 299
  - movements, 311, 319, 474
  - muscles, 471
  - nerves, 698, 701, 717, 723, 726, 742, 784, 787
  - surface relations, 121
  - surgical anatomy, 1387
  - in women, 121
  - veins, 963, 964, 965
  - X-ray examination, 1097
- Thrombosis of femoral vein, 1418
- **Thumb**, 217
  - arteries, 922, 923
  - homology, 293
  - movements, 334
  - muscles, 395
  - nerves, 734, 737, 741
  - in pronation and supination, 237
  - variation, 247
  - veins, 985
- **Thymus**, 115, **1334**
    - cervical, 1335
      - accessory, 1336
    - IV. vestiges, 1337
    - internal, 1337
    - thoracic, 1336
  - arteries, 914, 1336
  - development, 48, 49, 1336
  - function, 1321
  - lymph vessels, **1021**, 1336
  - nerves, 1336
  - structure, 1336
  - veins, 1336
- Thyreoid gland. *See* **Gland**, thyreoid
- Thyreoidectomy and thyreotomy, 1379
- **Tibia**, 248, 262, 267, 278
    - platyknemic, 271, 300
  - attachments, 270
  - compared with femur, 299
  - epiphyses, 90, 271
  - fracture, 1456
  - homology, 293
  - nerve supply, 762
  - nutrient artery, 958
  - ossification, 271
  - retroversion, 267, 271
  - structure, 271
  - surgical anatomy, 1456
  - variations, 271, 354
- Tilt of pelvis, 255
- **Tissues**, 4
    - growth, atrophy, and death, 9
  - adenoid, of nose, 798
  - of arteries, 863
  - of capillaries, 865
  - chromaffin or chromaphil, 1323
    - formation, 37
    - origin, 36
  - connective, nerve-endings in, 856
    - origin, 34
    - subendothelial, 864
  - erectile, of vagina, 1306
  - extraperitoneal, 475, **476**, **1151**, 1223
      - of pelvis, 490, 1151
    - in hernia, 1399
    - surgical anatomy, 1400
  - fibrous, white, 84
  - of heart, 863
- **Tissues**—*continued*
  - scleratogenous, 33
  - sinusoidal, of liver, 1042
  - spongioblastic, of spinal medulla, origin, 40
  - sustentacular, of nervous system, origin, 40, 41
  - of vascular system, 863
  - of veins, 865
- **Toes**, 248
  - arteries, 958, 959, 962
  - bones, 286
  - development, 45, 80, 81, 291
  - homology, 293
  - joints, 248, **363**
  - lymph vessels, 1022
  - movements, 285, 287, **364**
  - nerve supply, 760, 761, 762, 764, 765
  - surgical anatomy, 1447
  - veins, 996, 997
- Tomes' fibrils, 1111
- Tone of muscle, 367
- **Tongue**, 3, 1103, **1118**
    - bifid, 1236
  - arteries, 463, 464, **891**, 1123, 1124
    - surgical anatomy, 1381, 1382
  - development, 50, **1236**
  - incisions, 1373
  - lymph vessels, **1013**, 1124
    - surgical anatomy, 1373
  - muscles, **463**, 1123
    - development, 497, 498, 709
  - nerves, 690, 698, 700, **1125**
  - structure, 1123
  - surgical anatomy, 1372
  - tactile corpuscles in, 858
  - veins, 971, 1124
- Tongue-tie, 1374
- **Tonsil** of cerebellum, 573
    - development, 574
  - lingual, 1120
    - surgical anatomy, 1372
  - **palatine**, 1138
    - arteries, 892, 893, 895, 1140
    - development, 1236
    - lymph vessels, **1014**, 1140
    - nerves, 688, 698, 1140
    - relation to arteries, 1140
      - to styloglossus, 464
    - structure, 1140
    - surgical anatomy, 1374
    - veins, 1140
  - pharyngeal, 1136
    - surgical anatomy, 1376
  - tubal, 832, 1137
- Tooth of malleus, 833
- Tooth-band, 1233
- Top of skull, 129
- Topography, cranio-cerebral, 1349
- **Torus** levatorius, 1138
  - occipitalis transversus, 196
  - palatinus, 214
  - tubarius, 832, 1138
  - uretericus, 1265
  - uterinus, 1300
- Trabeculæ carneæ, 873
  - cranii, 186
  - of lymph glands, 1003
- **Trachea**, 3, 87, 448, 473, 1061, **1077**
    - bifurcation, level, 115, 1394
      - in child, 1062
  - abnormal relation to carotid artery, 886, 889
  - arteries, 911, 914

- **Trachea**—*continued*
  - communication with œsophagus, 1146
  - development, 46, 50, **1099**
  - fascia, 448
  - in laryngoscopic examination, 1076
  - lymph vessels, 1014
  - nerves, 701
  - structure, 1080
  - surgical anatomy, 1379
  - veins, 967
- Tracheotomy, 1379
- **Tract** or **Tractus**. *See also* **Fasciculus** and **Bundle**—
  - ilio-tibial, 259, 268, 270, **406**, 417, 418
    - relation to knee joint, 346
    - surgical anatomy, 1449, 1450, 1453, 1455
  - intermediate cell, 44
    - derivatives, 34
    - formation of, 32
  - spiralis foraminosus, 200, **838**, 839
  - of **nerve fibres**—
    - myelinisation, 534
    - acoustic, 653
    - callosal, crossed, 611
    - comma, origin, 535
    - descending, of vestibular nerve, 603
    - fronto-pontine. *See* **Fibres**
    - olfactory, **621**, 663
      - connexions through anterior commissure, 645
      - development, 620
      - function, 625
      - relation to skull, 157
        - to sphenoidal sinus, 177
    - optic, 542, **616**, **679**
      - arterial supply, 904
      - connexions, 617
      - relation to brachium superius, 581
        - to communicating artery, 904
        - to peduncle, 580, 582
    - sensory, 648
    - solitarius, 565, 594, **596**
    - spinal, of trigeminal, 599
      - in medulla oblongata, 548, 565, 599
        - in pons, 567, 569, 599
      - connexion with facial nerve, 598
      - relation to accessory nerve, 594
        - to facial nerve, 597
        - to fasciculus olivo-cerebellaris, 558
        - of fasciculus spino-cerebellaris, 563
        - to vagus, 594, 596
        - to vestibular nerve, 603
    - tegmental, central. *See* Fasciculus thalamo-olivaris
    - temporo-pontine. *See* **Fibres**
    - visual, 656
- Tragus auriculæ, 79, 129, **823**
- Trans-illumination of frontal sinus, 1363
- Transmission of tendencies, 22, 25
- Transplantation of ureter, 1414
- Traube's space, 1408
- Tree, genealogical, 2
- **Triangles**. *See also* **Trigone**
  - anterior of neck, 459, 1380
  - of auscultation, 369, 371, 372, 1428
  - carotid and digastric, surgical anatomy, 1381
  - femoral, 407, 412, 413, **416**
    - surgical anatomy, 1453
  - gnathic, 297
  - of Hesselbach, 485, 1224
    - surgical anatomy, 1399
- **Triangles**—*continued*
  - lumbar, 371, 479
    - surgical anatomy, 1428
  - luminous, of ear, 829
  - muscular, surgical anatomy, 1384
  - of neck, anterior, 459, 1380
    - posterior, 459, 460, 468, 1380
      - surgical anatomy, 1385
  - prevertebral, 1384
  - submental, surgical anatomy, 1378
  - suboccipital, 442, 444
    - surgical anatomy, 1387
  - supracondylar, medial, 1442
  - supramarginal, 1350
  - suprameatal, **139**, 140, 198
    - surgical anatomy, 1359
  - urogenital, 1418
  - vertebral, 1384
- Triangular subcutaneous surface, 273
- **Trigone, trigonum**. *See also* **Triangle**
  - acustici. *See* **Area**
  - of bladder, 1264
  - collateral, 633, 634
  - habenulæ, 609, 612
    - development, 606
  - N. acustici. *See* **Area**
  - N. hypoglossi, 552
  - N. vagi, 552
  - olfactorium, 621
  - pectinale, 1276
- Triquetrous bone, 240. *See also* **Os**
- **Trochanter**, greater, **261**, 264
    - surface anatomy, 1449
  - lesser, **261**, 264
    - homology, 293
    - surgical anatomy, 1449
  - third, 266
- **Trochlea**, 87, 227
  - of humerus, **227**, 231
  - of superior oblique, 135, 455
  - tali, 279
- Tröltsch, recesses of, 836
- Trophoblast, 25, 26, 27, 58
  - plasmodial, 58
  - plasmodial or syncytial layer of, 62
- **Truncus** or **Trunk**—
  - aortic or arterial, 72, 1032
    - division of, 1035
  - of brachial plexus, 728
    - lowest, 118, 1386
  - caudal, inferior, 768
    - superior, 718
  - of corpus callosum, 628
  - costo-cervical, 914
    - development and morphology, 1054
  - lumbo-sacral, 757
  - lymph. *See* **Lymph Trunk**
  - **sympathetic**, 105, 473, **780**, **784**
      - development, 792
      - structure, 779
    - abdominal part, 785
    - cephalic and cervical parts, 780
      - relation to fascia, 448
      - surgical anatomy, 1377, 1384
    - pelvic part, 786
    - thoracic part, 784
  - thyreo-cervical, 911
    - abnormalities, 911, 912, 914
    - development and morphology, 1054
  - vitello-umbilical, 72, 73, 74, 1042
- **Tube, auditory**, 147, 201, 465, 466, **831**
  - cartilaginous part, 88, 152, 200, 831

- **Tube, auditory**—*continued*
  - in needling mandibular nerve, 1367
    - arteries, 832, 893, 895, 899
      - in child, 832, 1359
        - osseous part, **152**, 199, 831
        - pharyngeal orifice, 1138
      - in fœtus and at birth, 832
    - lymph vessels, 1018
    - nerve, 698, 832
    - origin, 48, 57
    - surgical anatomy, 1359, 1376
    - veins, 832
  - obstruction, effect on visibility in tympanum, 1357
  - passage of catheter, 1376
  - relation to internal pterygoid, 458
  - in swallowing, 467
- digestive, 1101
- egg, of ovary, 1296
- medullary. *See* **T.**, neural
- **neural**, 28, 44, 123, 495, 496, 501, 503
  - closure, 502
  - derivatives, 36, 39
  - development, 35, 43, 707
  - differentiation, 37
  - relation to mesoderm, 33
- **uterine**, 1293, **1297**
  - arteries, 931, 943, 1298
  - development, 1310
  - entrance of ovum, 18
  - homologue in male, 1272
  - lymph vessels, **1026**, 1298
  - nerve supply, 791, 1298
  - structure, 1298
  - veins, 1298
- **Tuber, Tubercle, Tuberosity**, 87
  - of auricle, **822**, 823
  - cinereum, 542, 548, 560, 600, 607, **613**
    - development, 39, 606
    - vein of, 977
  - cloacal, 1311, 1317
  - coccygeal, 1317
  - corniculate, 1069
    - in laryngoscopic examination, 1076
  - cuneate, 560
  - cuneiform, of larynx, 1069
    - in laryngoscopic examination, 1076
  - Darwin's. *See* **T.** of auricle
  - epiglottic, 1069
    - in laryngoscopic examination, 1076
  - impar, 51, 1236
  - intervenosum, 871
  - labial, 1105
  - lingual, of teeth, 1114, 1115
  - olfactory, 621
    - function, 625
  - omentale of liver, 1184
    - of pancreas, 1196
  - supratragicum, 823
  - of teeth, 1109
  - of thalamus, anterior, **609**, 610
  - of thyreoid cartilage, 1063
  - **of bones**—
    - adductor, **263**, 264, 265
      - surgical anatomy, 1455
    - articular, of sacrum, 106
      - homology, 112
      - of *skull*, 138, 144, 150, 197
        - connexion with zygoma, 138, 139, 150
        - relation to infratemporal fossa, 141
          - to mandible, 152, 179
          - to spine of sphenoid, 146
- **Tuber, Tubercle, Tuberosity**—*continued*
  - **of bones**—*continued*
    - of atlas, anterior, 97, 148
      - posterior, 97
    - of calcaneus, anterior, **277**, 278
      - lateral and medial, **277**, 278
    - carotid, 96, 1384
      - surgical anatomy, 1384, 1386
    - of cervical transverse processes, 96
    - conoid, 224, 225
    - coracoid, 224
    - costal, 224, 225
    - of crest of ilium, **249**, 259
      - level, 101, 250
      - surgical anatomy, 1449
    - of crest of scapula, 220, 223
    - of cuboid, 281
    - deltoid, 225, **229**
    - dorsal, of radius, 235, 236
      - surgical anatomy, 1445
    - femoral, 266
    - of fifth metatarsal, 285, 286
    - frontal. *See* **Eminence**
    - genial, 178
    - gluteal, 264
      - variations, 266
    - of humerus, 226
        - surgical anatomy, 1439
      - greater, **226**, 229
        - homology, 293
      - lesser, **226**, 229
    - iliac, **251**, 260
    - of iliac crest, **249**, 259
      - level, 101, 250
      - surgical anatomy, 1449
    - infra-glenoid, 219
    - ischial, **251**, 252, 259, 260
      - surgical anatomy, 1449
    - jugular, 164, 194
    - malar, 134, 216
    - marginal, of zygomatic. *See* **Process**
    - of maxilla, 128, **141**, **144**, 147, 211, 212
      - relation to palatine bone, 129
    - mental, 177
    - of metatarsal, fifth, 285, 286
    - of navicular, of *foot*, 283
        - formation and homology, 294
        - surgical anatomy, 282, 1457
      - of *hand*, 240, 242
        - formation and homology, 294
        - surface anatomy, 238, 1445
    - parietal. *See* **Eminence**
    - pharyngeal, **148**, 195
    - post-glenoid, 139, 150, 152, **198**
      - variation, 202
    - pterygoid, 148, 163, 205
    - pubic, 253, 259, 260
      - in female, 258
      - ossification, 255
      - relation to hernia, 1398
      - surgical anatomy, 1453
    - quadrate, **262**, 264
    - of radius, **234**, 236
      - dorsal, 235, 236
        - surgical anatomy, 1445
    - of rib, 117
    - of root of zygoma, **138**, 139, 146, 153, 197
      - relation to cavernous sinus, 158
    - of sacrum, 106
      - homology, 112, 113
    - scalene, 118

- **Tuber, tubercle, tuberosity**—*continued*
  - of **bones**—*continued*
    - of scapular crest, 220, 223
    - sellæ, **157**, 158, 202
      - in skiagram, 1365
    - for serratus anterior, 119
    - supraglenoid, 219
    - of talus, medial, 279
      - posterior, 279, 280
        - ossification, 288
    - of tibia, **267**, 271
      - level, 271
    - transverse, of sacrum, 106
      - homology, 113
    - of transverse processes, cervical, 96
    - of ulna, 231, 233
- Tubules of kidney, 1253
  - seminiferous, 1273
    - development, 1315, 1316
- Tumours, malignant, cell division in, 10
  - from notochord, 30
- **Tunica** albuginea of penis, 1284
    - of spleen, 1343
    - testis, 1273
      - development, 1315
  - conjunctiva, 817. *See also* **Conjunctiva**
  - dartos. *See* **Muscle**
  - externa of arteries, 864
    - of capillaries, 865
    - of lymph vessels, 1002
    - of veins, 866
  - fibrosa oculi, 802
  - interna of arteries, 864
    - of lymph vessels, 1002
    - of veins, 865
  - media of arteries, 864
    - of lymph vessels, 1002
    - of veins, 866
  - vaginalis testis, 1272
    - development, 1280
    - surgical anatomy, 1400
  - vasculosa oculi, 805
    - testis, 1273
- Tunnel, carpal, 238
  - of Corti, 843, **844**
- Turkish saddle. *See* Sella turcica
- Twin chromosomes, 12
- Tympano-hyal, 201
- Tympanum, 124, 126, **140**, **826**. *See also* **Cavity, tympanic**
- Type, segmental, of animals, 2

- Ulcer of duodenum, 1409
  - of stomach, 1408
- **Ulna**, 217, **230**, 234
  - homology, 293
  - nerve supply, 734
  - nutrient artery, 924
  - ossification, 233, 234
  - in pronation and supination, 237, 238
  - structure and variations, 234
  - surgical anatomy, 1445
- **Umbilicus**, 28, 44, 59, 477, 483
    - at centre of body, 82
    - in child, 1398
    - formation, 43
  - connexion with superior mesenteric artery, 1040
  - level, 101, 1398, 1402
  - lymph glands and vessels, 1023
  - nerves, 746
  - veins, 999
- Umbo membranæ tympani, 829
- Uncus, 87
  - of cerebrum, 627
    - arteries, 904, 909
    - veins, 977
- Ungues. *See* Nails
- Unit of lung substance, 1096
- Upper limb. *See* **Limb, upper**
- Urachus. *See* **Lig.**, umbilical, middle
- **Ureter**, 476, 491, 493, **1255**
      - constrictions, 1256, 1416
      - development, 1310, **1313**
      - structure, 1257
      - variations, 1258
    - arteries, 930, 931, 942, 943, 1258, 1416
    - lymph vessels, **1026**, 1032
    - nerves, 791, 1258
    - veins, 990
  - communication with rectum, 1223
  - level, 1434
  - relation to rectum, 1218
  - surgical anatomy, 1405, 1413, 1414, **1416**, 1425, 1426, **1429**
    - exposed from behind, 1430
  - transplantation, 1414
  - X-ray examination, 1416, 1417
- **Urethra**, 1269, 1289
      - internal orifice, 1259
        - at birth, 1266
        - position, 1260
    - arteries, 945
    - development, 52, 53, 1310, 1311, **1314**, 1318
    - nerves, 770, 791, 792
  - female, 490, 494, **1269**
      - external orifice, 1270, 1308
    - lymph vessels, 1026
    - structure, 1270
    - surgical anatomy, 1425, 1426
    - veins, 993
  - male, 490, 1269, 1271, **1289**
        - external orifice, 1283, **1292**
      - cavernous part, 1289, 1291
      - membranous part, 1289
      - prostatic part, 1287, 1289
    - examined with endoscope, 1419
    - lymph vessels, 1023, 1025
    - structure, 1292
    - surgical anatomy, 1418, 1419
- Urine entering bladder, 1419
  - extravasation, 404, 475, 487, 1418
- UROGENITAL SYSTEM, 1245
- **Uterus**, 18, 1293, **1298**
        - cervix, 491, **1299**
      - bi-cornuate, 1303
      - pregnant, 1303
    - at birth, 258
    - communication with rectum, 1223
    - development, 1310, **1316**
    - at different ages, 1303
    - periodic changes, 1303
    - sinks into pelvis, 258
    - variations, 1303
  - artery, 931, 943, 1303, 1426
  - lymph vessels, **1026**, 1304
  - nerves, 785, 786, 791, 1304
  - relations, 1302
  - structure, 1302
  - surgical anatomy, 1425
  - veins, 992, 1304
- **Utricle** of ear, 840
    - development, 56, 848

Utricle of ear—*continued*
    nerve, 602, 837, 839, 840, 846
  prostatic, 1277, **1289**
    development, 1310, 1316
Uvula of cerebellum, development, 573
  of palate, 1106, 1107, **1108**
    nerves (sensory), 688
  vesicæ, **1265**, 1287

Vagina, 18, 494, 1293, **1304**
      orifice, 1308
      vestibule, 1308
        development, 53
    arteries, 943, 1306
    communication with rectum, 1223
    development, 1310, 1311, 1315, 1316
    examination of, 1427
    lymph vessels, **1026**, 1306, 1426
    nerve supply, 792, 1306
    peritoneum, 1226, 1300, 1306
    structure, 1306
    surgical anatomy, 1425
    veins, 992, 1306
Vagina M. recti abdominis. *See* **Sheath**
  of styloid process, 198
  vasis, 864
Vaginæ mucosæ tendinum, 305, 368
Vallecula cerebelli, 541, 544, 575
  epiglottic, 1068, 1121
    in laryngoscopic examination, 1076
Vallum (of vallate papillæ), 1122
  unguis, 852
Valves, anal, 1219, 1220
  aortic, 874
    surface anatomy, 1396
  of Beraud, 820
  bicuspid. See **V.**, mitral
  of colon, 1204
    level, 1434
    surgical anatomy, 1411
  of coronary sinus, 870, 871, 964
    development, 1037
  of lymph vessels, 1002
  mitral, 872, 874
    development, 1034
    surface anatomy, 1396
  of portal system, 998
  pulmonary, 873
    surface anatomy, 1396
  pyloric, 1167
    during digestion, 1166
  semilunar, of aorta, 874
    of pulmonary artery, 873
  spiral, of gall bladder, 1192
  tricuspid, 872, 873
    development, 1034
    surface anatomy, 1396
  of ureter, 1265
  of veins, 865
    of portal system, 998
  of vena cava inferior, 870, 871, 988
    development, 1037
  of vermiform process, 1206
Valvulæ conniventes. See **Plicæ** circulares
Variations. *See also* **Abnormalities**
  of accessory process, 112
  of acetabulum, 255
  of acoustic meatus, 202
  of acromion, 223
  of anal canal, 1223
  of angle of sternum, 116
  of apertura piriformis, 214, 297

Variations—*continued*
  of arches of vertebræ, 112
  of articular processes, 112
  of atlas vertebra, 111
  of brachial plexus, 730
  of cæcum, 1205
  of calcaneus, 290
  of carotid canal, 202
  of carpal bones, 247
  of clavicle, 225
  of coccyx, 112
  of common peroneal nerve, 749
  of costal cartilages, 123
  of costal facets, 112
  of cuboid bone, 290
  of cuneiform bones, 290
  of dens epistrophii, 112
  of duodenum, 1180
  of epistropheus, 112
  of ethmoid bone, 207
  of femoral nerve, 749
  of femur, 265, 266
  of fibula, 275
  of foramen ovale of skull, 206
  of foramen rotundum, 206
  of foramen spinosum, 206
  of foramina transversaria, 111, 112
  of frontal bone, 191
  of gall-bladder, 1193
  of gluteal tuberosity, 266
  of greater palatine canal, 215
  of hamulus lacrimalis, 209
  of hip-bone, 255
  of humerus, 230
  of hypoglossal canal, 196
  of intercosto-brachial nerve, 743
  of jugular fossa, 202
  of kidney, 1252, 1254
  of lacrimal bone, 209
  of lacrimal fossa, 191
  of linea aspera, 266
  of liver, 1187
  of lumbar curvature, 299
  of lung, 1094
  of mammary gland, 1319
  of mamillary processes, 112
  of mastoid process, 831
  of maxilla, 214
  of maxillary sinus, 214, 215
  of median nerve, 230
  of metacarpal bones, 247
  of metatarsal bones, 290
  of nasal bone, 210
  of navicular bone of foot, 290
  of obturator nerve, 749
  of occipital bone, 196
  of occipital sinus, 981
  of odontoid process, 112
  of œsophagus, 1146
  of olecranon fossa, 230
  of optic foramen, 206
  of orbit, 297
  of orbital process, 215
  of os hamatum, 294
  of palate, 213, 297
  of palatine bone, 215
  of pancreas, 1198
  of parietal bone, and foramen, 192
  of patella, 267
  of peritoneum, 1155
  of phalanges, 247, 290
  of piriform aperture, 214, 297

- **Variations**—*continued*
  - of post-glenoid tubercle, 202
  - of radius, 237
  - of rectum, 1223
  - of ribs, 123
  - of sacral canal, 112
  - of sacrum, 106, 112
  - of scapula, 223
  - of septum of heart, 876, 966
  - of sphenoid, 206
  - of sphenoidal sinus, 206, 210
  - of spheno-palatine foramen, 205
  - of spheno-parietal sinus, 981
  - of sternum, 116
  - of stomach, 1164
  - of styloid process of metacarpal, 247
  - of stylo-mastoid foramen, 202
  - of superior orbital fissure, 206
  - of supra-orbital notch, 191
  - of talus, 290
  - of tarsal bones, 290
  - of teeth, 1117
  - of temporal bone, 202
  - of thumb, 247
  - of tibia, 271, 354
  - of tibial nerve, 749
  - of tongue, 1236
  - of transverse processes, 112
  - of trochlear process, 290
  - of ulna, 234
  - of ureter, 1258
  - of uterus, 1223, 1303
  - of vertebræ, 111
  - of vertebral arches, 112
  - of vertebral column, 111, 299, 1436
  - of vomer, 210
  - of zygoma, 202
  - of zygomatic arch, 217
  - of zygomatic bone, 216
- Varicocele, 1421
- **Vas** *aberrans* of brachial artery, 920
    - of external iliac artery, 950, 955
    - of popliteal artery, 957
    - of thoracic aorta, 929
  - deferens. *See* **Ductus**
  - prominens of cochlea, 843
  - spirale, 843
- **Vasa** aberrantia, 1059
  - afferentia of kidney, 1254
    - lymph, 1001
  - efferentia of kidney, 1254
    - lymph, 1001
  - lymphatica. *See* **Lymph vessels**
  - vasorum, 866
- Vater's ampulla, 1194, 1406
- Vault of skull, 154
  - at birth, 183
- **Veins** or **Venæ**, 861, **963**
    - in children, 866
    - development, 1041
    - morphology, 1057
    - nerve supply, 866
    - structure and tissues, 865
    - valves, 865
  - advehens, 1042
  - cardinal, 966
  - cava superior, left, 964, 966
  - head, primary, 1045
  - post-axial, of limbs, 1058
  - post-cardinal, 74, 1047
    - derivatives, 1042
    - morphology, 1057
- **Veins** or **Venæ**—*continued*
  - post-cardinal—*continued*
    - left, 967
  - pre-axial, of limbs, 1058
  - pre-cardinal, 73, 74, 1044
    - derivatives, 1042
    - morphology, 1057
  - revehens, 1042
  - subcardinal, 74, 1048
    - derivatives, 1042
    - morphology, 1057
  - supracardinal, 74, 967, 1049
    - derivatives, 1042
  - umbilicalis, 59, 60, 71
    - impar, 71, 1041, **1044**
    - left, 999, 1041, 1044
    - right, 1041, 1044
  - vitelline, 61, 71, 1041
      - derivatives, 1041, 1042
      - function, 1042
    - right, 967
  - vitello-intestinal, 72, 73
  - vitello-umbilical, 74, 1042
  - capillary, 865
  - comites, 964
    - of limbs, 983, 993
        - development and morphology, 1059
      - of lower limb, 993, 994
        - abnormalities, 998
      - of upper limb, 983, 987
  - deep, 964
      - valves in, 866
    - of lower limb, 993, 994
    - of upper limb, 983
  - emissary, 981, 982
    - of carotid canal, 151, 971, 981, 982
    - of condyloid canal, 149, 981, 982
    - of foramen cæcum, 157, 982
    - of foramen lacerum, 162
    - of foramen ovale, 147, 974, 981, 982
    - of foramen Vesalii, 147, 981, 982
    - frontal, 157, 982
    - of hypoglossal canal, 149, 982
    - mastoid, 136, 824, 974, 981
    - occipital, 196, 974, 982
    - parietal, 130, 974, 982
  - nutrient, of bones, 86
  - portal, 998, 1191
    - development, 1043, 1058
    - morphology, 1058
    - peculiar structure, 866
    - surgical anatomy, 1406
  - pulmonary, 963
    - connexion with bronchial veins, 967
    - morphology, 1058
    - orifices, 867
    - in root of lung, 1095
    - within lung, 1097
  - satellite, 994
  - superficial, 964
      - in fascia, 367
      - valves in, 866
    - of lower limb, 993, 996
    - of upper limb, 984
  - systemic, 963
  - vasorum, 866
  - visceral, 964
- **Veins of organs and regions**—
  - of abdomen, 987, 990
  - of acoustic meatus, external, 826
  - of anal canal and anus, 992, 1222

Veins of organs and regions—*continued*
- of arm, 985
- of auditory tube, 832
- of auricle of ear, 824, 973
- of back, 967, 990
- of bladder, 492, 493, 992, 993, 1269
  - morphology, 1058
- of brain, 672, 975, **976**, 977, 978
  - development, 1047
  - relation to membranes, 671
- of bronchi, 967, 1095
- of bulb of urethra and vestibule, 992
- of buttock, 992
  - abnormalities, 994
  - development and morphology, 1058
- of cæcum, 1000
- of cerebellum, deep, 978
  - superficial, 977
- of cerebrum, 672, **976**, 977, 1047
  - relation to membranes, 671
- of chorioid, 807
- of chorioid plexuses, 672, 976
- of clitoris, 992, 993
- of cochlea, 971
- of colon, 1000, 1001
- of conjunctiva, 818
- of corpora cavernosa, 992, 993, 1285
- of corpora quadrigemina, 977
- of corpus callosum, 977
- of corpus mamillare, 977
- of corpus striatum, 977
- of cranium, 975
- of diaphragm, 967, 969, 990
- of digits of foot, 996, 997
    - morphology, 1058
  - of hand, 984
    - morphology, 1058
- of diploë, 132, 973, **975**, **976**, 981, 982
  - connexion with sinuses and external veins, 1347
  - opening into lacunæ, 670
- of ductus deferens, 992, 993
- of duodenum, 1180
- of dura mater of skull, 976
  - spinalis, 982
- of ear, external, 824, 826, 830
  - internal, 167, 847
  - middle, 836
- of eyeball, 803, 807, 809, 812, 974
- of eyelids, 818
- of face, 971
- of fingers, 984
- of foot, 996, 997, 998
- of forearm, 985
- of gall-bladder, 998, 1000, 1193
- of gluteal region, 992
  - abnormalities, 994
  - development and morphology, 1058
- of hand, 984
- of head, 970
- of heart, 870, 871, 876, **964**
  - abnormalities, 966
  - morphology, 1058
- of hip-joint, 992
- of hypophysis of brain, 1338
- of internal ear, 167, 847
- of intestine, 1000, 1172
- of iris, 809
- of kidney, 990
  - within kidney, 1254
- of labium majus, 997
- of lacrimal gland, 819

Veins of organs and regions—*continued*
- of leg, 994, 995, 996, 997
- of limb, lower, 993
    - development, 1041
    - morphology, 1058
  - upper, 983
    - development, 1041
    - morphology, 1058
- of lips, 973
- of liver, 989, 998, 1190, 1191
- of lung, 963, 967, 1095, 1097
- of lymph glands, 1003
- of mamma, 1320
- of medulla oblongata, 149, 978
- of meninges of brain, 976
- of mid-brain, 977
- of naso-lacrimal duct, 820
- of neck, 968, 969, 970
- of nose, 799, 800, 974
  - connexion with sagittal sinus, 157, 978
- of œsophagus, 966, 1000, 1148, 1398
- of orbit, 974
  - communications, 135, 973, 974
- of ovary, 931, **991**, 1297
  - abnormalities, 988
  - development, 1049, 1050
- of palm of hand, 984
- of pancreas, 1000, 1198
- of parotid gland, 1131
- of pelvis, 991
- of penis, 993, 997, 1285
    - deep, 992
    - dorsal, deep, 340, 489, 945, 993
      - superficial, 993
  - in penis, 1285
- of pericardium, 966
- of perineum, 992
- of pharynx, 146, 971, 974, 1143
- of pineal body, 977
- of pleura, 969
- of pons, 978
- of prepuce, 993
- of prostate, 992, 993, 1288
- of pterygoid canal, 974
- of pterygoid muscles, 974
- at pylorus, 1158
- of pylorus, surgical anatomy, 1407
- of rectum, 992, 1000, 1222
- of retina, 813
- of scalp, 973
  - connexion with sinuses, 1347
  - within scalp, 1347
- of sclera, 803
- of scrotum, 997
- of seminal vesicle, 992, 993
- of skin, 852
- of skull, 975
- of sole of foot, 996
- of spinal medulla, 983
  - relation to pia-mater, 673
- of spleen, 1000, 1343
  - morphology, 1058
  - peculiar structure, 866
- of sternum, 969
- of stomach, 1000, 1169
  - development and morphology, 1058
- of submaxillary gland, 1132
- of substantia perforata, 977
- of suprarenal gland, 990, 1328, 1329
  - abnormalities, 988
  - development, 1049
- of tela chorioidea, 672, 976

Veins of organs and regions—*continued*
- of testicle, 990, 1274
  - abnormalities, 988
  - development, 1049, 1050
  - peculiar structure, 866
- of thigh, 994, 996, 997
- of thorax, 963, 964, 965
- of thumb, 985
- of thymus, 1336
- of thyreoid gland, 970, 971, 1331
  - morphology, 1058
  - surgical anatomy, 1379
- of toes, 996, 997
- of tongue, 971, 1124
- of tonsil, 1140
- of trachea, 967
- of tuber cinereum, 977
- of tympanic cavity, 836
- of tympanic membrane, 830
- of umbilicus, 999
- of uncus, 977
- of upper limb, 983
  - development, 1041
  - morphology, 1058
- of ureter, 990
- of urethra (female), 993
- of uterine tube, 1298
- of uterus, 992, 1304
- of vagina, 992, 1306
- of vermiform process, 1000
- of vertebrae, 982
- of viscera, 964

Veins or **Venæ, named**—
- acromial, 985
- advehens, 1042
- alveolar, inferior, 458, 974
    - relation to spheno-mandibular ligament, 315
  - superior, posterior, 974
- anal, 992, 1222
- anastomotic, of cerebrum, 977
- angular, 971, 973
  - connexion with sagittal sinus, 978
- antero-lateral, of spinal medulla, 983
- antero-median, of spinal medulla, 983
- appendicular, 1000
- ascending cervical, 969
- ascending lumbar, 990
- auditory, internal, 847
  - in meatus, 167
- auricular, posterior, 150, 449, 973
- axillary, 983
  - development and morphology, 1058
  - peculiar structure, 866
  - surgical anatomy, 1439, 1441
- **azygos**, 473, 966
    - arch, 966
      - level, 1433
  - abnormalities, 967, 988
  - development, 1042, 1047, 1049, 1058
  - morphology, 1058
  - peculiar structure, 866
- basal, of brain, 977
  - development, 1047
- **basilic**, 381, 986
    - development, 1041, 1058
    - morphology, 1058
    - surgical anatomy, 1442
  - median, 986
- basi-vertebral, 982
- bronchial, 967, 1095
  - morphology, 1058

Veins or **Venæ, named**—*continued*
- buccinator, 456, 974
- capillary, 865
- **cardiac**, 964
    - abnormality, 966
    - morphology, 1058
  - anterior, inferior and middle, 964
  - great and small, 964
- cardinal, 966
- cava *inferior*, 473, 476, 963, 966, **987**
      - orifice, 867, 870
    - abnormalities, 967, 988
    - arterial supply, 937
    - development, 1042, 1044, 1048, 1049, 1050, 1058
    - morphology, 1058
    - nerve supply, 789
    - structure, 866
    - surgical anatomy, 1417
  - *superior*, 963, 965
        - left, 878, 964, 966
      - orifice, 867, 870
    - abnormalities, 966, 988
    - development, 1042, 1047, 1057, 1058
    - morphology, 1057, 1058
    - surgical anatomy, 1396
- central, of liver, 989, 1190, 1191
- **cephalic**, 377, 985
      - in monkeys, 1058
    - abnormal ending, 973
    - development, 1041, 1058
    - morphology, 1058
    - at shoulder, 373
    - surgical anatomy, 1439, 1443
  - median, 986
- cerebellar, deep, 978
  - superficial, 977
- **cerebral**, 976
      - development, 1047
      - relation to membranes, 671
    - anterior, 977
    - deep, 976
    - great, 672, 977
    - inferior, 977
      - of embryo, 1047
    - internal, 672, 976
    - middle (deep and superficial), 977
    - superficial, 976, 977
    - superior, 977
- cerebri magna, 672, **977**, 1047
- cervical, ascending, 969
  - deep, 969, 974
  - transverse, 973
- chorioid, of cerebrum, 672, 976
  - of eye, 807
- circumflex iliac, deep, 995
  - superficial, 997
- cochlear, 971
- colic, left, 1001
  - middle and right, 1000
- comitans N. hypoglossi, 971
- **comites**, 964
    - development and morphology, 1059
  - of lower limb, 993, 994
    - abnormalities, 998
  - of upper limb, 983, 987
- cordis minimæ, 870, 871, 964
- coronary, of stomach, 1000, 1169
  - development and morphology, 1058
- cubital, median, 985
  - absence, 986
- cystic, 998, 1000, 1193

- **Veins or Venæ, named**—*continued*
  - deep cervical, 969, 974
    - circumflex iliac, 995
    - of clitoris, 992
    - facial, 971, 974
    - of forearm, 986
    - of penis, 992
    - temporal, 139, 974, 976
      - diploic tributary, 976
    - of tongue, 1124
      - surgical anatomy, 1373, 1374
      - visible in mouth, 1123
  - descending, from common facial, 971
  - digital, of foot, 996, 997
      - morphology, 1058
    - of hand, 984
      - morphology, 1058
  - diploic, 975
      - connexions with sinuses and veins outside, 1347
      - opening into lacunæ, 670
    - frontal, 132, 973, 975
    - occipital, 976, 982
    - temporal, 976, 981
  - dorsal, of clitoris, 993
    - linguæ, 1124
    - metacarpal, 985
    - metatarsal, 996
    - of penis, deep, 489, 945, 993, 1285
        - entering pelvis, 340
      - superficial, 993
  - emissary, 981, 982
    - of carotid canal, 151, 971, 981, 982
    - of condyloid canal, 149, 981, 982
    - of foramen lacerum, 162
    - of foramen ovale, 147, 974, 981, 982
    - of foramen Vesalii, 147, 981, 982
    - frontal (of foramen cæcum), 157, 982
    - of hypoglossal canal, 149, 982
    - mastoid, 136, 824, 974, 981
    - occipital, 196, 974, 982
    - parietal, 130, 974, 982
  - epigastric, inferior, 995
    - superficial, 997
    - superior, 969
  - ethmoidal, anterior, 136, 157
    - posterior, 136, 157
  - facial, anterior, 971, 974
      - morphology, 1058
      - surgical anatomy, 1366, 1381
    - common, 971
      - surgical anatomy, 1382, 1383
    - deep, 971, 974
    - posterior, 974
      - abnormalities, 975
      - relation to mandible, 180
  - femoral, 407, 415, 993, **994**
      - abnormalities, 998
      - development and morphology, 1059
      - peculiar structure, 866
      - thrombosis, 1418
    - superficial, 997
  - fibular, primitive, 1058
  - frontal, 135, 973
  - gastric, left. *See* **V.**, coronary
      - development and morphology, 1058
    - right, 1000
      - development and morphology, 1058
    - short, 1000, 1169
  - gastro-epiploic, left and right, 1000, 1169
  - gluteal, inferior, 992
      - abnormal, 994

- **Veins or Venæ, named**—*continued*
  - gluteal, inferior—*continued*
      - development and morphology, 1058
    - superior, 992
  - hæmorrhoidal, inferior and middle, 992, 1222
      - morphology, 1058
    - superior, 1000, 1222
  - head, primary, 1045
  - hemiazygos, 967, 968
      - abnormalities, 967, 988
      - development, 1042, 1049
      - peculiar structure, 866
    - accessoria, 966, 968
      - abnormal, 967
      - development, 1042, 1049, 1058
      - morphology, 1058
  - hepatic, 963, 989, 1191
    - abnormalities, 988
    - development and morphology, 1044, 1058
    - peculiar structure, 866
  - hypogastric, 490, 991
    - abnormalities, 991
    - development, 1042, 1048, 1049, 1058
    - morphology, 1058
  - hypophyseal, 1338
  - ileo-cæcal and ileo-colic, 1000
  - iliac, *circumflex*, deep, 995
      - superficial, 997
    - *common*, 991
      - abnormalities, 988, 991
      - development, 1042, 1048, 1049, 1058
      - morphology, 1058
      - peculiar structure, 866
      - surgical anatomy, 1417
    - *external*, 993, 995
      - abnormal, 991
      - development and morphology, 1058, 1059
      - peculiar structure, 866
  - ilio-lumbar, 991
    - connexion with ascending lumbar, 990
  - infra-orbital, 133, 135, 452, **974**
  - innominate, 115, 968
    - abnormalities, 966, 967
    - in child, 1379
    - development, 1042, 1047, 1057
    - morphology, 1057
    - surgical anatomy, 1396
  - intercapitular, of foot, 996
    - of hand, 984
  - intercostal, 967, 969
    - *anterior*, 967, 969
    - *posterior*, 117, 967, 983
        - abnormalities, 967
      - first or highest, 967, 969
      - superior, left, 967
          - development, 1042, 1047, 1048, 1057
          - morphology, 1057
        - right, 967
  - interlobular, of kidney, 1254
    - of liver, 989, 1190, 1191
  - intervertebral, 983
  - intestinal, 1000
    - in intestine, 1172
  - jugular, *anterior*, 447, **973**
      - abnormalities, 973
      - connexion with common facial, 971
      - in tracheotomy, 1379
    - *external*, 459, **972**, 974
        - posterior, 973
      - abnormalities, 973
      - development, 1047, 1058

Veins or **Venæ, named**—*continued*

- **jugular**—*continued*
  - *external—continued*
    - morphology, 1058
    - surgical anatomy, 1381, 1385
  - *internal*, 150, 164, **970**
    - bulb of, inferior, 970
      - superior, 151, 970
        - relation to ear, 1358
    - abnormalities, 971, 973
    - arterial supply, 894
    - development, 1042, 1046, 1047, 1057
    - morphology, 1057
    - peculiar structure, 866
    - relation to ear and antrum, 151
    - surgical anatomy, 1377, 1381, 1382, 1384
- lingual, 971, 1124
- **lumbar**, 983, 990
  - abnormalities, 988
  - ascending, 990
    - left, 967
    - right, 966
- mammary, internal, 914, 968
- marginal, of heart, left, 964
- masseteric, 456, **974**
  - relation to mandible, 180
- maxillary, internal, 141, 145, **974**
  - morphology, 1058
  - relation to spheno-mandibular ligament, 315
- median basilic and median cephalic, 986
  - surgical anatomy, 1444
- median, of forearm, 986
  - surgical anatomy, 1444
  - of medulla oblongata, 978
- **meningeal**, 149, 975, **976**
  - opening into lacunæ, 670
  - anterior, 157
  - middle, 147, 154, 974
    - relation to spheno-mandibular ligament, 315
  - posterior, 166
- mental, 179
- **mesenteric**, 1000
  - development, 1043, 1058
  - morphology, 1058
  - peculiar structure, 866
  - inferior, 1000
    - relation to internal hernia, 1179
  - superior, 1000
    - relation to pancreas, 1195
- metacarpal, dorsal, 985, 996
- minimæ cordis, 870, 871, 964
- musculo-phrenic, 969
- nasal, lateral, 974
- naso-frontal, 974
- oblique, of left atrium, 868, 964
  - development, 1042, 1058
  - morphology, 1058
- obturator, 992
  - in foramen, 254
  - relation to distended bladder, 1264
    - to ductus deferens, 1276
    - to ovary, 1295
- occipital, 971, 974
  - abnormalities, 973
  - diploic tributary, 976
- ophthalmic, 135, 973, **974**
  - development, 1046
- ovarian, 931, **991**, 1297
  - abnormalities, 988

Veins or **Venæ, named**—*continued*

- ovarian—*continued*
  - development, 1049, 1050
- palatine, greater, 145, 974
  - lesser, 145
- pancreatico-duodenal, 1000, 1198
- pectoral, 985
- perforating, anterior, of internal mammary, 969
- pharyngeal, 146, 971, 1143
  - of pterygoid plexus, 974
- phrenic, inferior, 990
- popliteal, 993, 994
  - abnormalities, 998
  - development and morphology, 1058
  - leaving fossa, 264
- **portal**, 998, 1191
  - development, 1043, 1058
  - level, 1433
  - morphology, 1058
  - peculiar structure, 866
  - surgical anatomy, 1406
- post-axial, of limb, 1058
- post-cardinal, 74, 1047
    - derivatives, 1042
    - morphology, 1057
  - left, 967
- postero-lateral, of spinal medulla, 983
- postero-median, of spinal medulla, 983
- pre-axial, of limb, 1058
- pre-cardinal, 73, 74, 1044
  - derivatives, 1042
  - morphology, 1057
- pre-tarsal (of eyelids), 818
- primary, head, 1045
- **profunda** antibrachii, 986
  - cervicis, 969, 974
  - clitoridis, 992
  - faciei, 971, 974
  - femoris, abnormal, 998
  - iliaca circumflexa, 995
  - linguæ, 1124
    - surgical anatomy, 1373, 1374
    - visible in mouth, 1123
  - penis, 992
  - temporales, 139, **974**, 976
    - diploic tributary, 976
- of pterygoid canal, 974
- pubic, 996
- pudendal, external, superficial, 997
  - internal, 992
- **pulmonary**, 963
  - connexion with bronchial veins, 967
  - morphology, 1058
  - orifices, 867
  - in root of lung, 1095
  - within lung, 1097
- pyloric, 1158, 1407. (*See also* **V.**, gastric, right)
- radicular, of medulla oblongata, 978
  - of spinal medulla, 983
- rectæ of kidney, 1254
- **renal**, 990
  - abnormalities, 988
  - development, 1042, 1048, 1049, 1050
  - peculiar structure, 866
  - within kidney, 1254
- retinal, 813
- retro-tarsal (of eyelids), 818
- revehens, 1042
- sacral, lateral, 992
    - connexion with ascending lumbar, 990

- **Veins or Venæ, named**—*continued*
  - sacral—*continued*
    - middle, 938, 991
  - **saphenous**, *accessory*, 997, 998
    - *great*, 404, 405, **996**
      - abnormalities, 994
      - development and morphology, 1058
      - surgical anatomy, 1453, 1455, 1457
    - *small*, 407, 996, **997**
      - abnormalities, 994
      - development and morphology, 1058
      - surgical anatomy, 1457, 1459
  - satellite, of popliteal, 994
  - scapular, transverse, 973
  - septal, of superior labial, 974
  - sigmoid, 1001
  - **spermatic**, internal, 931, **990**, 1274
    - abnormalities, 988
    - development, 1049, 1050
    - peculiar structure, 866
  - spheno-palatine, 142, **974**
    - on septum, 169
  - **spinal**, 983
      - relation to pia mater, 673
    - antero-lateral and antero-median, 983
    - postero-lateral and postero-median, 983
    - radicular, 983
  - splanchnic, 1058
  - splenic, 1000, 1343
    - morphology, 1058
    - peculiar structure, 866
  - striate, inferior, 977
  - stylo-mastoid, 150
  - subcardinal, 74, 1048
    - derivatives, 1042
    - morphology, 1057
  - **subclavian**, 118, 375, **971**
    - abnormalities, 987
    - danger in operation, 971
    - development, 1041, 1058
    - morphology, 1058
    - surgical anatomy, 1385, 1439
  - subconjunctival, 818
  - subcostal, 473
  - sub-lobular, of liver, 1191
  - superficial, of thigh, lateral and medial, 997
  - supracardinal, 74, 967, 1049
    - derivatives, 1042
  - supraorbital, 132, 973
  - suprarenal, 990
    - abnormalities, 988
    - development, 1049
  - **temporal**, deep, 139, **974**
      - diploic tributary, 976
    - superficial, 139, **973**
      - surgical anatomy, 1349
    - middle, 139, 974
  - terminalis, 608, 631, 672, 976
  - testicular, 931, **990**, 1274
    - abnormalities, 988
    - development, 1049, 1050
    - peculiar structure, 866
  - **thyreoid**, 970, 971
      - in goitre, 1382
      - morphology, 1058, 1059
      - surgical anatomy, 1379
    - accessory, 1379
    - inferior, 970
    - middle and superior, 971
  - tonsillar, 1140
  - transverse cervical and scapular, 973
  - tympanic, 830, 836
- **Veins or Venæ, named**—*continued*
  - umbilicalis, 59, 60, 71
    - impar, 71, 1041, 1044
    - left, 999, 1041, 1044
    - right, 1041, 1044
  - uterine, 992, 1304
  - vaginal, 993, 1306
  - vasorum, 866
  - vermian, 977
  - of vertebræ, 982
  - vertebral, **969**, 974, 983
  - vesical, 492, 493, 993, 1269
      - morphology, 1058
  - visceral, 964
  - vitelline, 61, 71, 1041
      - derivatives, 1041, 1042
      - function, 1042
    - right, 967
  - vitello-intestinal, 72
  - vitello-umbilical, 72, 73, 74, 1042
  - vorticosæ, 807
    - piercing fascia bulbi, 802
    - piercing sclera, 803
- **Velum**, medullary, anterior, 543, 550, 569
      - arterial supply, 908
      - development, 38
      - relation to trochlear nerve, 601
    - posterior, 575
      - development, 571
- "Ventral," definition, 5
- **Ventricles of brain**, 542, 543
    - *fourth*, 542, 543, **550**
      - floor, 545, 551
      - roof, 578
      - origin, 41
      - surgical anatomy, 1352
    - *lateral*, 542, 543, 544, **630**
      - development, 41, 618
      - surgical anatomy, 1349, 1352
    - *third*, 542, 543, **614**
      - development, 41, 607
  - **of heart**, 861, 866, 872
      - development, 72, 1033
      - structure, 875
    - left, 873
    - right, 872
  - **of larynx**, 1071
    - development, 1098
    - in laryngoscopic examination, 1076
- Ventriculus. *See* **Stomach**
- Ventriculus terminalis of spinal medulla, 528
- Venulæ rectæ of kidney, 1254
- Vermiform process. *See* **Process**
- Vermis cerebelli, 164, 574, 577
    - development, 572
- Vernix caseosa, 855
- **Vertebræ**, 2, 85, 94
        - in adult and in child, 94
      - axis or epistropheus. *See* **V.**, cervical, second
      - prominens. *See* **V.**, cervical, seventh
    - false or fixed, 94
    - movable or true, 94
    - procartilage, 123
    - typical, 94
  - attachments, 95, 109
  - chondrification and development, 123
  - epiphyses, 91, 110, 306
  - growth, 89
  - homologies, 2, 112
  - ossification, 109

Vertebræ—*continued*
variations, 111
veins of, 982
cervical, 94, **96**, 108
typical, 96
felt from mouth, 1376
level of third and sixth, 1061
atlas, 97
development, 123
fusion with occipital, 196
homologies, 112
ossification and variations, 111
relation to skull, 148, 149
lateral mass, 97, **98**, 149
transverse process, 97, 149
surgical anatomy, 1383
second, 98
ossification, 111
variation, 112
seventh, 99
vein in transverse process, 969
coccygeal, 104
development, 124
lumbar, 94, 101, 108
typical, 102
levels, 101, 122, 250, 1152, 1159, 1402
fifth, 102, 437
sacralisation, 112, 1438
variations, surgical bearing, 1437
sacral, 102, 108
thoracic, 94, 99, 108, 120
typical, 100
levels, 99, 107, 115, 219, 220
first, 100, 120
ninth, tenth, and eleventh, 101
twelfth, 101, 120
Vertebrates, 91
Vertex of bladder, 1259
of skull, 130, 295
in women, 186
Vertical planes, 5
Vesalius, foramen of, 147, 161
Vesica fellea. *See* **Gall-bladder**
urinaria. *See* **Bladder**
Vesicles—
cerebral, 38, 186
derivatives, 38
cervical, 1336
ecto-mesodermal, 26, 27
ento-dermal, 27, 28, 31
ento-mesodermal, 26
lens, 820
optic, 607, 820
otic, 55, 78, 847
development, 502
pre-cervical, 47
seminal, 493, 1271, 1275, 1277
arteries, 943, 1279
development, 1310, 1316
lymph vessels, 1026
nerves, 791, 1279
relation to rectum, 1218
structure, 1279
veins, 992, 993
umbilical, 60
Vessels, blood, 3. *See also* **Arteries, Veins**
origin, 69
primitive, 69
formation, 71
chyle, 1173
lymph. *See* **Lymph vessels**
Vestibule, aortic, 874
of ear, 140, 167, 837
arteries, 895
surgical anatomy, 1361
of larynx, 1069
closure and opening, 1075
of mouth, 1102
development, 1232
surgical anatomy, 1374
of nose, 171, 795
of omental bursa, 1228
of vagina, 1308
origin, 53
Villi, chorionic, absorbing or free, 64, 66
anchoring, 64
primary and secondary, 59, 63, 64
intestinal, 1172
Vincula tendinum, 368
of fingers, 391, 392
of toes, 431
Visceroptosis, 1408
Vitellus, 17
Voice, "breaking," 1076
in laryngeal paralysis, 1073
Vomer, 124, 127, **209**
ala, 145, 146, 169, **209**
origin, 188
ossification, 210
at puberty, 210
seen through apertura piriformis, 133
from behind, 144, 145
in split skull, 169
structure and variations, 210
Vortex of heart, 875
Vulva, 1306

Walking, 437
Wall, nail, 852
Wax, ear, 826
Weight of brain, 664
of fœtus, 81, 82
of heart, 876
of liver, 1181
Wind-pipe. *See* **Trachea**
Wings of bats and birds, 2
Wings of sphenoid. *See also* **Sphenoid bone**
great, 127, 203
small, 126, 157, 203
Witch-bone. *See* **Talus**
Wolffian ridge, 44
Womb. *See* **Uterus**
Wormian bones. *See* **Sutural bones**
Wounds of scalp, 1347
Wrist, 217, **238**. *See also* **Carpus**
movements, 238, 294, 331, 336
Wrist-drop, 1443
Wry-neck, 1381

X-ray of bronchi, 1097
of duodenum, 1410
of lungs, 1097
of pleura, 1098
of stomach, 1165, 1407, 1408
of thorax, 1097
of ureter, 1416, 1417

Yolk, 17
sac, 60
relation to mesoderm, 32

Zona arcuata of basilar membrane, 843
  fasciculata, etc., of suprarenal, 1329
  orbicularis of hip, 342, 343
  pectinata of basilar membrane, 843
  pellucida and striata, 16
Zone, ependymal, of neural tube, 707
  hæmorrhoidal, 1220
  mantle and marginal, of neural tube, 41, 503, 707
  of oval and of round nuclei, 799
Zones of abdomen, 1151
Zonula ciliaris of retina, 813
  development, 820
Zygoma, 125, 126, **197**
    seen in base of skull, 144
      in side of skull, 138, 139
  anterior root, 138, 139, 144
Zygoma—*continued*
  posterior root, 138, 139, 144, 165
    surgical anatomy, 1349
Zygomatic bone, 124, 128, **215**
    seen in front of skull, 135
      in side of skull, 137, 138, 139
  jugal point, 139, 142
  origin, 188
  ossification, 216
  structure and variations, 216
Zygote, 7, 12, 13, 17, 18, 19, 20, 23, 24, 25, 26
  descent through tube, 61
  difference from oöcyte I, 24
  inner mass of, 30
  number of chromosomes, 25
  nutrition, 58, 69
  at third week, 77

THE END

Grey 428-430

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